Oral Rehabilitation for Compromised and Elderly Patients

Alexandre Mersel
Editor

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Foreword 1

Professor Alex Mersel, an internationally respected authority in geriatric dentistry, is the editor and author of several chapters in this significant new book titled *Oral Rehabilitation for Compromised and Elderly Patients.* This resource is directed toward teaching dentists how they can better provide evidence-based dental treatment for their aging patients. Professor Mersel has assembled an outstanding cadre of chapter authors who represent true gerodontic expertise in their respective disciplines. Together they examine such salient concerns as oral/systemic relationships, periodontology, endodontics, neurological/psychological dimensions, masticatory function and nutrition, diagnosis and treatment of destructive caries, minimally invasive restorative dentistry approaches, removable and fixed prosthodontics considerations, and prevention strategies.

Geriatric dentistry requires from the practitioner the best of clinical, psychological, and social skills and demands an integrated and collaborative approach. With these chapters providing expert guidance, dental professionals will have the opportunity to significantly expand their clinical capabilities for oral rehabilitation.

This text also effectively utilizes a case-based approach, recognizing that we often learn how to best care for our patients from our involvement with and observation of real cases. By considering authentic, complex, and multifaceted patient circumstances, a valuable "real-life" framing is created that promotes deeper engagement and authentic learning.

Douglas Berkey
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Foreword 2

Aging population? Today it seems outdated to consider the "senior" population as part of old age when we know that the appearance of dependency risk occurs at around 80 years on average. In addition, the heterogeneity of the age groups making up the elderly population should not be overlooked, so that all the very elderly cannot be considered to belong to a homogenous group. There is no strict definition of the elderly person.

For example, in France, in 1905, the birth of a social policy for old men set down the principle of compulsory assistance for old people who were indigent, infirm, and had incurable diseases. This legal provision thus offers the elderly without income the possibility of living in hospices or receiving a pension.

When considering the Nordic model of social protection, reference is often made to the principle of universality, as opposed to selectivity. Universalism is multidimensional. This means that all citizens have access to the same system of services and that this system offers rather uniform services in all countries.

We have to go back to fundamentals that the whirlwind of our daily life tends to sweep away. Old age is often a symbol of wisdom that combines self-awareness with other attributes: temperance, prudence, sincerity, discernment, and justice based on reasoned knowledge. Thus, the wisdom of the sages and the experience of the ages are perpetuated. I quote here from Konstantin Stanislavski: "May old wisdom guide young courage and youthful strength support the old wisdom. It is only in these natural conditions that art can flourish and have a future."

It is in this sense that the reference book *Oral Rehabilitation for Compromised and Elderly Patients* finds all its nobility.

Denis Bourgeois
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Preface

The development of knowledge in oral system sciences, the changes in health care, and the increase in the cohort of elderly people will have an important impact on daily dental practice.

With the increase in the number of elderly people, the numbers of edentulous patients will increase by 2050 to 40 million in Europe and 250 million in East Asia, according to the World Health Organization.

Rationale: Oral rehabilitation in this complex case is a difficult challenge. Medical and psychological factors are important, as are the skill of the general practitioner and the technical facilities. Also, the burden of these restorations is too great in a national health budget, as it is for a simple individual. Implant support overdentures are an excellent solution but are not accessible for most elderly patients.

Satisfaction of the elderly patient: A number of surveys have pointed out that on average, 30% of patients are not satisfied or do not feel comfortable with their dentures. This will be the cause of endless after-insertion visits.

A new approach: Since the 1940s and the 1950s, no important changes have been presented in textbooks. The important issues are impressions, phonetic impressions, the intermaxillary relationship, masticatory function and nutrition, the conjunction between implants and prosthetic restoration, the overall relation between the quality of dental care and patient satisfaction, and insertion strategies. With aging, more and more patients have remaining teeth. It is compulsory to maintain this status. Therefore, new treatments are recommended in periodontology, cariology, and endodontics. The elderly patient is a frail patient; any intervention could lead to a psychological or medical collapse. During treatment it is essential to maintain balance and in this way provide a good quality of life. Therefore, a new bioethical approach should be introduced into basic and continuing education programs. The publication of this book is an essential step.

Jerusalem, Israel — Alexandre Mersel

Contents

Introduction

In prosthetic dentistry, although practitioners generally apply the rules they have been taught, they may be very disappointed with the results.

In fact there is no evidence-based correlation between the quality of the prosthetic and the satisfaction of the patients. However, in recent years we have witnessed several attempts to update our clinical approach.

Unfortunately some dogmas seem to have held us back in the performance of prosthetic procedures. As Albert Einstein stated: “It is what we think we know that prevents us from learning more”.

With the huge increase of the elderly population the general practitioner in dentistry has to face important issues.

Scrutiny of classic prosthodontic theories shows that many common clinical procedures lack basic scientific support. There are now new strategies that need to be incorporated in conservative restorations.

Even classic endodontics is changing in response to new technology.

Periodontal disease is actually the main factor responsible for tooth loss.

Easy and simple treatment in all these fields leads to surprising results.

With aging, the needs of the patient are more complicated, and the number of aging patients needing removable prosthodontics is important.

Against this background, the chapters in this book are devoted to the taking of impressions, occlusion, jaw relation records and the relation between denture quality and patient satisfaction, and coordination between implants and removable prosthetic restoration. In consequently of some crucial dogmas are important issues are not underlined as the interferences of the systemic diseases.

The benefits of a specific psychological approach are also noted and age-related changes in the oral sphere are explained.

The aim of this book is to help the general dental practitioner to overcome difficulties in these areas with the employment of simple and easy procedures.

Geneva, Switzerland
20th December, 2017

Alexandre Mersel

Demography and Aging

1

Alexandre Mersel

Abstract

The aging of the population may be defined as a concept of shifts in age distribution. The study and research of this aging population is mainly driven by a concern for the burdening of social retirement programs. The aging of the population is mainly measured by increases in the percentage of elderly people reaching retirement age. Therefore, the definition of retirement age may vary, depending on the country.

1.1 Introduction

The aging of the population may be defined as a concept of shifts in age distribution. The study and research of this aging population is mainly driven by a concern for the burdening of social retirement programs. The aging of the population is mainly measured by increases in the percentage of elderly people reaching retirement age. Therefore, the definition of retirement age may vary, depending on the country. For example, in Europe, it was decided that 65 is to be considered the retirement age [1].

1.2 The Age Concept

This standard is usually utilized for the definition of elderly persons. Another important reference is the elderly dependence ratio (EDR). This index evaluates the retirement age of individuals compared with the working age. A patient may be retired but still working. The old age dependency ratio defines the ratio of the elderly who

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are dependent with those who are financially active. Currently, it is often utilized as the aging index indicator, which looks at the ratio of the number of individuals aged 65 and over, per 100 youths under age 15. For example, in Germany, Italy, Bulgaria, and Japan, the index is above 100, and by 2030 this index is projected to exceed 200. For administrative facilities, the head count ratio simply relates the number of persons in broad age categories. In the same way, the median age system indicates the age at which half the population is younger and a half is older. In the United States, the finding was 36 years. Unfortunately, these indexes do not take into consideration several factors and consequences of the aging process.

1.2.1 The Aging Population: A Global Phenomenon

With the beginning of the twenty-first century, the aging population has emerged as a major worldwide phenomenon. The global world population increased from approximately 2.526 billion in 1950 to 7.62 billion in 2015 and is projected to reach 8.083 billion in 2025 and 9.551 in 2050. Most will live in the developing countries. From a historical perspective, it was noted that the average life expectancy was around 40 years in the eighteenth century. The life expectancy reached 50 years in the twentieth century and then rose further to 80 years from the middle of the twenty-first century. In particular, the percentage of persons aged 65 years and over increased from 7.7 to 16.1% in the developed countries in comparison with an increase from 3.8 to 5.8% in developing countries. By 2050, China and India will have the largest older population. Japan, which has the largest share of the world's elderly, who are 60 years and over, will reach 44% in 2050. In the USA, 44 million citizens are aged 65 or over, and the number is expected to reach 89 million, that is double, by 2050 [2].

1.2.2 The Aging Population: Three Main Factors Increasing Life Expectancy

1.2.2.1 Age Dynamics

Between 2015 and 2030, the number of people living in the world aged 60 years and over is expected to grow by 56%; from 901 million to 1.4 billion. By 2050, the population of older people will double in size compared with 2016, reaching nearly 2.1 billion. At the same time, the cohort of "**oldest-old**" aged 75 and over will increase faster than the number of older persons. The projections indicate that the number, which was 125 million in 2015, will triple by 2050 to 435 million (Fig. 1.1).

Another important fact is that from 2010 to 2015, women outlived men by an average of 4.5 years. Consequently, women represent 54% of the global population aged 60 years old or over. Women constitute 61% of the "**oldest-old**" group. Nevertheless, in the coming period, the survival of men is expected to increase reaching 42% of the elderly population by 2050. The older population is increasing faster in urban districts than in the rural regions. As a comparison, on a global level, from 2000 to 2015, the number of people aged 60 years and over has increased by 68% in urban districts versus 25% in rural regions.

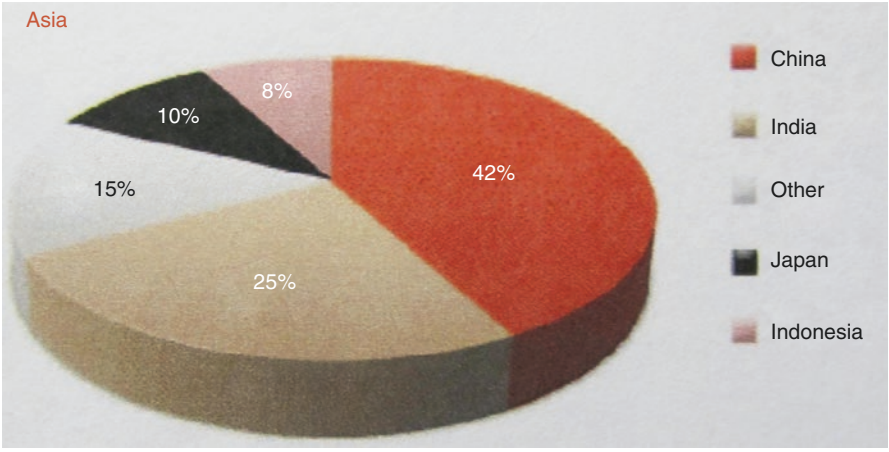

Fig. 1.1 Aging and edentulism—a projection

Consequently, elderly people are living concentrated in the urban cities. In particular, the **"oldest-old"** persons aged 80 years and over are living in the urban districts, which is an increase from 56 to 63% between 2000 and 2015.

1.2.2.2 Fertility Rates and Longevity Increase

The growing phenomenon of the elderly is a direct function of the levels of fertility from 60 years ago. The immediate reason for the population aging is the decline in fertility, but the increase in longevity contributes as well. In 2050, the life expectancy is evaluated to surpass 80 years in Europe, America, and Asia, and 70 years in Africa. In conclusion, the global proportion of older persons is estimated to increase from 14% in 2015 to more than 20% in 2050 (Fig. 1.2).

1.2.2.3 Factors of Life Expectancy

The reasons for this trend are the consequences of several factors: the amelioration of health conditions, the rise in health services, the increase in education, better nutrition in quality and in quantity, the instauration of psychological support, wide promotion of oral hygiene, and better housing conditions, with increased possibilities for dependent or handicapped people.

Medical Conditions

General health conditions or involvement may define oral rehabilitation. Systemic diseases are frequent, needing special care and prohibiting an invasive procedure. The most common diseases and the major causes of mortality are: heart diseases, cancers, cerebrovascular problems, arteriosclerosis diabetes, impaired lung diseases, and the neuro-psychological conditions, such as Parkinson's and Alzheimer's [3].

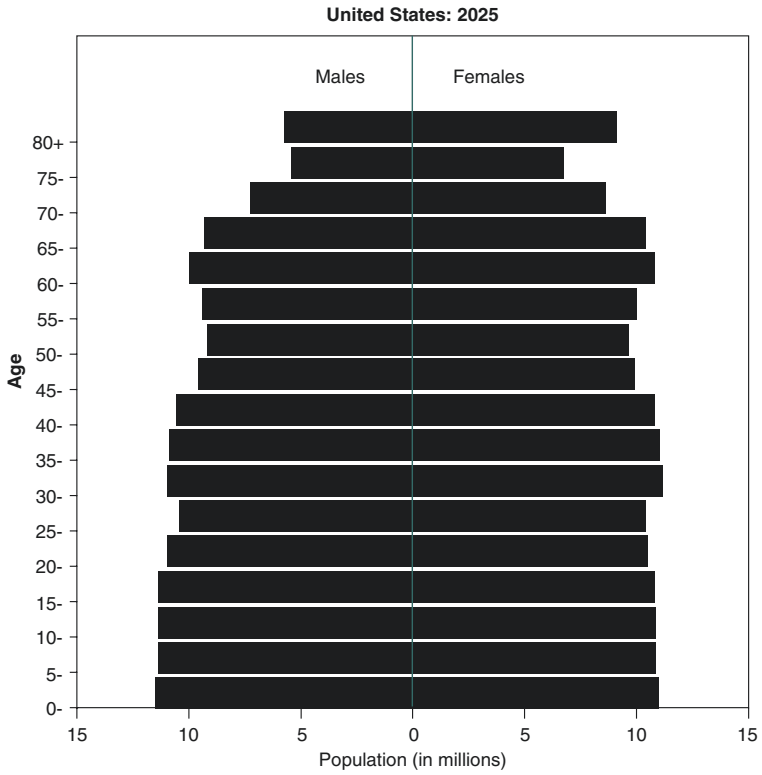

Fig. 1.2 Demographic situation in the USA by 2025

Mental Status Evaluation

During the first examination of the patient and before starting any diagnosis, prognosis or treatment, it is essential to carry out basic mental status testing. Dementia is the main brain illness of elderly patients. The practitioner must understand that elderly people who appear to have dementia may be suffering from pseudo-senility syndromes and may in fact have communication disorders.

Often, ageism contributes to an over-diagnosis of dementia. Therefore, it is crucial to have a good knowledge of the cognitive status (speech, hearing, and language difficulties), and to know how to evaluate a patient who is suspected of suffering from dementia. Aside from these factors, it was proved that "fatigue" is a clinical sign of biological aging. Frailty is described as a phase of acceleration in the aging process. Therefore, the identification of fatigue is an interesting parameter for knowledge about patients with increased vulnerability to stress conditions [4].

Oral Status of the Elderly

Aging is characterized by important changes in the human organs. The combination of these changes with age-related pathological conditions leads to the need for multiple medications to maintain their quality of life. There is a danger that taking a large number of medications could also provoke undesirable side-effects in the elderly, for example, mouth dryness [5].

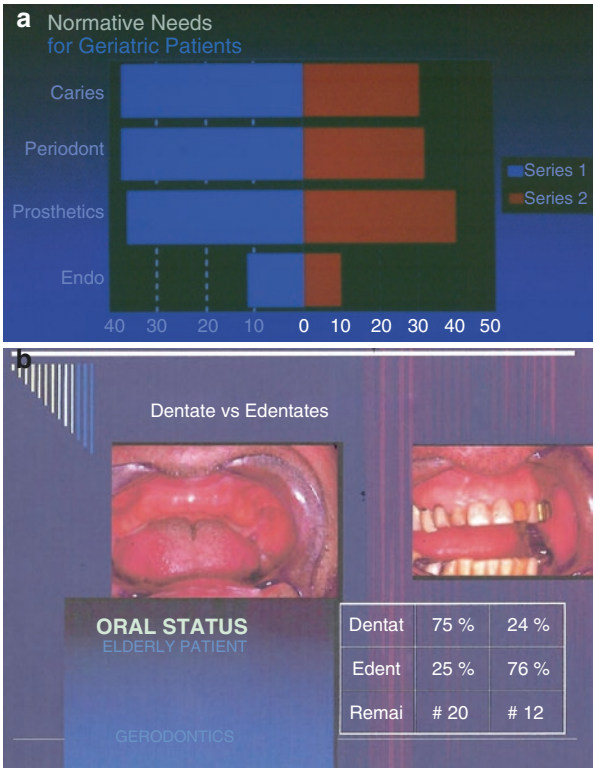

Fig. 1.3 (**a**) Normative needs for an elder population. (**b**) Dental status number of edentulous elderly

Edentulism

Edentulism is most common in the oldest cohort of the population. In the main European countries, there is a decline in the remaining natural teeth with increasing age. In Denmark, France, and Germany, the number of teeth is decreasing more rapidly between the ages of 60 and 70. In general, 25% of aged patients suffer from edentulism before the age of 80 years and 50% by the age of 90. Prosthodontic replacement of the missing teeth differed between countries. The WHO goal for the next decade is evaluated as having 20 remaining teeth at the age of 80 years. This target has been achieved by 25% of the population in most European countries (Fig. 1.3).

Aging and Sexuality

With the aging process, common stereotypes define the elderly as asexual. Nevertheless, many aged individuals continue to be active in a range of patterns of sexual activity, often shifting to other forms of sexual expression and intimacy in later life [6].

As the physiological changes in the oral sphere are clear indicators of patient aging, the silent patient's request is to overrule this handicap. Older adults are looking for a form of sexual activity to desire or be desirable. This emphasizes the importance of

Fig. 1.4 Vertical dimension at rest

the esthetic factor when planning orofacial rehabilitation. This is not only a matter of the color of the teeth, but a correct evaluation of the patient aspiration.

From this perspective, the dentist has the obligation to involve the patient's partner in the strategic decision about the esthetic target. Over the past few years, there has been an increase in sex education for senior patients, providing them with sound information about their problems. In fact, by developing this approach for harmonious dialogue is a matter of basic continuing education for the practitioner. An example is the relationship between the vertical dimension of the face and the facial aspect, and the shape of the lips (Figs. 1.4 and 1.5).

Old age refers to ages nearing the life expectancy of human beings, and thus the end of the human life cycle. In 2016, scientists identified the maximum lifespan to be an average of 115 years, with an upper limit of 125 years (en.wikipedia.org/wiki/old age).

Terms and euphemisms for the aged include: old people, seniors, senior citizens, older adults, the elderly, and elders. Old people often have limited regenerative abilities and are more susceptible to diseases and sickness than younger adults. The organic process of ageing is called **senescence**, medical study is called **gerontology**, and in the oral sphere **gerodontology.** The study of diseases that afflict the elderly is called **geriatrics**. The elderly also face other social issues around

Fig. 1.5 Vertical dimension of occlusion

retirement, loneliness, and ageism. Chronological age, denoted as old age, varies culturally and historically. Consequently, old age is a social concept rather than a biological stage.

1.2.3 The Necessity of a Bioethical Attempt

Despite the fact that the dentist applies the rules he/she was taught, he/she is very disappointed with the results. Unfortunately, there are dogmas that dragged down the prosthetic restoration to a pitfall for senior patients [7].

As gerodontology is not a priority in the basic educational syllabus, the profession is not able to deal with a growing minority of persons with atypical or unusual requirements looking for prosthodontic treatment who present outstanding features or variations from normality. Therefore, these handicapped patients are described as "denture cripples" and are unable to receive a conventional treatment or often cannot wear the dentures as completed by the dentists. The classical approach is devoted to the treatment of typical or normal patients, but for the old-old or typical patients, special diagnoses and solutions are recommended (Fig. 1.6) [8].

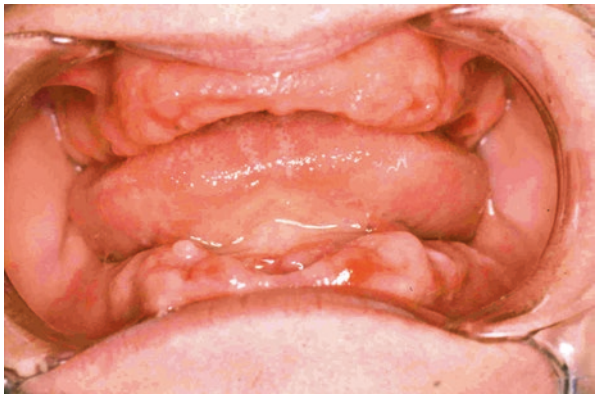

Fig. 1.6 Maxilla and mandible edentulous patient

A typical or conventional patient can be categorized as one concerned with the following characteristics:

1. A patient who comes to the dental office for prosthodontic treatment after or about losing his natural teeth.
2. His expectation of the dental care is that he will be provided with a set of removable dentures to partly replace the functions fulfilled by the natural teeth.
3. He agrees to the treatment and collaborates with the dentist during the clinical procedures and the necessary adjustments that follow the delivery of the dentures.
4. He does not present any severe systemic or physical limitation for the treatment and for the home self-care.
5. The masticatory muscles and the temporo-mandibular joints are reasonably healthy and have no functional limitations.
6. The residual ridges and their adjacent structures are of normal size and form, and able to provide a stable functional foundation for the dentures.
7. The soft and hard oral tissues are healthy and properly lubricated by the salivary flow.
8. The tongue and the tongue attachments are of normal size and position to allow the insertion and proper function of the mandibular prosthesis.
9. There is a minimal or non-existent gagging reflex at the posterior region of the maxilla during the treatment and after upper denture insertion. On a physiological vertical dimension on occlusion there is adequate denture space for the construction of the denture base and the artificial teeth.
10. Some special occlusal relations between the edentulous ridges permit the setting of the artificial teeth on top of or close to the residual crests and allow harmonious arrangements.
11. The patient shows a reasonable and positive attitude, acceptance and ability to adapt following delivery of the dentures.
12. *Last but not least: there are NO symmetrical patients, as learned in the conventional text-books.* Because the left and right sides are not symmetrical, this means that the teeth arrangements do not respect the patient's physiology.

In conclusion, with aging, there is no ideal patient who presents all the criteria described.

1.2.4 Physiological Design in Complete Dentures

The most frequent features are described:

1. Systemic diseases.

Most patients present one or two systemic diseases. The most common are hypertension, diabetes, and cardio-vascular problems [9]. Aside from these, there are also neurological systemic critical situations such as Parkinson's, Alzheimer's, and various types of depression. Various forms of cancer are also frequent.

2. Psychological behaviors.

One of the most difficult obstacles to successful treatment is a psycho-geriatric attitude and behavioral disorder [10]. *Aside from the classic organic brain syndromes, there are also paranoid states and affective disorders. These factors will barely compromise treatment planning.*

3. Economic limitations.

With the increase in life span and difficulties in the economic situation, an economic gap appears and consequently a diminution of financial possibilities [11].

4. Physiological evolution with aging.

There is a change in the elderly patient physiology with aging, such as a change in the supporting structures, the muscles, and the natural or acquired reflexes. In particular, bone resorption was studied, that is, the significant differences between the maxilla and the mandible. A growing difference between the right and left sides is noted.

Therefore, taking into consideration the major dogmas present in old text-books and articles, a new approach has to be introduced. For example, very few studies on the fundamental asymmetry in most individuals were found.

Usually, one side is shorter than the other. Often, the middle of the maxilla does not correspond to the middle of the face.

This is in contradiction with what was written in the traditional text-books.

In the same way, the condylar process is different on both sides, providing an unequal occlusal position. In general, the ridge resorption is centripetal in the maxilla and centrifugal in the mandible, causing a problematic cross-bite situation [12].

Dentists were taught to set up the artificial teeth on the residual ridges. As this anatomical landmark disappears, it is recommended to take advantage of the neutral zone and place the teeth between the tongue and the peripheral structures. *Phonetic impressions are of paramount importance for registration of the prosthetic design of the dentures* (Figs. 1.7, 1.8, 1.9, 1.10 and 1.11) [13].

Numerous statements of research have pointed out the asymmetry of the chewing cycles, inducing in this way a special occlusal balance system.

Another important factor is acquired para-function caused by poor prosthetic restorations and this creates a serious obstacle for the stability of the new dentures. When considering an adapted treatment planned for the old-old patient, this asymmetric factor must be taken into account.

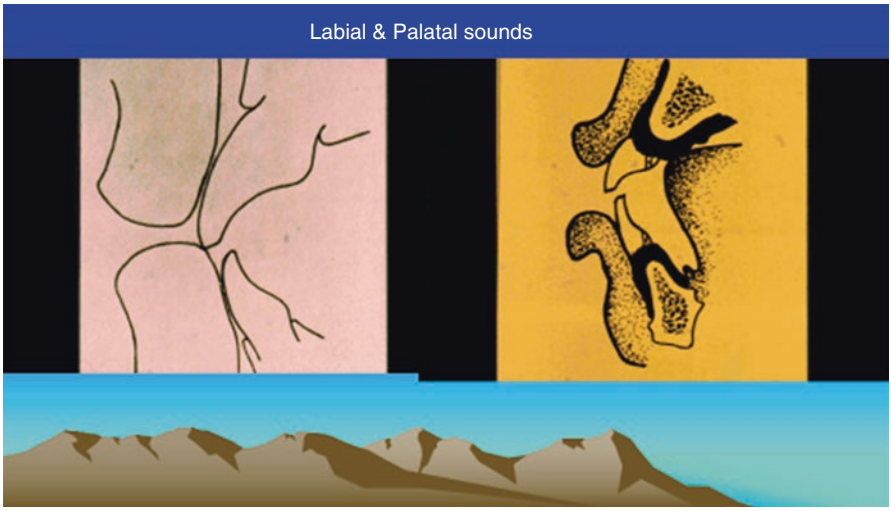

Fig. 1.7 Anterior piezo registration

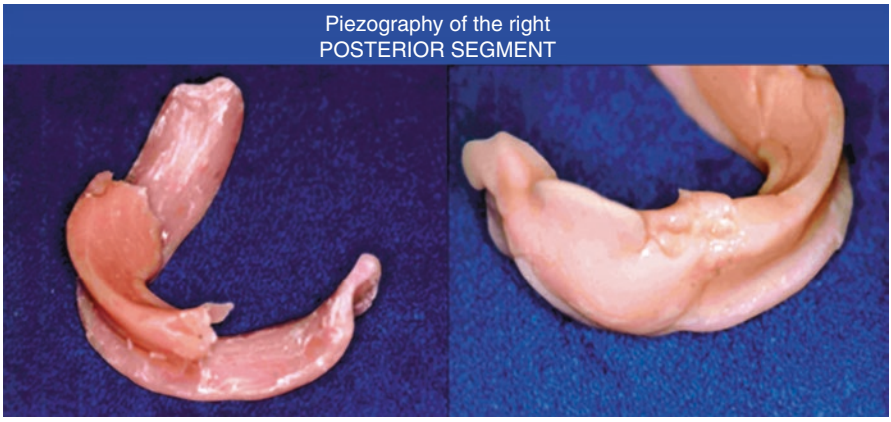

Fig. 1.8 Posterior piezo registration

1.2.5 Satisfaction with Complete Dentures

The elderly cohort is an important group who constantly has great difficulty in adjusting and wearing dentures. Therefore, they have a reduced quality of life and are dissatisfied, causing considerable problems to dentists. Identifying these patients before treatment gives the practitioner the possibility of modifying the approach and helping the patient to adopt more realistic expectations. There are many varied factors involved in dissatisfaction [14].

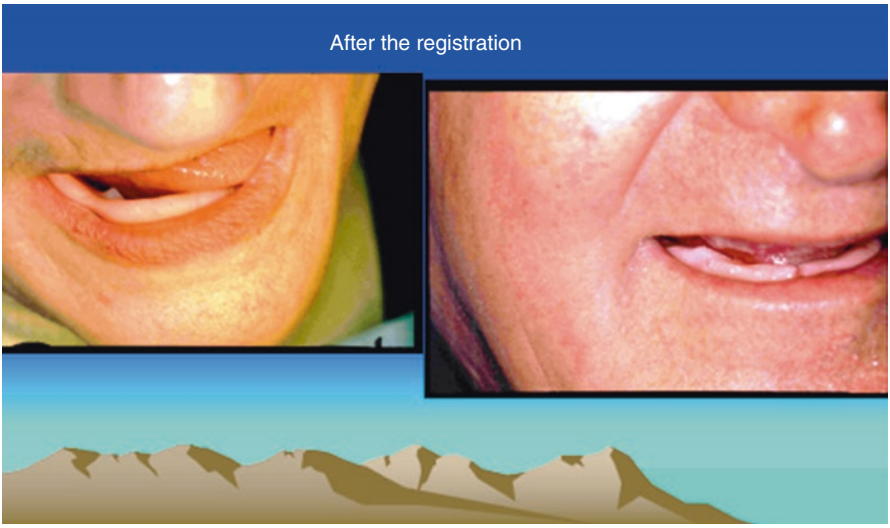

Fig. 1.9 Posterior piezo registration

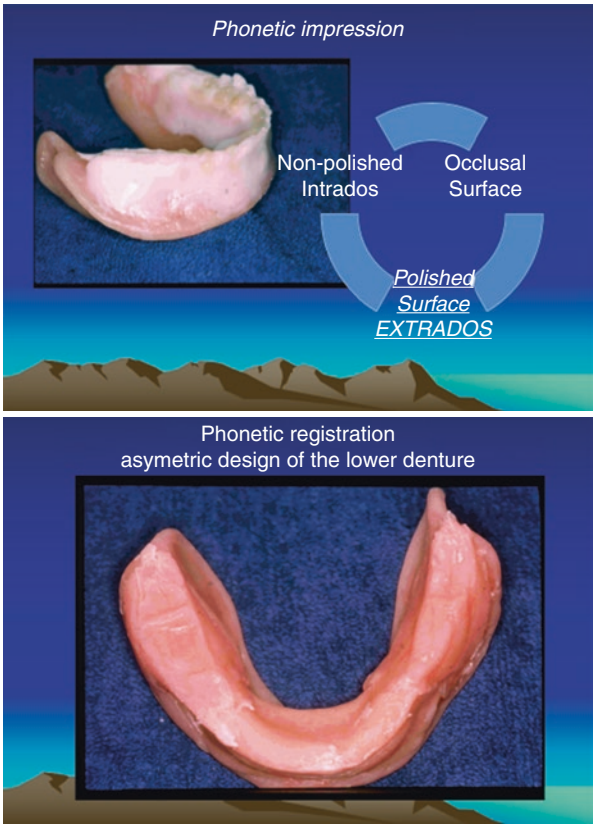

Fig. 1.10 Phonetic registration asymmetric design of the lower denture

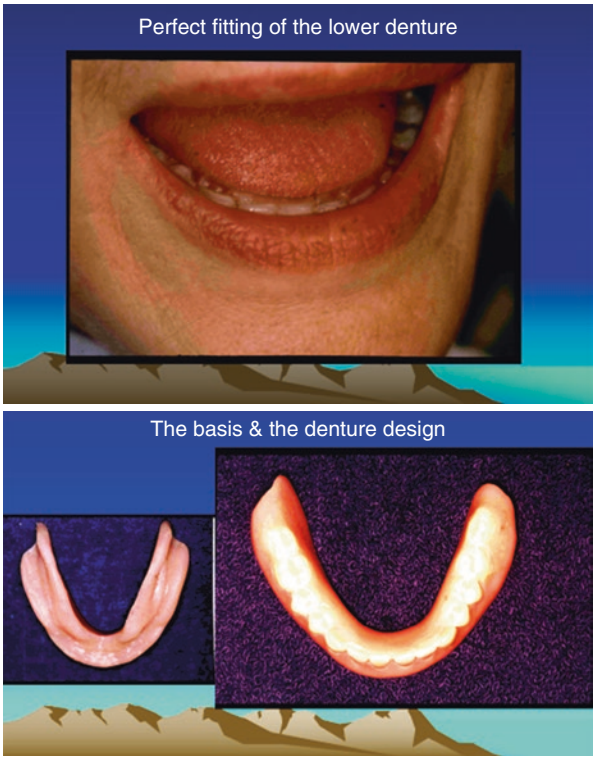

Fig. 1.11 Perfect fitting of the denture between the tongue and the buccal face of the cheek

1. Past denture experience is better related to denture satisfaction than to age.
2. Comfort is a decisive factor, because the patient is always comparing the new dentures with the old ones, in term of the denture design, the occlusal system, the freeway space, and phonetics.
3. Usually, the criteria for conventional dentures are: accepted esthetics, good retention and stability, ability to chew properly, and acceptable phonetics. A failure in one of these conditions leads to a deterioration of all oral rehabilitation.
4. Switching abruptly from an old to a new denture is often the reason for the destabilization of the geriatric patient. In this situation, the patient will never accept the new restoration.
5. This underlines the importance of the psychological aspects of the treatment of elderly patients. In the same way, the influence of systemic conditions and medication has an impact on the tolerance of dentures.
6. Only a step-by-step treatment plan with evaluation is recommended. These transitional steps are the *conditio sine qua non* for comprehensive and tolerated changes.

1.2.5.1 Immediate Dentures

An important challenge, both for the dentist and the patient, is the transition from the dentate to the edentulous status. For the geriatric patient, the loss of their remaining teeth causes a psychological and functional stress. The main problems arising concern function, because the patient cannot accept waiting a long healing period before the insertion of the definitive dentures and the esthetics, as there may be differences between the dentist's and the patient's esthetic perception. The use of conventional immediate dentures may not be an acceptable solution, because it presents difficulties concerning appearance and the psychological and emotional state, because a wax setup trial is not able to predict the final stage. Nevertheless, multiple extraction surgery can be very stressful even though the procedures are simple. Because of these factors, interim dentures are recommended. Usually, we can help the patient with this transition by converting his partial removable dentures or by providing him with provisional ones [15].

1.2.5.2 Overdentures

Epidemiological studies indicate that more patients will become edentulous in their old age when they are especially less able to adapt themselves to the limitations of complete dentures. One of the main problems is the lack of retention. Therefore, the overdenture approach is attractive. Two types of overdentures are currently in use (Figs. 1.12 and 1.13):

1. The type that rests on doomed, endodontically treated tooth roots with or without attachments. A conservation of the root is a valid and a practical measure in complete denture prosthodontics. Bone maintenance is the most significant advantage of a tooth-supported denture, providing a bone with volume and height that increases retention and stability and moreover allows the patient a better function and control by conserving intact proprioception.
2. The type that rests on an implant, supporting the denture with a large variety of mechanical devices. The Toronto Study states that this solution is of paramount importance for a complete lower denture (Fig. 1.14) [16]. Nevertheless, there are important factors limiting the use of implants in elderly patients:

– Bad anatomical conditions, acute bone resorption.
– Severe systemic diseases, or psychological problems.
– Anxious patients or dentists' perceived stress.

3. Benefits and risks perception. Recent studies indicate the extreme importance of psychological aspects of satisfaction with the complete denture treatment. The patient may be frustrated by his unrealistic expectations of prosthetic and implantology therapy [17].
4. Undergoing the surgical implant procedure, which is often traumatic, experimenting with the insertion of a similar prosthetic device can led to a pitfall.
5. Sometimes the expense and the long delay increase the negative behavior of patients.

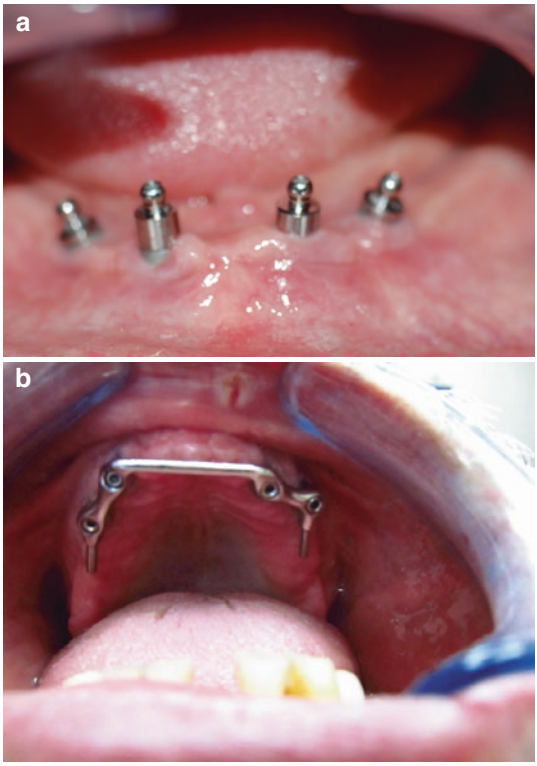

Fig. 1.12 (**a**) Implant overdenture (IOVD) with ball attachment. (**b**) Implant bar overdenture

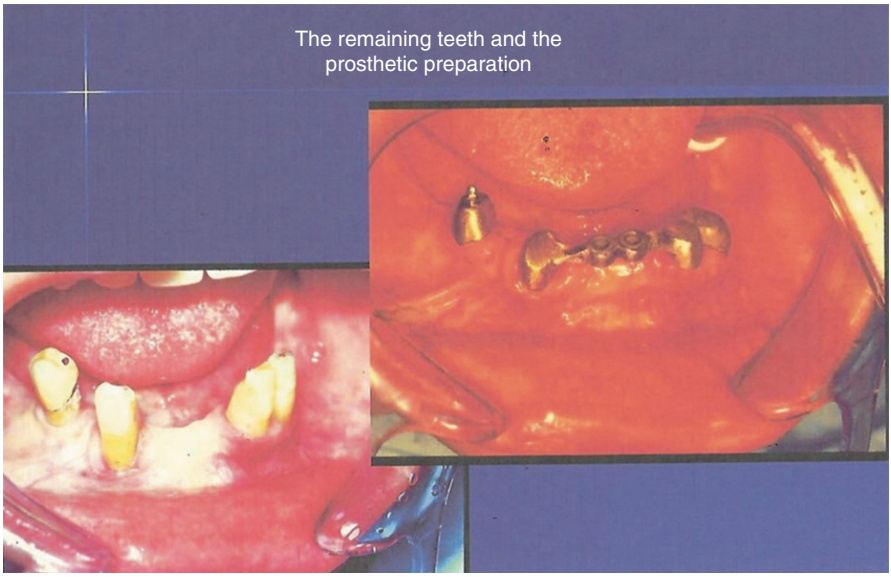

Fig. 1.13 Overdentures on natural teeth

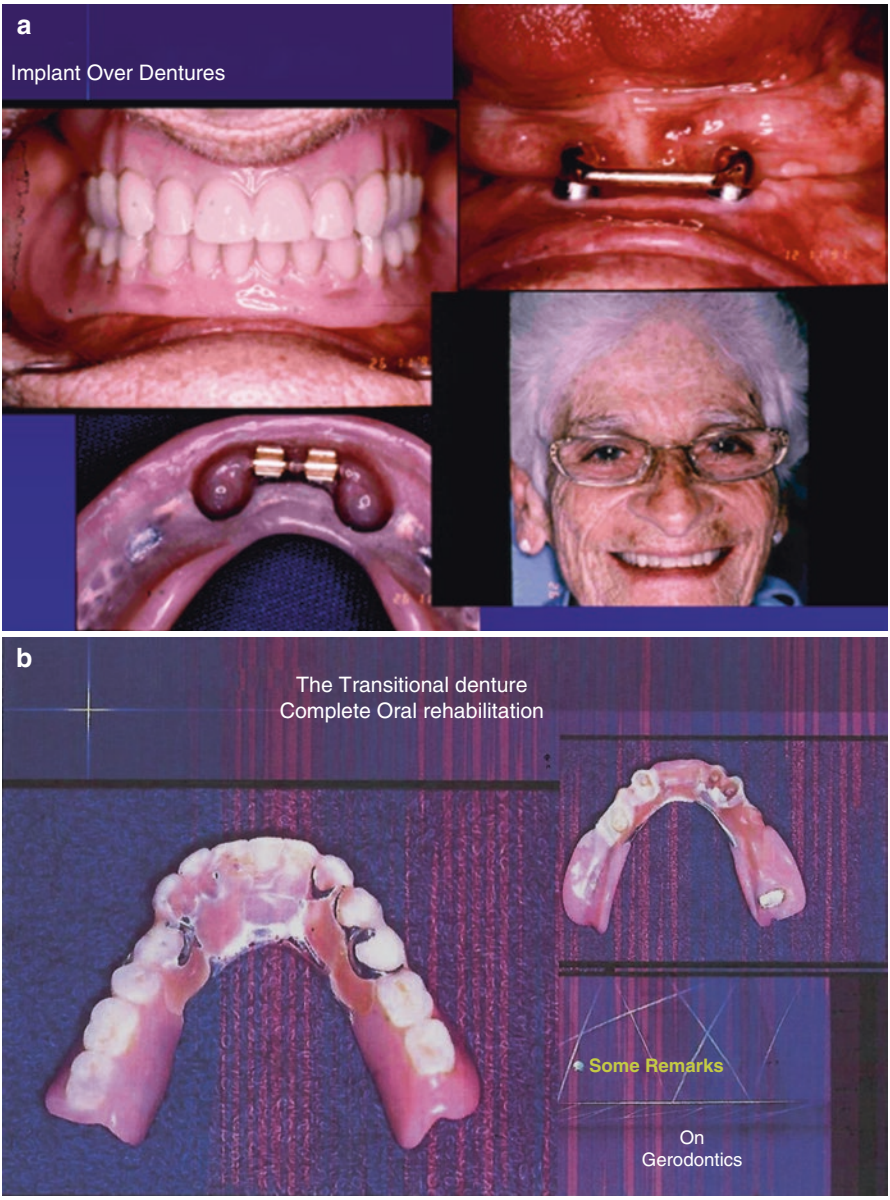

Fig. 1.14 (**a**) Bar overdenture. (**b**) Transitional overdenture on natural teeth

1.3 Rationale

All the above descriptions take a specific approach to the elderly/frail patient. It is a fact that ageing is a process that affects each patient differently. Chronological age is not the only indicator of geriatric status. There is a tremendous variability in the biological and psychological aspects between patients. Consequently, there should be a specific approach to each individual. Treatment of these patients requires a realistic risk benefit evaluation. One of the most significant challenges is adapted management. To avoid unhelpful and stressful situations and a large financial burden, it is recommended to proceed with a step-by-step schedule, thus enabling constant revaluation. This requires first palliative treatment and then transitional or intermediary restorations (Fig. 1.4).

When considering the permanent or final stage, it is essential to act from a preventive perspective, always giving the possibility of a repair or a transformation of the prosthetic devices [18].

To summarize this non-conventional approach, *minimally invasive management is highly recommended* [19].

1.3.1 Ethical Rules

There are ethical rules that must be imperatively respected by the practitioner:

- Adapting carefully the standard of care in geriatric dentistry to the patient's functional and cognitive impairment, his medical condition, and his socio-economic situation and motivation.
- Avoiding creating irreversible traumatic situations: "primum non nocere".
- Providing immediate pain- and infection-free comfort.
- Reaching a transitional oral function in addition to a more esthetic appearance.
- Accomplishing subjective personal satisfaction and increasing motivation.
- Taking into consideration the time factor. This should be an important and decisive guideline for treatment planning.
- Finally, achieving oral rehabilitation is key to oral quality of life.

1.3.2 Remarks

The age concept*: how old are you*? (Fig. 1.15)

Usually, this is one of the first questions that the dentist asks.

Often, there is confusion between the patient's answer and his medical psychological status. In fact, there are various approaches to this problem:

Fig. 1.15 Overdenture with ball attachment

1. Chronological age

The birth date is the main point determining the correct age.
Since the German Chancellor Bismarck, and for economic reasons, 65 years old is the landmark between active and retired people.
Certainly, this criterion is obsolete when considering actual evolution.

2. Psychological evaluation

Various tests help the practitioner to set up an evaluation of the patient's behavior. This is a key reference for adapted treatment planning.

3. Medical anamnesis

This is an essential indicator of the medical condition. Drug intake is sometimes difficult to obtain, owing to loss of memory or hesitation of the patient. It is recommended to establish contact with the relevant physician to receive a clear opinion on the medical status.

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Systemic Diseases and Oral Health of the Aged Patient

2

Guillaume Campard

Abstract

Preservation of adequate masticatory function in the aging population can provide significant benefits such as infection control and nutrition to elderly patients' overall health. It is now understood that oral health and systemic conditions are closely related, and the two may be mutually dependent and reciprocal. A persistent inflammatory state is a challenge to the body that has been proven to correlate periodontal disease with systemic conditions such as cardiovascular disease and diabetes. In turn, reduction of such inflammation can be beneficial to both oral health and systemic conditions. This chapter summarizes the scientific evidence supporting the close relationship between oral and systemic well-being.

2.1 Introduction

It is a common assumption that the aging process in the oral cavity involves an irreversible degenerative mechanism that inevitably leads to loss of teeth. As a result, many people assume that a natural consequence of aging is tooth loss, as they may have watched their own parents lose teeth to caries or periodontal disease over time. This was possibly associated with bleeding, swollen gingiva, and sometimes even pain. Patients often believe these symptoms are a natural phenomenon of aging and unrelated to one's health status.

For a long time, periodontal diseases were considered "isolated" diseases, impacting only the oral cavity and strictly resulting from local processes. Consider this: persistent bleeding gums aren't often a health status concern for patients, whereas if there was persistent bleeding from the skin, a patient is more likely to

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seek medical consultation. This poor understanding of periodontal disease and its correlation to global health is the consequence of a long-standing misconception about the pathophysiology of periodontal diseases. It has now been established that periodontal diseases are not merely degenerative in nature. They not only share common pathological mechanisms with other chronic systemic diseases but also can be directly related to them. An ongoing challenge for the medical community is taking this evidence into account and including the oral cavity and periodontium when considering patients' overall health.

2.2 Periodontal Disease: An Inflammatory Disease with an Infectious Etiology

Periodontal diseases (gingivitis and periodontitis) are diseases that alter or destroy the supporting tissues of the teeth. An inflammatory reaction, triggered by the presence of bacteria, generates changes in the metabolism of mineralized and non-mineralized connective tissues leading to tissue destruction and attachment loss. In the 1960s, the "nonspecific theory" stated that the burden of the bacterial load in one patient's mouth was directly correlated with the severity of inflammation and periodontal tissue destruction. Further evidence showed the bacterial load was not the only pathological parameter, and the composition of the bacterial biofilm was also critical in the development of the disease. In chronic periodontitis, Socransky et al. [28] classified the main identified periodontal bacteria in groups according to their pathological potentials. For instance, the red complex composed of three bacteria Pg (*Porphyromonas gingivalis*), Tf (*Tannerella forsythia*), and Td (*Treponema denticola*) are some of the strongest periodontal pathogens involved in the progression of periodontal diseases. The bacterial metabolism generates mediators that trigger and maintain inflammation, through different ways: release of toxins or lytic enzymes and activation of metabolic cascades in the host cells by bacterial molecules known as PAMPs (pathogen-associated molecular patterns) present in various bacterial virulent factors such as LPS (lipopolysaccharide) and PGN (peptidoglycan).

These pathogenic bacteria and their metabolic products not only stay within the periodontal pocket, they are capable of invading the adjacent connective tissue (such as Pg) and reach the blood stream to disseminate throughout the body.

The presence of specific periodontal pathogens and a heavy bacterial load associated with poor oral hygiene are not the only conditions required to have periodontal disease. An observational study performed by Loe et al.[32] on a cohort of Sri Lankan laborers having similar limited to no access to oral cares showed the natural history of periodontal disease was variable among individuals exposed to a given environment. Some patients would display rapid attachment loss and early tooth loss when others would have limited to no attachment loss. It was understood the bacteria were an etiologic factor that would generate disease which expression varies among individuals. Later on, the concept of host susceptibility arose to explain how the genetic background as well as acquired or environmental factors can

influence the onset and the progression of disease for an individual. It is now estimated that 50% of the adult population suffers from periodontitis with 10–15% of severe forms of diseases.

2.3 Inflammation: A Common Factor Between Periodontal Diseases and Systemic Diseases

In a susceptible individual, the persistent inflammatory reaction triggered by the bacterial biofilm leads to disease. In the early stages, the innate immunity leads to an elevated production of pro-inflammatory mediators such as Il-1β, Il-6, and TNF-α that are produced by immune cells (macrophages, neutrophils) and also residents cells (epithelial cells, endothelial cells). These mediators allow inflammatory cell recruitment, migration, and differentiation. Since this innate immunity response fails to get rid of the bacterial aggression, the inflammatory reaction fails to resolve and becomes chronic. An adaptive inflammatory reaction starts. T cells and B cells are recruited and differentiated; cell-mediated immunity with antigen presentation and humoral immunity with immunoglobulin production maintain an inflammatory infiltrate within the periodontium. Elevated levels of pro-inflammatory cytokines (Il-1, Il-2, TNF-α, INF-γ) and immunoglobulins remain, and metabolic changes lead to connective tissue destruction through lytic enzymes (MMPs) and bone resorptive mediators (such as RANK-L).

Many systemic diseases such as diabetes, cardiovascular diseases, or rheumatoid arthritis are diseases in which a chronic and dysregulated inflammatory reaction is involved as in periodontitis, although the etiology is different. It has been hypothesized that the production and circulation of pro-inflammatory mediators or cells from one site to the periodontium could be a cofactor to the development of periodontal disease. Inversely, the persistence of elevated levels of pro-inflammatory mediators and bacteria in the periodontium could have a detrimental effect on inflammatory systemic diseases. Although a lot is yet to be understood, evidence suggests associations, and maybe causality might link periodontal diseases and inflammatory systemic diseases.

2.4 Diabetes and Periodontal Diseases

Diabetes is an endocrine disease associated with a deficient insulin production leading to hyperglycemia and hyperlipidemia. Many complications are correlated to diabetes including cardiovascular diseases with micro- and macrovascular complications, neuropathy, retinopathy, nephropathy, and impaired healing. Periodontitis was proposed as another complication in the early 1990s [2]. Diabetes concerned 171 million people in the year 2000 and may increase to 366 million people by 2030 [1]. Type 1 diabetes generally affects children and young adults. It is associated with an autoimmune destruction of the pancreatic islets involved in insulin production. Type 2 diabetes is more prevalent in adults and is a major

concern for the aging population. It is generated by an acquired insulin resistance due to an inadequate production of insulin by pancreatic β-cells. Inflammation and immune cell dysfunction might be involved in acquired insulin resistance.

Chronic hyperglycemia might have detrimental effects on the periodontium through different pathways. Taylor et al. [3] recently proposed possible mechanisms linking periodontitis and diabetes. Authors stated that, with regard to the existing evidence, the presence of diabetes or the level of diabetic control might not directly influence the composition of the periodontal microbiota. However, the existing studies only studied a limited fraction of the periodontal microbiome. The hypothesis is still valid, but more research is needed.

Many studies observed a correlation between diabetes and elevated levels of pro-inflammatory cytokines (Il-1, Il-6, TNF-α), mainly in the gingival crevicular fluid (GCF) and saliva [5, 6, 9]. The data is sometimes limited (with regard to type 1 diabetes) or inconsistent, so it is not yet possible to clearly identify the pathogenic effect of diabetes on the periodontal status. It seems that altered local factors, rather than systemic ones, could explain the detrimental effects of diabetes on the periodontium.

Hyperglycemia can modify mineralized tissue homeostasis acting disturbing signaling pathways such as the RANK/RANKL axis. For instance, Santos et al. [4] found a correlation between a poor glycemic control in type 2 diabetic patients and unfavorable RANKL/OPG ratios, whether periodontitis was treated or not.

Hyperglycemia leads to glycation of multiple molecules, including lipids and proteins, called AGEs (advanced glycation end products). It has been demonstrated that AGEs are present in gingival tissues and saliva of diabetic patients [30]. Diabetic patients have elevated levels of cell-surface receptors for advanced glycation end products (RAGE). The activation of these receptors generates multiple metabolic changes leading to increased production of lytic enzymes (such as MMPs) and pro-inflammatory cytokines [31]. Toll-like receptors involved in the innate immunity and initial stages of inflammation can also be activated by AGEs [24].

Oxidative stress is also consistent with diabetes [29]. Hyperglycemia is associated with high levels of reactive oxygen species that maintain the hyperproduction of pro-inflammatory mediators and chronic inflammation in the end. At last, it is speculated that dyslipidemia associated with diabetes could contribute to periodontal inflammation through adipokines [9, 10].

Taylor et al. [3] proposed a schematic representation of the current understanding of the mechanisms linking diabetes and periodontitis. Other factors, such as genetics, smoking, and age, can influence the "vicious circle" displayed on Fig. 2.1.

From a clinical point of view, evidence suggests there is an association between poor glycemic control and the severity of periodontal disease [7]. Four main retrospective and prospective studies including a total of 4512 participants diagnosed with type 2 diabetes reviewed by Borgnakke et al. [25] showed a correlation between HbA1C (glycated hemoglobin, a robust measure of glycemic control) and the severity of periodontitis. Progression of periodontal disease was stronger for patients having increasing HbA1C levels. There were also more diabetic complications for patients suffering from severe forms of periodontitis.

There is evidence suggesting that nonsurgical treatment of periodontitis might improve the glycemic status of a diabetic patient, with regard to HbA1C levels [8].

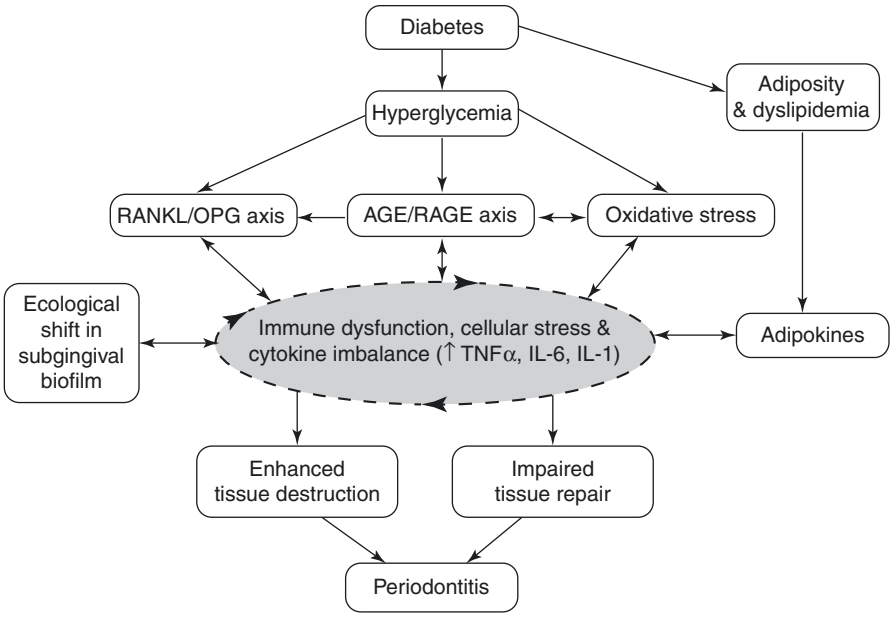

Fig. 2.1 Pathologic mechanisms that may link periodontitis and diabetes. From Taylor et al. [3]

A meta-analysis performed by Engebretson et al. [27]showed a significant HbA1C reduction of 0.36% 3 months after mechanical debridement. The magnitude of HbA1C is modest, but it is equivalent to the adjunctive effect of a second drug to a pharmacological diabetic treatment.

Based on this existing level of evidence, guidelines are now available for health professionals and patients [26]. The main recommendations are summarized below:

- Patients diagnosed with diabetes should be told that periodontal disease risk is increased by diabetes. A periodontal examination is recommended, as well as oral health education.
- Diabetic patients with extensive tooth loss should benefit from dental rehabilitation to enhance mastication and proper nutrition.
- Diabetic patients with periodontitis may experience more difficult glycemic control and a higher risk of diabetic complications. Periodontitis management should be systematically offered by dentists.
- Patients presenting without a diabetes diagnosis but with obvious risk factors for type 2 diabetes and periodontitis should be referred to a physician.

2.5 Cardiovascular Diseases and Periodontal Diseases

Cardiovascular diseases are a group of medical conditions that include coronary heart diseases (myocardial infarction, angina), cerebrovascular diseases, and peripheral arterial diseases, and they are a major cause of death. Cardiovascular diseases

affect adults with an increasing proportion for elder people. In the United States, about 11% of people between 20 and 39, 70% of people between 60 and 79, and more than 80% of people over 80 years old suffer from cardiovascular diseases, with a stronger prevalence and an earlier cause of death for men versus women. In 2009, direct and indirect costs of cardiovascular disease are estimated to be over $312 billion [11]. Controlling risk factors for cardiovascular diseases is a major public health challenge.

The atherogenesis leading to atherosclerosis is generated by an inflammatory reaction which has similarities with the one occurring in the periodontium with periodontitis. In the early stages of atherogenesis, an increased permeability and adhesiveness of the vascular endothelium allows platelet adhesion as well as lipoprotein and leukocyte migration into the artery wall. An inflammatory reaction takes place with a release of pro-inflammatory cytokines such as Il-1, TNF-α, IFN-γ, and chemokines. Lipid-laden monocytes and macrophages (called foam cells) form fatty streaks with T lymphocytes and migrating smooth muscle cells. The advanced artery wall lesion is composed of a necrotic core and a peripheral fibrous cap that reduces the diameter of the vessel lumen and which is susceptible to detach and generate cardiovascular complications, such as myocardial infarction or stroke [12].

Evidence suggests periodontal pathogens can migrate into arterial walls and may play a role in the atheromatous lesion development. Haraszthy et al. [13] showed the presence of bacteria in 72% of human carotid biopsies. Forty-four percent were positive for at least one periodontal pathogens targeted (Tf, Pg, Aa, Pi.). These pathogens were found in association in 59% of the periodontal pathogen-positive specimen. It is hypothesized periodontal pathogens could contribute to maintain the inflammatory reaction within the arterial wall through their metabolic activity.

C-reactive protein (CRP) is a major cardiovascular risk predictor. It is a protein produced by the liver in response to systemic inflammation. Serum CRP concentrations are regularly dosed in patients with a cardiovascular disease for risk assessment [14]. CRP could just be a surrogate marker, but it is suspected to be an active pro-inflammatory mediator. There is evidence suggesting the association between elevated CRP levels and chronic or aggressive periodontitis [15]. It has also been demonstrated that patients combining cardiovascular diseases and periodontitis had higher CRP levels than patients having one or the other condition [16].

A recent systematic review [17] evaluated the existing evidence for an association between periodontitis and the incidence of atherosclerotic cardiovascular diseases (including coronary heart disease, cerebrovascular disease, and peripheral arterial disease). The authors observed an association between periodontitis and the incidence of atherosclerotic cardiovascular diseases, the risk being stronger for cerebrovascular diseases. Interestingly, stronger association is observed in males and younger subjects. It was also observed that there is no association between periodontitis and coronary heart disease incidence for people over 65. At last, only one study found an association between never-smokers and secondary cardiovascular event.

There is evidence showing that periodontal therapy can have both positive and negative impact on systemic variables. Mechanical debridement is rapidly followed

by an acute inflammatory response through a release of pro-inflammatory cytokines, an impairment of endothelial function, and a perturbation of hemostatic event [18]. Long-term outcomes are more favorable and can lead to decreased levels of cardiovascular disease biomarkers, such as CRP, TNF-α, and MMPs, among others. The consequences of these variable modifications on one patient's health status are still controversial. Negative short-term consequences of mechanical debridement are probably limited and might only interest high-risk individuals with comorbidities. Periodontal treatment could also improve the cardiovascular health status of an individual at risk on the long term through the reduction of pro-inflammatory factor circulation or endothelial function improvement. For instance, several meta-analysis confirmed the significant reduction of serum CRP levels (ranging from −0.2 to −1 mg/L) a few months after scaling and root planning [18].

In the last decade, two consensus reports were published by, respectively, the *American Journal of Cardiology* and *Journal of Periodontology* editors [19] and the committee of the Joint EFP/AAP Workshop on Periodontitis and Systemic Diseases [20]. Recommendations are formulated based on the available evidence to health practitioners and are summarized below:

- Practitioners should inform patients of the strengthening evidence of periodontitis as a risk factor for developing atheromatous cardiovascular diseases.
- Since no causal relationship is yet established between periodontitis and atheromatous cardiovascular diseases, the rationale for periodontal treatment remains the preservation of the dentition rather than the improvement of one cardiovascular status.
- Periodontitis patients with other risk factors for atheromatous cardiovascular diseases (i.e., dyslipidemia, family history of cardiovascular disease, smoking) should be referred to a physician if no medical examination was performed within the last year.
- Reduction of lifestyle common risk factors for both diseases should be addressed in the dental office, in collaboration with other specialists if needed.

2.6 Respiratory Diseases and Oral Health

Investigations have been carried out to evaluate the relationships between oral health and chronic obstructive pulmonary disease and pneumonia.

Chronic obstructive pulmonary disease is an inflammatory disease of the lungs and airways with a progressive airflow limitation. It is mainly caused by tobacco smoking and can be aggravated by viral or bacterial infections. A study performed by Katancik et al. [21] showed an association between elder people aged 70–79 with periodontitis and airway obstruction, only in former smokers. However, the evidence is still weak, and the linking mechanisms are still uncertain.

Evidence linking oral health and pneumonia is stronger, especially for ventilator-associated pneumonia, which is a subset of nosocomial hospital-acquired pneumonia. A biofilm can form on the surface of the endotracheal tube and generate lower

airway infections. Since it has been demonstrated that specific respiratory pathogens such as *Staphylococcus aureus* and enteric species can colonize the oral cavity, it has been hypothesized that the mouth could act as a reservoir for respiratory pathogens, leading to increased ventilator-associated pneumonia. Scannapieco et al. [22] concluded in a systematic review that "improving oral hygiene through mechanical and/or topical chemical disinfection or antibiotics reduced the incidence of nosocomial pneumonia by an average of 40%." The trend seems equivalent for elderly people in hospital and residents living in nursing home. Oral hygiene appears to be beneficial for these populations with a preventive effect on mortality from pneumonia and nonfatal pneumonia. Evidence suggests that improving oral hygiene could prevent one in ten cases of death from pneumonia [23].

2.7 Other Systemic Diseases

An association between periodontal disease and other systemic disease such as obesity, rheumatoid arthritis, cancer, chronic kidney diseases, and cognitive impairment is being studied. The available evidence is weak since available studies use variable criteria with surrogate parameters to define periodontitis, and many confounding factors can bias the interpretation of the data for these multifactorial diseases. More research is needed to understand the mechanisms underlying and linking these conditions.

Conclusion

The understanding of the preponderant role of inflammation in the physiopathology of periodontal disease opened a new era in possible links between systemic diseases and oral health. The new concept of periodontal medicine is promising based on the amount of evidence mainly gathered for the last 20 years. Associations between periodontitis and diabetes or atherosclerotic cardiovascular diseases are proved although causality is yet to be established. Improvement of oral hygiene for elderly living in nursing home and hospitalized patients results in a significant reduction of nosocomial pneumonia morbidity and mortality. Maintaining oral health in the aging population more exposed to systemic disease provides benefits that go beyond the oral cavity and may become even more critical in the near future, as stronger scientific evidence is gathered.

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The Treatment of Periodontal Diseases in Elderly Patients

3

Maria Gabriella Grusovin

Abstract

Periodontal disease is a chronic disease and its effects accumulate with age. It represents an important oral health issue in elderly patients. Age-related biological changes in periodontal tissues and in immune response could alter the answer to the microbiological challenge that causes periodontal diseases. The microbiota burden itself can be different. Periodontal diseases have an inflammatory nature and can play a role in the pathogenesis of no communicable chronic diseases that are particularly common among the elderly. Great care should be dedicated to a comprehensive anamnesis, where consultation with the medical doctor performs an important role. Treatment approaches follow the general rules of the treatment of periodontal diseases but modifiers are linked to the biological changes due to age, chronic diseases, medications and socio-economical issues. Besides the degree of dependence in performing normal activity, hand strength and manual dexterity must be considered in both therapy planning and in the maintenance protocol. Minimally invasive surgical approaches should be considered in periodontal and implant therapy. Great care should be dedicated to the maintenance of oral hygiene.

3.1 Epidemiology and Peculiarities of Periodontal Disease in the Elderly Patients

3.1.1 Epidemiology

The number of elderly patients is increasing in most of the planet, and it will continue to grow in the next future. Substantial increase in life expectancy occurred in recent years, rising from 65 years for men and 69 for women in 2000–2005 to

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69 years for men and 73 years for women in 2010–2015, but with large disparities across countries. There is not a common agreement about the cut-off age to consider a person elder, but most of the developed world consider elder as 60–65-year-old persons, since this is considered as the age of retirement in most of the countries. The data of the United Nations Department of Economic and Social Affairs (https://www.un.org/development/desa/publications/world-population-prospects-the-2017-revision.html) show that the number of persons over 60 is expected to more than double by 2050 and to more than triple by 2100, rising from 962 million globally in 2017 to 2.1 billion in 2050. The number of persons over 80 is also estimated to raise from 137 million in 2017 to 425 million in 2050 to 909 million in 2100.

One of the main issues is to increase the rate of successful ageing people. Age increases the risk of health disorders, even if many older adults can maintain good functional abilities. A particular condition is the frailty syndrome that can be defined as a progressive age-related decline in physiological systems that results in decreased reserves of intrinsic capacity, which confers extreme vulnerability to stressors and increases the risk of a range of adverse health outcomes [1]. Oral health is important to maintain a satisfactory quality of life that implies retaining adequate nutrition, the absence of pain and diseases but also preserving a smile that helps in normal relationship.

In the developed world, the quantity of remaining teeth has increased, and the edentulism is diminishing due to prevention and to the augmented social importance of retaining teeth [2]. So the need for dental care in old people will augment in future, and periodontal treatment will play a major role. Periodontal disease is one of the most important causes of tooth loss, followed by caries and periapical lesions.

Periodontal disease is a chronic disease and its effects accumulate with age. The 1999 International Workshop for a Classification of Periodontal Diseases and Conditions considers gingivitis, chronic periodontitis and aggressive periodontitis [3]. In gingivitis, there is inflammation of soft tissues but no progressive periodontal attachment loss. Periodontitis is a chronic inflammatory disease caused by a microbial infection within the supporting tissues of the teeth and results in progressive attachment and alveolar bone loss. The tissue damage results from dysregulated and prolonged inflammatory responses to the persisting subgingival biofilm.

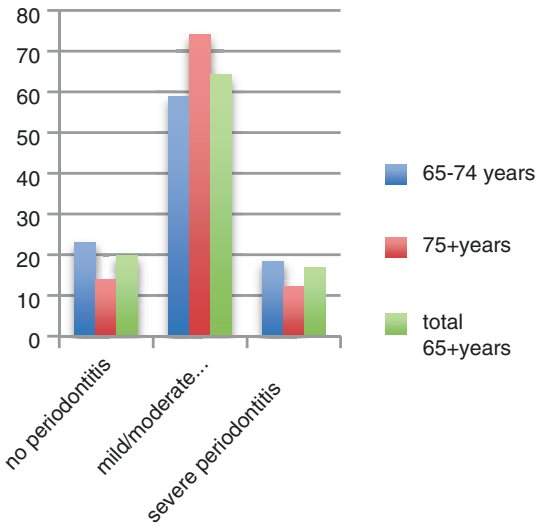
Difference in bacteria challenge and/or in the immune response of the patients can lead to different forms of the diseases. Aberrant or exaggerated immune/inflammatory responses have been implicated in the aetiology of severe forms of periodontitis. Risk factors for periodontal disease can be distinguished in modifiable (smoke, medication, diabetes, stress, obesity) and no modifiable (genetic predisposition, race, sex).

In the world, severe periodontal disease is expected to affect 10.8% of the population, and it is the sixth among pathologies affecting patients. The peak of incidence for severe periodontitis is between 30 and 50 years, and the prevalence remains similar afterwards [2], but given its cumulative nature, periodontal disease increases with age. In the United States, the National Health and Nutrition Examination Survey 2009–2012 estimated the presence of mild/moderate periodontal disease in 64.1% of male and 64.1% of female in the age group older than 65 years. The prevalence of severe disease was of 16.2% in male and 6.4% in female, while only 19.8% of male and 29.5% of female were disease-free [4] (Table 3.1).

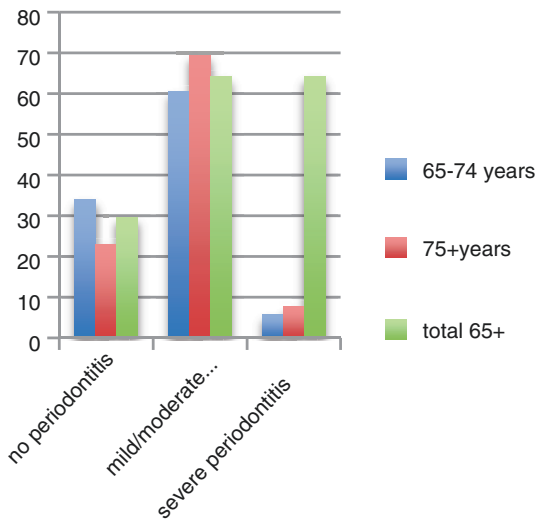
Cross-sectional data from individuals in a Swedish population between 60 and 96 years of age showed that tooth loss and progressive periodontitis are common among individuals ≥81 years of age and are linked to poor oral hygiene also in patients on regular supportive dental visits [5].

Table 3.1 Distribution of periodontitis (percentage out of 100) (National Health and Nutrition Examination Study (NHANES) 2009–2012 (n = 1511) from Eke et al. [4]

Male



Female



1084 with periodontitis: minimum 15 teeth and 4 teeth with at least one site with PPD and PAL >5 mm
246 with periodontal health: minimum 20 teeth and <20% BOP
(modified from Feres et al. [10])

In summary, data show that periodontal disease is an important health issue in elderly people and its extent and severity increases with age, while only a relatively small proportion of patients experience severe periodontal destruction.

3.1.2 Are Periodontal Diseases Affected by Ageing?

The cumulative effects of periodontal disease result in higher severity and extent in older ages, but ageing could affect periodontal disease directly through biological alteration of the tissues and immune response or indirectly via physical, cognitive and socio-economical impairment.

Age-related alterations are present in the periodontium, and these must be differentiated from true oral/dental disease. Age alone does not cause critical periodontal attachment loss.

Cellular senescence implies an arrest in proliferative capabilities of cells, the oral epithelium is thinning, and there is less keratinization, with fibroblast alteration and less production of collagen. The blood supply to the dental structures demonstrates degenerative and arteriosclerotic changes. The periodontal ligament space becomes narrower with less organized periodontal fibres, less cellular presence and areas of calcification. Type I collagen, the most abundant protein in the periodontium, decreases with age. Alveolar bone has decreasing mineral density and remodelling activity due to less osteoblast chemotaxis and less osteoclast differentiation.

Aged periodontal tissues show important deficiencies in the wound healing response, and it is possible that the tissues damaged from the inflammatory insult are not restored in the proper way.

The ageing process is dependent on defence and antistressor mechanisms, and the immune system plays a major role [6]. Ageing is characterized by immune senescence, i.e. a reduction in the capability to answer to antigenic stimulation and by an increase in pro-inflammatory status termed “inflammaging”. There is an age-related altered neutrophil function, increased neutrophil persistence, increased secretion of pro-inflammatory cytokines (interleukin-1B, IL-6, IL-17, prostaglandin E2) and upregulated expression of genes that contribute to a pro-inflammatory state [7]. It is still not clear whether such age-related changes in immune response are connected to increased disease susceptibility.

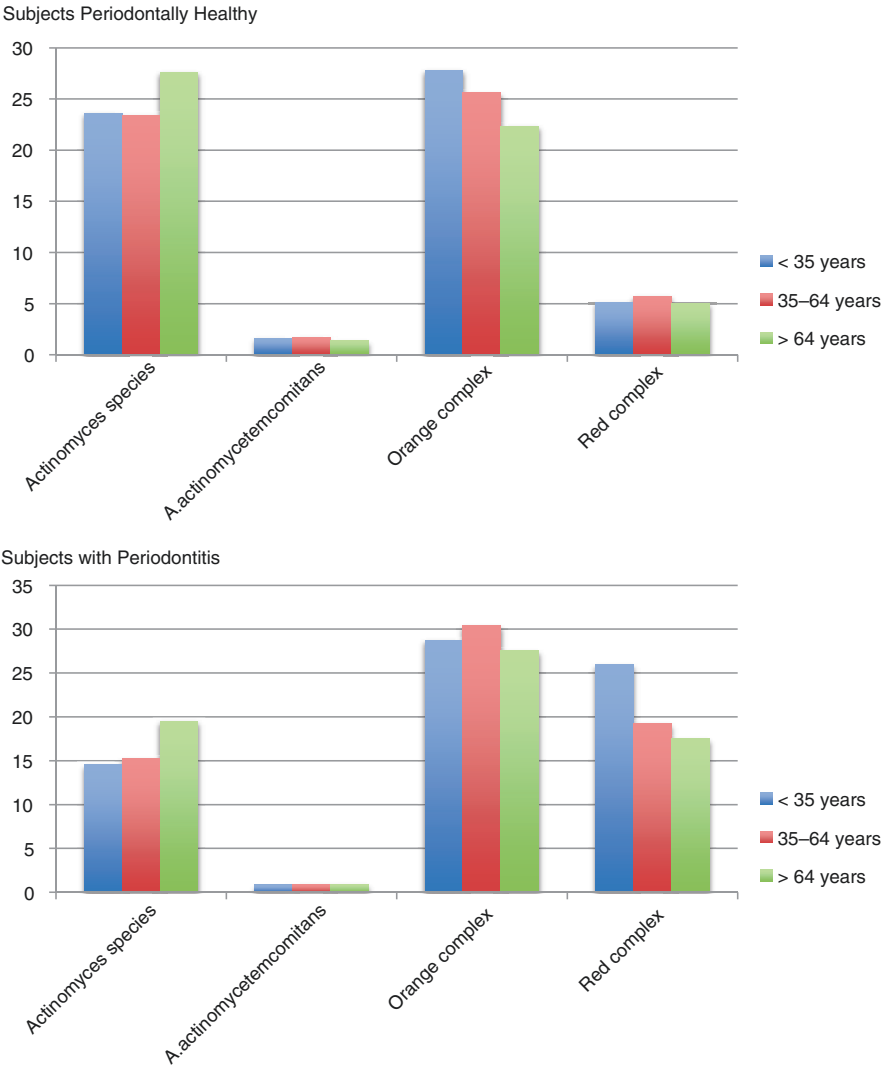
A reduction in the innate and adaptive immune response ability to couple with the bacterial challenge can lead to a more destructive inflammation. In an experimental gingivitis model, no significant differences in plaque accumulation were seen between young and older subjects, but the aged ones showed more severe gingivitis [8] showing a possible difference in inflammatory response. On the other side, a review of oral health among older people concluded that in spite of the biological changes during ageing, there is little evidence that these modifications predispose to more periodontal breakdown [9].

The impact of ageing on the composition of oral microbiota remains unclear [10]. A change in the immune response and of the inflammatory status can influence the oral microbiota, but the composition of the subgingival biofilms of older adults

healthy and with periodontitis is very similar to the one of the younger subjects [10]. A higher level of *Actinomyces* in supragingival plaque is present, and this can be due to a higher prevalence of exposed roots (Table 3.2).

The type of progression of periodontal disease may be different than among younger patients. In a 5-year study, the incidence of attachment loss in elderly was linked to gingival recession more than to increased probing depth, and the progression was site specific and not associated with smoking habits [11]. Gingival

Table 3.2 Mean proportion (percentage out of 100) of 40 taxa in subgingival samples from 1330 subjects (cross-sectional and longitudinal studies conducted at the Centre for Clinical Research at Guarulhos University, Brasil, and at the Forsyth Institute, USA)



recession which increases with age is linked to increased risk for cervical caries. Besides, many medications can decrease salivary flow. Caries on the exposed root surfaces are an important problem in elderly patients.

Periodontitis is a multifactorial disease, and its more severe forms are limited to a part of the ageing population.

A compromised medical condition can alter the disease progression.

Age-related changes are present in the periodontium. Cellular senescence, altered wound healing, immune senescence and "inflammaging" are influencing periodontal response to bacterial challenge. It is not clear if they can predispose to periodontal disease progression. Attachment loss is more linked to the presence of recession than to increasing probing depth, so an increased risk of root caries is present.

3.1.3 Is the Presence of Periodontal Diseases Affecting the Ageing Process?

Oral health and systemic health are closely related. Petersen PE in the 2003 World Oral Health Report reported that common risk factors can be recognized in periodontal diseases and non-communicable chronic diseases as tobacco use, diet, excessive alcohol consumption, stress and poor oral hygiene. Periodontal disease in particular with its infectious and inflammatory nature can influence systemic diseases. Periodontitis has been related with a raised serum pro-inflammatory state, shown by increases in C-reactive protein (CRP), in pro-inflammatory cytokines (e.g. tumour necrosis factor-α (TNF-α)) and in a reduction in anti-inflammatory markers (e.g. interleukin-10 (IL-10)). Besides, chewing on involved teeth may lead to the introduction of periodontal bacteria through the epithelium with host response stimulation and exacerbation of systemic inflammation [12]. Bacteria can enter the blood stream and set up infection in distant organs and stimulate inflammation, and direct bacteria aspiration can cause pneumonia.

The relative increase in systemic pro-inflammatory state and the decrease in anti-inflammatory state caused by periodontitis can enhance systemic "inflammaging" and affect different systemic diseases that occur more frequently among the elderly and have been related to periodontal disease: cardiovascular diseases (CVD), type 2 diabetes, rheumatoid arthritis, alteration of kidney function, aspiration pneumonia, chronic obstructive pulmonary disease, Alzheimer and dementia.

A clear association between periodontal disease and **CVD** is present in male subjects under 65 years [13]. Little is known about this association in the very old. Periodontitis can influence atherosclerotic process in different ways: the direct bacterial invasion of epithelial and endothelial cells and of the blood stream can stimulate host response or direct set up infections or infection can enhance production of active mediators that can exacerbate systemic inflammation. Experimental studies have shown that the presence of these periodontal pathogens and oral bacteria in the atheroma could induce platelet activation and aggregation through collagen-like platelet aggregation-associated protein expression [14].

Type 2 diabetes increases the risk for periodontitis. Periodontal disease is associated with reduced glycaemic control in type 2 diabetes patients, but treatment studies gave contradictory results. While glycaemic control was improved by periodontal therapy, in some studies also in older patients, the same result was not obtained in others [15], but they are difficult to compare, and different biases could have influenced the results.

An association between periodontal disease and **rheumatoid arthritis** has been found. There is also some evidence that periodontal treatment improves arthritis status.

Decreased kidney function in the elderly was associated with periodontal disease [16]. It is not clear if periodontal treatment can improve kidney disease.

Aspiration pneumonia is provoked by aspiration of oropharyngeal-infected secretions. It is common in patients affected by dysphagia or with depressed consciousness, which affects more frequently the elderly. The bacteria often originate from the oral cavity, so a good oral hygiene could help in the prevention of such a complication.

Periodontal disease was found to be an independent risk factor for **chronic obstructive pulmonary** disease [12].

Dementia and Alzheimer were found associated with fewer teeth and with periodontitis [12].

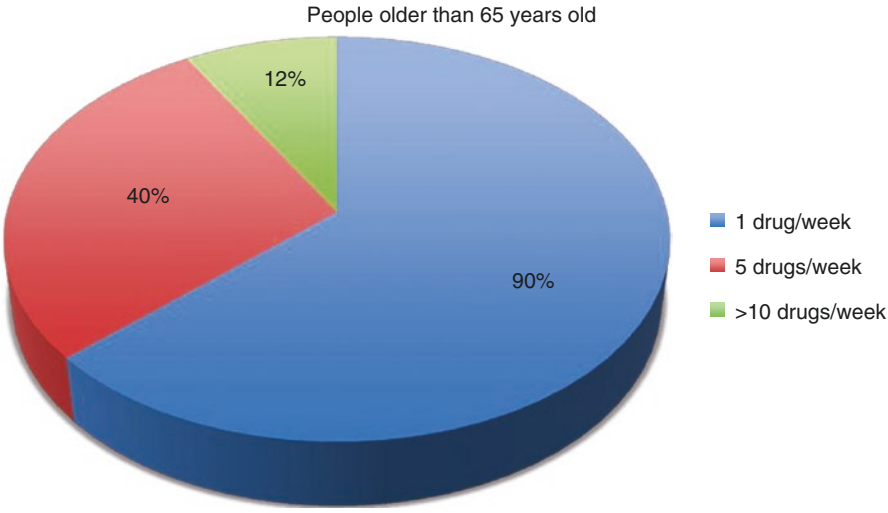
Tooth loss linked to periodontal disease can reduce masticatory efficiency and can contribute to the development of the frailty syndrome, which can affect older people.

Several chronic diseases common in elderly people may be influenced by periodontal disease, probably due to the microbiological challenge and to the increase in pro-inflammatory status. The strongest association has been found for CVD, type 2 diabetes and respiratory diseases, but it is increasing for neurodegenerative diseases, rheumatoid arthritis and chronic kidney diseases. The effect of periodontal treatment on these diseases is not clear. It is logical to presume that to significantly reduce the risk for chronic diseases, patients should maintain good oral health through life [12], but treating periodontal disease can help in maintaining good systemic health. Particular attention should be given to the maintenance of oral hygiene in frail older adults, like hospitalized patients or the one with dementia.

3.1.4 Medication Influence on Periodontal Diseases

Older patients have a higher prevalence of chronic and multiple illnesses, and prescription drug use increases substantially with age. Among people ≥65, approximately 90% take at least 1 drug per week, > 40% use at least five different drugs per week, and 12% use ≥10 different drugs per week [17] (Table 3.3). The frail elderly, hospitalized patients use more drugs, up to seven to eight different drugs in resident patients [18].

Table 3.3 Percentage of people older than 65 years old taking one or more drugs per week [17]



Drugs most commonly prescribed in elderly patients include "statin" drugs for hypercholesterolemia, antihypertensive agents, analgesics, drugs for endocrine dysfunction including thyroid and diabetes medication, antiplatelet agents or anticoagulants, drugs for respiratory conditions (e.g. salbutamol), antidepressants, antibiotics and drugs for gastroesophageal reflux disease and acid reflux. The most frequent over-the-counter medications taken by older adults include analgesics, laxatives, vitamins and minerals [18].

Some of these drugs can have effect on the oral cavity and the periodontium.

Xerostomia is the subjective symptom of dry mouth that not always coincides with real lack of saliva. Diabetes, radiation and Sjogren's syndrome are often linked to this disease, and anticholinergic, antidepressants, antihistamines, antihypertensive, anti-parkinsonism, antipsychotics, diuretics and tranquillizes can all depress salivary production. Xerostomia is linked to an increase in caries presence, and old people with exposed roots due to periodontal disease are more at risk for root caries.

Antihypertensive and immunosuppressant drugs can induce gingival overgrowth. **Gingival overgrowth** is the most frequent side effect of systemic medication on periodontal tissues. It is frequently linked to phenytoin (50% of the patients), cyclosporine (30%) and calcium channel blockers (10%) [19]. Often some of these drugs are used together with an increased effect on the disease. Age is considered as an important risk factor for both cyclosporine- and phenytoin-induced gingival overgrowth, the younger be more prone to develop this problem probably due to hormonal influence. Good oral hygiene reduces the inflammatory component in the gingival tissue and reduces the effect of drug-induced overgrowth. A cohort of patients develops the disease despite good plaque control, due to the genetic fibroblast heterogeneity.

Different drugs cause oral lichenoid reactions (Fig. 3.1). The most commonly implicated drugs include beta-adrenoceptor blockers (e.g. propranolol, atenolol),

Fig. 3.1 Lichenoid reaction due to beta-adrenoceptor blockers

antidiabetic drugs (e.g. chlorpropamide and tolbutamide), gold salts and non-steroidal anti-inflammatory drugs [19]. Most examples have been presented as case reports, and diagnosis is often difficult and implies stopping the suspected drug and re-evaluate the patient.

Anti-inflammatory steroids, non-steroidal drugs and anti-TNF-α agents could instead exert a positive effect on chronic periodontitis, but the evidence is still uncertain, and none of these medications has proved to be a valuable adjunct in the treatment of periodontal disease. The impact of hormone replacement therapy on periodontitis is difficult to define. Some periodontal benefit has been reported, and it probably linked to the hormone-induced reduction of the risk of osteoporosis [20].

Patients who were prescribed with bisphosphonates, anti-aggregants and anticoagulants are at risk of serious side effects during invasive dental procedures such as extractions and surgery. **Bisphosphonates** are the most common drugs used for osteoporosis treatment. They inhibit osteoclast activity preventing bone resorption and reducing its turnover. According to the American Association of Oral and Maxillofacial Surgeons [21], the frequency of osteonecrosis in the jaws in patients receiving intravenous BPs is 0.8–12%, while oral BPs give an estimated incidence of 0.7 per 100,000 person years of exposure. Proposed risk factors include the time of exposure, intravenous administration, concomitant chemotherapy, smoking, glucocorticoid use, diabetes mellitus and periodontal disease. A recent review [22] suggests that implant placement should be avoided in patients under IV BPs—a washout period of 3–6 months is advisable for surgical procedures—while there is no contraindication in patient taking oral BPs for <5 years.

Anticoagulant therapy (OAT) is very common in the elderly. In OAT patients (INR 2–4), discontinuation of medications is not recommended for minor oral surgeries including implants, since they have no higher risk of post-operative bleeding than patients who discontinue their medication. The use of topical haemostatic agents is recommended, and non-steroidal anti-inflammatory agents should be avoided.

Drugs prescription increases with age, and many medications can have an effect on oral cavity and periodontal tissues. A comprehensive list should be

collected. Xerostomia, gingival overgrowth and lichenoid reactions are the most frequent drug side effects. Good oral hygiene is of primary importance and can lessen some drug side effect. Care should be exerted when extraction or surgical treatment is necessary in the presence of anticoagulants and of bisphosphonates. Eventual change of medication should be discussed with the treating doctor.

3.2 Prevention and Treatment of Periodontal Disease in the Elderly

3.2.1 General Consideration

Periodontal treatment aims to lower the microbiota load to a level that can be managed by the patient biological defence. Clinically the therapy goals are low levels of bleeding on probing (BOP <15% of sites), shallow probing depths (PPD <5 mm) and absence of suppuration. The core of the treatment is supra- and subgingival biofilm removal that can be achieved non-surgically or surgically. Effective self-performed plaque removal and recall attendances during supportive periodontal therapy are key elements for success.

Ageing per se seems to have very limited effect on the outcomes of prevention or treatment of periodontal diseases [23], but the level of health and dependence, rather than chronological age, influences treatment results and approaches. Healthy and successful ageing people seem to have similar response to therapy than younger one; oral hygiene maintenance is mandatory.

Clinicians should consider the presence of care pathways, which are designed to guide practitioners along evidence-informed approach to delivering care in a manner that provides a predictable outcome. The Seattle Care Pathway is an example for older adults, which are classified in five categories from pre-dependant to highly dependant. Assessment, prevention, treatment and communications are described for every category [24].

The first step in elderly patient treatment is an **initial assessment** of the patients' level of dependency, considering their physical, medical, and psychological condition and cognitive impairment. Communication with other health professionals who are caring for the patients is often of crucial importance to obtain all relevant information.

A comprehensive health history is of primary importance for the elderly. A proper time allocation should be dedicated, and frequent update of medical condition should be considered. The visit should include assessment of general health status, medications, risk factors for oral diseases, dietary habits, evaluation of the ability of performing oral hygiene manoeuvres, cognitive impairment, independency, access to care and socio-economic factors. Additionally, tests such as the salivary flow test could be considered. Patient's desire and expectations should be valued, and treatment alternatives should be considered taking into account the probability of positive outcomes, the impact on quality of life, the ability to tolerate the stress of treatment and the remaining life expectancy.

The World Health Organization recognizes that in the elderly, the important risk factors for oral health are socio-economical status and education, lifestyle, institutionalization, low level of oral hygiene and manual dexterity and medications (WHO 2012 - http://www.who.int/mediacentre/factsheets/fs318/en/).

Communication is an important part of patient treatment. Information about relationship between oral health and systemic diseases should be provided to the patients and/or to the people taking care of the elder patients [4]. The retention of healthy dentitions is linked with well-being and self-esteem and more importantly to the maintenance of good masticatory function, which allow a healthy diet necessary to delay physical decline.

There is a lack of data on the efficacy of different treatment approaches for periodontal disease in the older adult. Important modifiers of the success of periodontal treatment include general health status/presence of chronic diseases, the modifying effect of medications (both beneficial and adverse effects), health literacy and socio-economic factors. Periodontal therapy in the elderly must be related to medical conditions, ability to access to care and the ability to perform adequate oral hygiene that is of paramount importance. Extreme care should be dedicated to oral hygiene instruction and to the maintenance programme.

3.2.2 Therapy

Age-related alterations in the periodontal tissues might be potentially associated with an impaired healing response, at least in the early phase following treatment.

Non-surgical therapy aims at the elimination of biofilm that causes infection.

In moderately advanced and advanced form of periodontitis, age did not influence the result [25]. Similarly, a retrospective study analysing the outcome of non-surgical therapy after 1 month [23] concluded that age had a limited effect on treatment response but there was a significant higher risk of residual pockets in elder patients.

Traditional non-surgical therapy implies the use of hand or ultrasonic instruments. New interesting approaches using airflow powder can display a less invasive treatment for the elderly, even if data are still lacking. Clinically shorter chair time is used, and sites difficult to reach (i.e. under old prosthetic works, implants, etc.) can easily be cleaned up. Glycine powder air polishing is more effective at removing subgingival biofilm than manual or ultrasonic instruments; a standard air polishing nozzle is used in periodontal pockets up to 4mm probing depth, while a subgingival nozzle is used in deeper pockets. Less tooth structure is removed [26].

Medication can induce several periodontal modifications. The most common is drug-induced gingival overgrowth. **Drug-induced gingival overgrowth treatment** implies first removal of bacteria load, and then gingivectomy is the main treatment option to reduce the hyperplastic tissue. The use of systemic and topical antibiotics has been studied, and there is some evidence that azithromycin can have some effect on cyclosporine-induced gingival overgrowth, probably reducing bacterial infection

Fig. 3.2 Crown lengthening in an 86-year-old woman allows maintenance of her teeth

[27]. Chlorhexidine mouthwash and folic acid mouthwash appear to have some effect on phenytoin-induced gingival overgrowth [19]. A change in the medication should be discussed with the medical doctor.

Periodontal surgery can be used to eliminate residual periodontal disease after proper non-surgical therapy or to gain tooth substance in case of fractured teeth and crown/root caries. Where residual periodontal pockets with bleeding on probing are present, elimination of pathological pockets could be done by resective therapy (i.e. reduction of soft tissue depth and remodelling of nonsupporting and supporting bone to gain a morphologic correct form) or by regenerative therapy (i.e. reducing soft tissue depth by regenerating periodontal attachment). Periodontal plastic surgery can be used to correct soft tissue deformities. In old people, gingival recession is in most cases caused by loss of supporting tissue both buccally and interproximally, so gingival coverage is not possible. Crown lengthening is instead a frequent procedure. Minimally invasive approaches should be strived to (Fig. 3.2).

The ageing process can negatively affect all stages of wound healing, haemostasis, inflammation, cell proliferation/migration and extracellular matrix secretion [28]. In cutaneous wound models, the effect of ageing seems to primarily delay the healing rather than affect its quality, and this can be connected to the histologic alterations described before [28].

Few studies evaluated the outcome of different surgical approaches related to age [25, 29]. Holm-Pedersen and Löe [29] showed a delayed and impaired healing process following gingival biopsies in older compared with younger patients. No

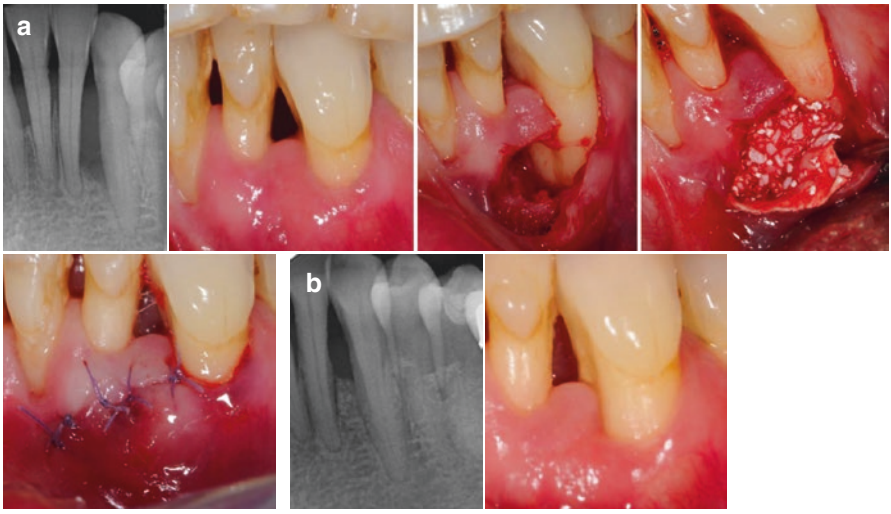


Fig. 3.3 Minimally invasive surgical approach in regenerative therapy of a 70-year-old woman. (**a**) Baseline and (**b**) 1-year follow-up

difference in short- and long-term treatment outcomes following surgical and non-surgical debridement was found in another study [25].

The medical history of the patients should be updated frequently, and the effect of chronic condition and of medication on surgery should be considered.

Healthy old patients can successfully be treated with regenerative techniques. Minimally invasive surgical technique should be chosen (Fig. 3.3).

3.2.3 Implant Therapy

Implant therapy is one of the therapeutic options for geriatric patients. It requires a good communication with the patient to lessen misunderstanding regarding the procedure, the possible complications, the outcomes, the cost and the future commitment to maintain the result.

Increasing of chewing efficiency should be considered of primary importance.

For edentulous patients, stabilization of dentures with implants reduces peri-implant bone and masseter atrophy and increases chewing efficiency improving bite force, denture comfort and the patient's oral health-related quality of life [30]. In partially edentulous patients, implant treatment is sought to restore normal function and aesthetics, and it is more and more preferred to removable partial denture also in elderly patients. In patients with severe xerostomia, maintenance of the teeth can be difficult due to severe root caries. Implant can represent a solution. Besides, implant-supported prostheses may protect the alveolar mucosa from trauma.

Age-related consideration involves success and survival of the implants, early and late complications, risk factors related to general health conditions and

maintenance of the prosthetic/implant complex [31]. Ageing patients may have a delayed soft tissue early wound healing related to an increased release of inflammatory mediators. Bone healing can also be affected by a reduction in stem cells and in angiogenesis that could result in a delayed osseointegration [31]. Osteoporosis can be present more frequently in the elderly, and there is limited evidence that it can negatively affect osseointegration, but a definitive conclusion cannot be made [32]. Bisphosphonate taken for osteoporosis can cause osteonecrosis in the jaws. A recent systematic review [33] indicates that the success rate of implants is not reduced by bisphosphonates. Few studies were included, most of them retrospective, so careful discussion with the patient and the treating medical doctor is advisable since there are studies reporting complications. Limited information is present about the importance of the length of oral bisphosphonate treatment, while systemic bisphosphonates are considered a contraindication [22]. Medical risk factors are more common in the elderly and should be carefully considered. Nowadays, anticoagulant discontinuation is not recommended since the risk of post-operative bleeding is very low with an INR of up to 3.5 and the use of local haemostatic agents like tranexamic acid. Patient and caregivers should be instructed to control minor bleeding—apply pressure to the area, and do not rinse the mouth.

Patient manual force and dexterity should be evaluated in relation to the ability of handling the dental prosthesis and implant and prosthesis hygiene. Rheumatoid arthritis and arthrosis/osteoarthritis may impair denture management and are common in elderly patients. The involvement of caregivers and family members in treatment planning should be considered.

There are no data that ageing influences implant success and complications negatively, even if healing process could be delayed. Patients older than 65 [34] and 79 [35] years old showed similar prognosis than younger patients. Chronic diseases like diabetes, medications, smoking and previous periodontal disease are risk factors for implant treatment, and they should be considered with care in old patients. Radiotherapy results in a significant increase in the risk of implant failure, in particular in the maxilla [36]. On the other side, implant therapy in patients with controlled systemic disease appears feasible.

Economic issues could prevent the treatment. A study where the mandibular overdenture treatment was offered free of charge showed that 36% of the participants refused the treatment due to fear of surgery and satisfaction with current denture, underlining the importance of good communication, and that the cost is not always the most important issue [37].

Careful planning should be implemented to allow minimizing surgical trauma, and minimally invasive treatment should be preferred. Nowadays, many options showed good results. Flapless surgery gives less swelling and pain to the patients, even if it can be more demanding to the clinicians. Transcrestal sinus lift can be implemented. Guided implant surgery allows planning before surgery, and the use of minimally invasive approaches can be simplified. Short implants give less complication than bone augmentation techniques, whereas narrow-diameter implants and tilted implants can avoid the need for horizontal augmentation [38] (Fig. 3.4).

Fig. 3.4 Minimally invasive implant rehabilitation in a 79-year-old woman with severe periodontitis and peri-implantitis. Tilted, short and immediately loaded implants were used. Temporary restorations are still present on implants. Peri-implantitis was non-surgically treated. Maintenance of good oral hygiene is mandatory

Implant biological complications include peri-implant mucositis, reversible infection-induced inflammation in the implant soft tissue without bone loss and peri-implantitis, where also bone loss is present. In the literature, the prevalence of mucositis and peri-implantitis depends on the definitions, so it is different in different studies. It can rise with age due to increased implant function in the mouth and/or to changes in immune response due to age. The maintenance of good oral hygiene plays an important role especially for mucositis. Particular care should be given to cleansability of the prosthetic work. Careful oral hygiene instruction should be given to the patients and/or relatives who are taking care of the patient itself. Oral and denture hygiene problems are more common in dependant patients. Aspiration of microorganism can cause aspiration pneumonia in geriatric patients. The ability

of the patients should be examined, and removable restoration could be preferred for ease of cleaning. In manually impaired patients, unsplinted attachments are preferred, and implant superstructure should be designed to allow a back-off strategy to facilitate oral hygiene at final stages.

Ageing does not appear to affect implant success and survival, but the medical condition together with the cognitive and physical impairment of the patient should be carefully considered and can reduce implant outcomes. Efficacy of chewing is particularly important in the elderly, and implants can improve this aspect significantly. Minimally invasive surgical techniques should be preferred, even if the successful ageing patients appear to present no differences compared to the younger ones. Inability to maintain good oral hygiene is related to peri-implant inflammation, and particular care should be given to the cleansability of prosthetic restorations and the maintenance appointments. Training of family members or of the staff who is in charge of the elder should be considered.

3.2.4 Supportive Periodontal Therapy

Prevention is the key issue in all patients and particularly in the geriatric ones. Primary prevention aims at preventing disease, whereas secondary prevention aims at preventing disease recurrence. Disease recurrence refers to disease progression (i.e. significant periodontal attachment loss) in patients successfully treated for periodontitis. Ideally successful treatment of periodontitis (BOP >15%; PPD <5 mm) should be reached before patients start supportive periodontal therapy (SPT). However, not all patients especially the older ones will achieve this result, but they will still benefit from SPT. The frequency of dental visit was not related to the presence of plaque, gingival inflammation or bone levels [39], but sporadic supportive therapy leads to more tooth and bone loss.

Primary prevention based on patient performed control of the biofilm and routine professional mechanical plaque removal (PMPR) are effective in achieving a decrease in gingival inflammation and a decrease in the prevalence of mild to moderate periodontitis, as stated by the recent consensus report of group 1 of the 11th European Workshop on Periodontology on effective prevention of periodontal and peri-implant diseases published in 2015 [14].

Primary and secondary prevention and supportive periodontal therapy are strictly related to the ability of maintaining a good oral hygiene. Cross-sectional data [5] showed that tooth loss and progressive periodontitis are frequent among 60–96-year-old patients and are linked to poor oral hygiene also in patients in a regular maintenance programme.

Old patients should be carefully instructed in oral hygiene measures, but they can have problems with dexterity and holding the brush. The use of oral health aids, such as electric toothbrushes, manual toothbrushing with wide-handle grips and floss-holding devices, may improve oral health among the elderly. Additional aids should be considered, i.e. mouthwashes.

Cognitive impairment can diminish the efficacy oral hygiene instruction that should be reinforced and simplified. Education of the caregiver should be considered part of the supportive treatment. The patients of aged care homes give a particular problem. A study showed that less than one-third of the residents had their teeth cleaned twice a day, and when assistance was required, only 30% had their teeth cleaned once/twice a week [40]. Particular care should be given to educate the aged care staff.

Nutrition can play an important role for older and frail patients. Flavonoids and omega-3 can decrease the inflammatory activity and improve health. Dietary supplementation with specific nutrients should be considered.

Probiotic therapy, i.e. colonization of the oral cavity with bacteria favourable to periodontal health, can be an interesting approach for old patients.

There are no studies that address the optimal frequency of SPT in the elderly. Usually a frequency of two to four times per year is advisable, but the frequency should be based on patient risk profile.

Good oral hygiene and prevention of disease are of primary importance in the elderly. Maintenance appointment should be tailored to health and cognitive conditions, and oral hygiene tools must be chosen consequently. Additional aids such as mouthwashes, probiotics and nutritional supplements should be considered. Caregivers should be educated in oral hygiene maintenance.

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Physiological Changes in Endodontics

4

Z. A. Oscar von Stetten

Abstract

The avarage age in Elders rises as the amount of retained teeth due the success of prohylaxis and advanced dentistry. The rising detnal awareness of the elder patients is often very high. Tooth retention does not only mean a higher qualtiy of life but also has impacts on overall health as it guarentees a better food digestion and, indirectly, a better self-cofidence and participation i nsocial activities. This chapter should provide a short description of the physiological changes in the elder patient as give a strategy, how to decide and process a root canal treatement in elder patients.

4.1 Introduction

The number of own teeth has increased in older adults and dentists today are faced with the challenge of preserving critical teeth. It will always be necessary to recognize that endodontic therapy should be considered.

Strategic treatment planning is essential, and the preservation of key teeth will facilitate satisfactory function in older patients. As nutrition is one of the key factors for overall life quality, preservation of own teeth should have the highest priority. These teeth can be important in achieving an intact anterior arch, acting as a pillar for removable partial dentures or the preservation of the alveolar bone.

In some cases, this can only be achieved by endodontic treatment. When a root canal is infected, there is no reason why good endodontic treatment in healthy elderly patients should not work.

In many cases, the teeth of older adults are compromised by dental diseases such as caries and periodontal disease and tooth wear with pathological or physiological

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risks. The vitality of the teeth may have been affected by these processes. Very often it is a coincidental finding on an X-ray. The treatment options for addressing this situation include either extraction of the tooth or root canal treatment.

Endodontic intervention in the elderly is considered to be technically challenging as the root canal system is sclerosed, with a high probability of partial or complete sclerosation.

In the past, extraction was the more frequent form of treatment. Nowadays, with progress in instrument manufacturing technology and the use of optical aids, however, extraction can be avoided.

The point of the tooth holder is to have "healthy" teeth and to obtain satisfactory oral function and food intake, in addition to a social life, well into old age. The age of a patient is often confused with a disease.

The prognosis of endodontic treatments in older adults is not worse than the prognosis for younger patients.

The biggest differences are in patient handling. The patient should be comfortable in the treatment chair, as a root canal treatment can take a long time. Just think of chronic back pain, artificial joints, arthritis, and more.

There are only a few general medical contraindications to root canal treatment (Figs. 4.1, 4.2 and 4.3).

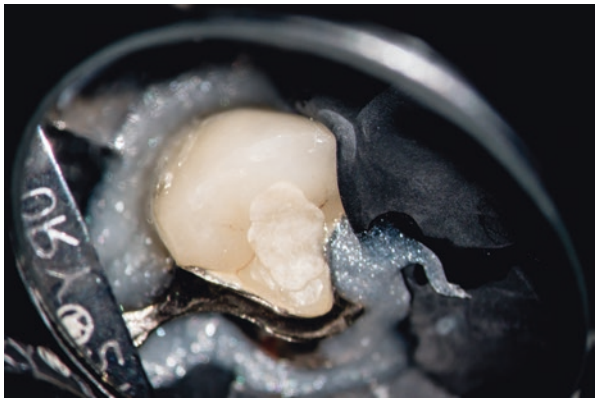

Fig. 4.1 Initial presentation of the case with cavit/cotton pellet

Fig. 4.2 Due the size of the cotton pellet, an adequate thickness of the cavit was not reached

Fig. 4.3 Picture after removal of the cotton pellet. multiple bur marks and a destroyed pulpal floor map

Fig. 4.4 After frist flush of irrigation the structures become more visible. Axis deviation by the RD too much towards the buccal aspect becomes obvious

As the most important may be mentioned:

Patient's previous radiation therapy of the head and neck area. To reduce the risk of periapical disease, which makes extraction of the irradiated bone necessary, all possible foci of infection should be removed before the start of radiation therapy.

Compromised compliance, for example, in patients with Parkinson's disease, tremors or dementia.

Endocarditis-prone patients usually do not have a contraindication to root canal treatment. The risk of developing endocarditis can be covered by the recommended uptake of antibiotics before treatment (Figs. 4.4, 4.5 and 4.6).

4.2 Is the Tooth Strategically Important?

Before endodontic treatment is executed, the worthiness should be critically examined. In the decision-making process, the following considerations should be included:

1. Preservation of an intact dental arch, aesthetic zone.
2. Retention of a removable dental prosthesis, in particular to avoid a free-end situation.
3. Maintenance of the occlusal stability and vertical dimension.

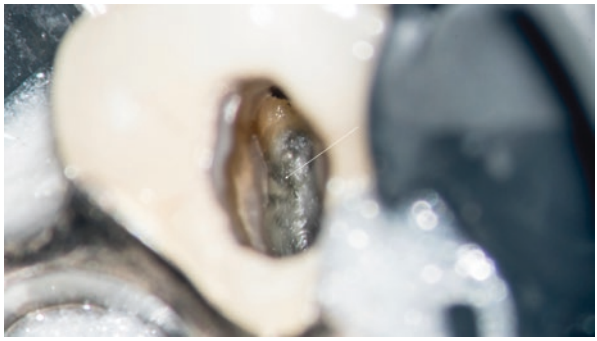

Fig. 4.5 Careful observation of the wet pulpal floor under high mangnification. The dark spot embedded inside the tertiary dentin is obvious

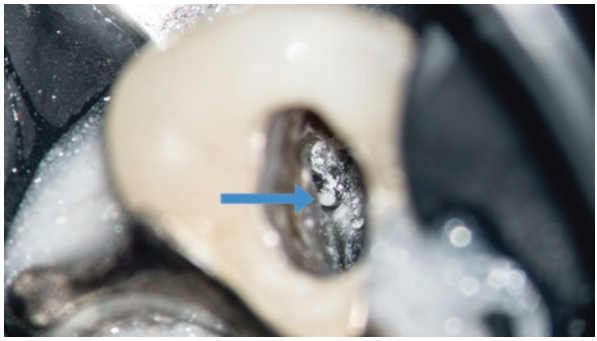

Fig. 4.6 After throughing the dark spot with a small carbide bur (Munce bur), the orifice becomes visible

To be sure to get the maximum beenfit for the patient undergoing a root canal treatement, an assesement of the value to conderve the tooth must be made in a team-based approached with a special view on the long-termoutsome of he treatement plan.

It is not worth undertaking conservation if the teeth in question either play no role in long-term planning or must be assessed as nonrestorable. This means in general as conditio sine qua non, that all the restorations, broken or decayed areas must be removed before a definitive evaluation can be made.

Factors such as costs and treatment ability of the patients must also be taken into account. If the planning is beyond the financial scope of the patient or is so lengthy and complicated, the treatment will infeasible.

4.3 Barriers to Successful Endodontics in Old Age

Age-induced changes occur in the pulpal complex.

Over the years, the tooth undergoes different changes in dentin properties that may play a role in the definitive treatment option for the treated tooth. Tooth retention also has to be highly strategically planned and discussed with the patient from a prosthodontics view. Sometimes, endodontic treatment is not the optimal solution for the needs of the patient, although when it is needed, it does not have a worse outcome prognosis compared with a younger population subgroup. Maintaining oral health is important for the elderly, as it contributes to the overall quality of life.

4.4 Changes in Teeth Physiology

Over the years, a tooth responds to various stimuli such as fillings, various dental procedures, crowns, caries, and periodontal conditions. Over time, the tooth experiences this stimulus and the pulp–dentin complex reacts to it. This can essentially influence the overall prognosis and the strategical treatment plan (Figs. 4.7 and 4.8).

Degeneration of odontoblasts has been reported with vacuities being visible before they atrophy and disappear from areas of the dental pulp. The activity of the aged odontoblasts is reduced and therefore the reaction to stimuli such as exposed dentin or caries is no longer very fast and efficient. The secondary dentin is more irregularly formed as the odontoblasts are not differentiated as younger odontoblasts. The secondary dentin is formed throughout a person's whole life, mostly on the pulpal floor and the coronal to the middle part of the root rather than on the roof of the pulp chamber. It is more irregular and can impair the effort to find the canal orifices during an endodontic procedure. As the pulpal floor map is not visible owing to the apposition of the secondary dentin, it may take more effort to reveal all the canal orifices and to instrument them. Also, the sclerosation takes place in the root canal dentin, closing the dentin tubules and probably preventing biofilm ingrowth into the dentinal tubules, enhancing the success of the disinfection procedure throughout the chemo-mechanical debridement phase.

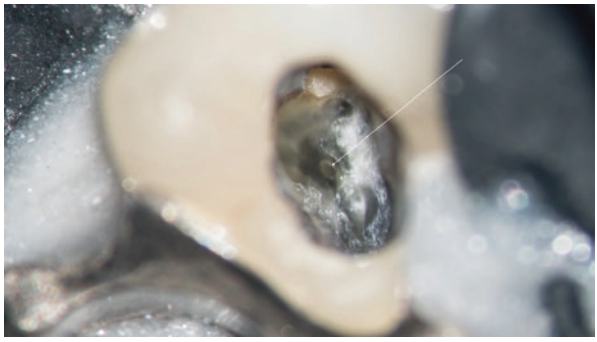

Fig. 4.7 After exploration with an Orifice opener (Dentsply) the suppuration begins immediately

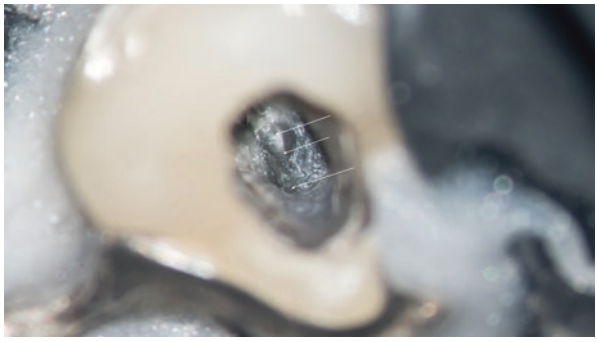

Fig. 4.8 Following the white connection line between the buccal and palatal canal leads to the calcified orifice of the palatal canal

The space for the pulp decreases with the deposition of regular secondary dentin over the entire lifetime of service. This happens most often to the pulp horns, the floor, and roof of the pulp chamber in molars, which are converted from a large dentin core that is curved in youth and a flat plate in old age. In the case of careless drilling, it may occur that the practitioner has already gone too deep, because he/she has not recognized the obliterated pulp chamber as such. In the front tooth area, the tooth mark pulls back in a cervical direction, is narrower, and there is often no soft tissue in the crown.

In the roots, the deposit is always concentric with the center of the dentin mass. The deposit is often most clearly pronounced in the coronal areas of the channel system, wherein the deeper areas of the root canals remain largely intact, even in old age. This knowledge is important to avoid iatrogenic problems such as perforations, or via falsa (Figs. 4.9, 4.10 and 4.11).

The pulp chamber is reduced by secondary and tertiary dentin, which leads to a reduction in the clearance of dentin tubules that are opened by caries, trauma, or dentures.

Fig. 4.9 Final picture of the root canals filled and cleaned access opening

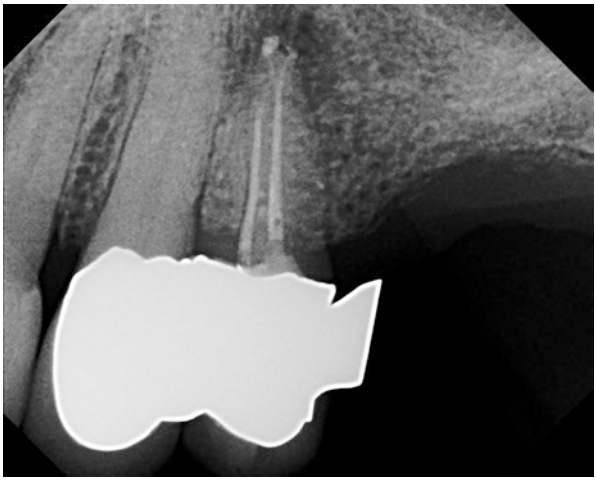

Fig. 4.10 Final Radiograph

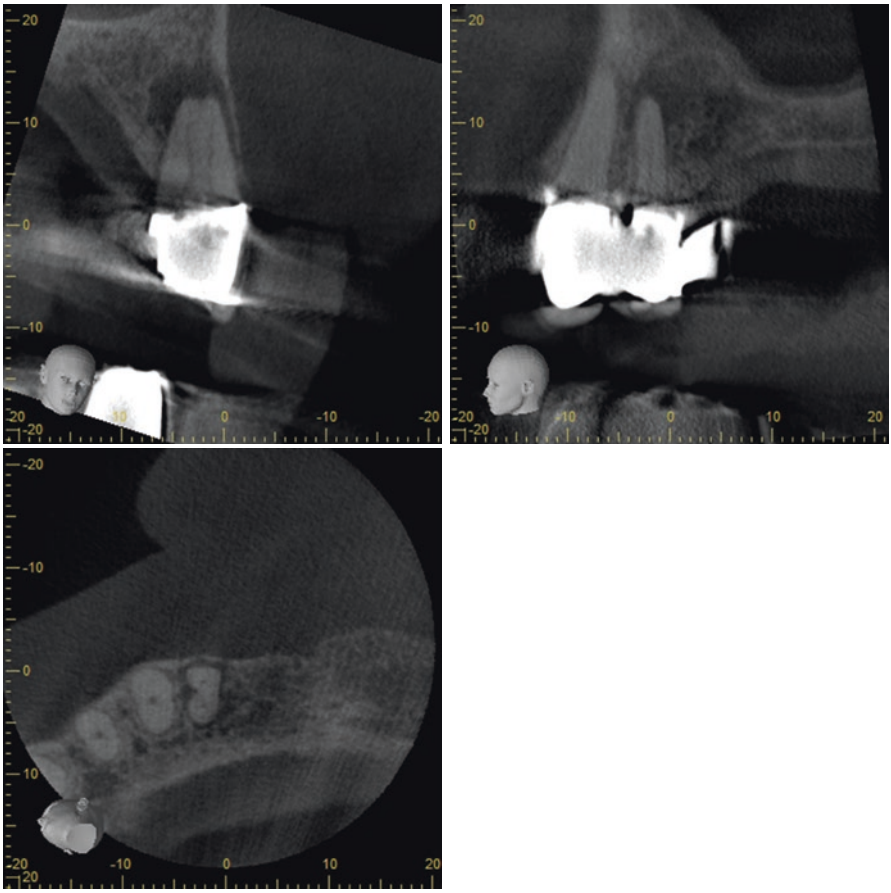

Fig. 4.11 CBCT-Slices showing no procedural problems, the obliteration, the extent of the AP and the canal configuration as the location of the orifices

The reaction of the Pulp represents a material that was deposited, under such circumstances, of the original, surviving odontoblasts. Reparative dentin, instead, comes from the new pluripotent cells that migrate after the death of the primary odontoblasts in the injured sites and differentiate. These changes are limited, mostly based on the coronal areas of the canal system, where external stimuli and noxious agents have the greatest effect.

Increased cementum deposition, mainly in the middle third, but in many cases also at the apical level, makes a radiological diagnosis of the root canal system difficult. Sometimes, this cementum deposition results in a deviation of the original apical foramen. This seems to be influenced not only by age-related issues, but also by environmental factors.

Owing to the apposition of secondary dentin, the pulp chamber volume is significantly decreased, often ending up in the "obliteration" of the pulp chamber with

either solid sclerotic territory dentin or with pulp stones floating in the chamber. This not only makes the endodontic procedure more difficult, but also influences the vitality and makes the sensibility testing more complicated and unreliable. Because of calcifications, testing with cold or even electrical pulp testing does not deliver a response. This is supported by a decrease in the pulpal blood supply and reduced innervation due to the degeneration of the nerve bundles in the pulp complex. The reduced pulpal blood flow is also responsible for the reduced regeneration capacity of the pulp. Direct capping procedures should be evaluated critically in the elderly patient as the long-term success decreases over time.

Degeneration of the pulp tissue is a trigger for the formation of pulp stones. This can lead to an obstruction of the root canal space as they are not firmly adherent to the duct wall when trying to reach the apical area too quickly.

Pain perception is reduced in the elderly and in some cases the patient already has chronic pain episodes; thus, the state of acute pain is often delayed. Thus, the patient cannot recall an acute pain episode, but the pulp dies quietly and is only discovered by chance on a routine radiograph or by the presence of a fistula.

Cumulative micro-traumas, often over a long period of time, reduce the vascularization and the cell content of the pulp, with a related increase in the associated fibrosis. By the thickening of the dentin mantle and the increasing distance to the remaining pulp tissue, the pulp no longer respond so well to thermal changes and to thermal testing, for example, cold spray is less useful for diagnosis. In heavily restored teeth in particular, this can hinder a correct thermal testing.

Overall, the reliability of pulp sensibility testing is good, especially when Endo-Ice is used together with an electric pulp test. Test cavities are not reliable because of the physiological changes inside the tooth.

4.5 Can We Save the Tooth?

A predictable treatment requires access to the infected canal space. This can be complicated by a limited opening of the mouth, unfavorable tooth alignment or over-eruption, intolerance of lengthy surgical procedures or calcification of the pulp of a tooth space.

The main objective of root canal treatment is the prevention or healing of apical periodontitis. Whether the assessment is of a tooth with large or obliterated pulp of a tooth space or a barely visible channel system, the biological treatment goals are the same.

Apical periodontitis is mediated by microorganisms; thus, access to these spaces is crucial. Rarely, microbes are also spread in large numbers beyond the apex into the peri-radicular tissue. These cases are clinically undiagnosable, but reveal themselves with a prolonged healing time or even growing of the apical lesion during the follow-up period. Rather, the leakage of toxins through the apical and lateral channel junctions leads to a reaction of the host, in particular, the formation of an apical granuloma. The treatment, therefore, is aimed at stopping and eradicating microbial

infections from the channel space to eliminate as far as possible and to prevent reinfection. In cases where this happens before the apical periodontitis has developed, the prognosis overall is better than in cases with an existing lesion. In the case of well-established apical periodontitis, the best possible elimination of root canal infection creates the conditions for the restoration of healthy periapical tissues.

The expectations of root canal treatment are high, and many quote success rates of over 90%, with 80% or less for the realistic general practice. The question is whether freedom from symptoms and clinical retention of the tooth are already counted success, or whether radiological healing is necessary. An important question is whether the immune system of the host plays a key role in the outcome, and whether older people can expect worse results than young people. Such an age-related observation has not been made in the epidemiology (the markers are missing!), and it is generally accepted that root canal treatment in young people is just as predictable as within elderly patients, provided that the infection is well controlled. However, technical challenges associated with appropriate infection control are much greater in the elderly.

4.6 Diagnosis in the Aged

The diagnosis of pathological conditions is based on patient history, clinical examination, and imaging. Although classic acute symptoms of pulpitis and periapical pathosis in elderly patients are often reported, many patients carry an endodontic disease without being aware of it. Frequently, the necrosis is discovered as an incidental finding without the patient remembering or experiencing any painful symptoms, or the patient has sometimes lived for a long time with a odontogenic, symptom-free sinusitis or recurring swelling and discomfort.

There is no single test for the assessment of the pulp condition. Thermal and electrical tests are usually applied to obtain better quality information about the status of the symptomatic teeth. An increased obliteration or fibrosis of the pulp may decrease sensitivity to thermal and/or electrical testing. The search for provocation tests can also be a challenge for heavily restored teeth.

X-rays are essential, both in diagnosis and in the assessment of the restoration. A good X-ray image, if possible, in parallel with technology, is essential. In recent years, this has been digital volume tomography. The 3D view of a tooth is very valuable and provides evidence for technical difficulties during treatment (obliterations, pulp stones, orifice localization, etc.), also aiding in the assessment of the whether the teeth are worth preserving.

In the examination of the X-rays, non-odontogenic cause of the lesion should always be taken into consideration.

The 3D image of the tooth allows for the addition of more precise planning of the procedure. Where the pulp was located, where the entrances the channel systems are located and an estimation of the working length can be conducted. This information will allow a substantially more gentle root canal treatment, as the search of the

channel systems does not require the tooth to be sacrificed unnecessarily, and overall, less time is needed, which contributes, under certain circumstances, to improved compliance of the patient.

The importance of creating a bacteria-free work area should not be questioned. Only in very few exceptional cases may this be waived. In addition to isolation of the tooth from the oral cavity, protection of the patient from the rinsing liquids or aspiration of a root canal instrument is a medico-legal issue. A bite wedge supports the patient in opening the mouth and also increases the compliance of the patient.

In the case of a severely destroyed, horizontally or oblique fractured tooth, there are also ways to use the rubber dam to isolate the tooth. Sometimes, a little improvisation is required. There are no contraindications for the application of the rubber dam. Good education in advance and good patient management are paramount. In the case of deviating axis of the crown/root, it can be helpful to mark the root axis using a text marker on the crown. The same applies in the case of bridges, in which the tooth surfaces are often looking similar. To avoid procedural errors, such as treating the wrong tooth or a bridge unit, the use of a text marker is very helpful.

4.7 Access Cavity

The correct access cavity is probably the greatest technical challenge in root canal treatment.

In the case of the orientation of the access cavity, a 3D image is very helpful. If this is not available, the usual rules for the preparation of an access cavity apply.

The access should start with the definition of a classic access cavity, wherein front teeth in front of a more incisal access point should be chosen, as this type of access leads to a higher substance conservation and allows more direct access to the canal system. In the case of obliterated teeth in particular, it is difficult to maintain the correct axis and there may be a buccal perforation. The axis of the drill should be checked constantly. Optical aids such as loupes or a microscope should always be used. Missing depth control combined with a loss of the correct axis in access is one of the main reasons for perforations.

Metal carbide drills, such as the Meisinger long neck round burs, Maillefer long neck or the Munce burs, are ideal. Instruments with long and narrow shafts allow the active rose head to be observed at any time. When working with magnification, there are often visual clues due to the change in color, texture, and translucency of the mineralized deposits in the former pulp space compared with primary dentin.

Some advocate the use of fine ultrasonic tips, to gently come forward to the apical part of the root canal system. These instruments, however, can lead to the drying and burning of dentin, which, however, distracts from the natural properties of the tooth, the color and translucency change and lead to incorrect preparation of the access cavity. Furthermore, a sandblaster can be used to create a uniform surface. After sandblasting, a drop of NaOCl sufficient to create a high contrast between the pulp chamber floor and the orifices is used. This makes it easier to recognize obliterated orifices.

In intervals, areas of discolored tissue should be explored with a DG16 probe to find the "sticky" point as a root canal orifice or the entrance to a calcification within the canal system. If no penetration of the probe is found in a simple manner, the supposed orifice should not be promoted or further explored, as this will lead to an iatrogenic problem (perforation). Under these circumstances, the carefully targeted probing and drilling away of the tertiary dentin should be continued until the penetration of the probe is about 1–2 mm.

In the case of multiple roots, the teeth of the chamber should be completely uncovered. Following trends to minimize the access cavity can lead to procedural errors and unrevealed anatomy, which lead to failure in the long term. The diamond drill with a blank end (Endo Z, or Diamendo, Maillefer) are ideally suited to preparing the walls of the pulp chamber with a light divergence and to avoid injury to the chamber floor.

Pulp stones are usually identified as a rule as glassy, translucent inclusions in the chamber. These should be removed to the dark floor of the pulp chamber with its extremely important roadmap of growth lines, which lead the viewer to the channel orifices. Ultrasonic scalers are also powerful tools for the fragmentation and removal of the pulp stones, but are not as aggressive as ultrasonic tips or drills. Here, it is important to proceed carefully to avoid damage to the chamber floor, which can provide a semblance of a channel orifice. For this reason, sound- or ultrasound-driven tools should not be operated in one place, but used with smooth movements in the area.

Usually, after all the orifices are revealed with a long neck drill and visualized, they are explored to form a secure access to the canal systems. Uncertain orifices with a doubtful appearance are checked with an electronic apex, before further engagement. The apex locator delivers instantly the reading "apex reached" if the supposed orifice is indeed a perforation. The perforation should then be immediately repaired and the search continued in another place.

4.8 First Probing of the Channel

After the orifices are successfully opened, a light preflaring up to a maximum depth of about 3–4 mm is recommended. The industry provides a rich file selection, and the choice of instrumentation system for treatment is always a personal decision. We prefer the ProTaper SX file, which is inserted into the channel and used to a maximum depth of 4 mm and within teeth with multiple roots, the file is always used in a direction away from the furcation. Before the preflaring, no attempt to reach the apical part of the canal should be made, as the danger of blocking is very high. The preflaring allows a first glide path and the first access for the fluids, and removes the first obstruction in the coronal portion. Lubricants and lotions are more likely to be counterproductive and should not be used. NaOCl is sufficient and should be used quickly.

Small files, typically of ISO 06/25 mm in length, or special files (Pathfinder files C) with increased rigidity are gently pushed into an alternating rotational movement

in the channel whilst the instrument is rotated slightly between the fingertip and thumb (watch winding motion). If the instrument no longer operates apically, resist the temptation to apply pressure. The instrument should be pulled out, the canal should be irrigated, then the file is reintroduced into the canal system and worked using the watch-winding motion toward the apex. Prebending of the instrument tip is very helpful. Irrigation should always be performed between the instruments and the instrument should never be used in the dry channel. The pulp chamber should always be filled up with NaOCl and the solution should be replenished frequently. This strategy should be followed until the working length (apex locator control) is reached safely and consistently.

It should be recalled that channels are often coronally narrower than in the apical portion. If the instrument binds in the coronal obstruction at an early stage it may lead one to the wrong conclusion that the channel is obliterated in its entire length and the selected final working size is chosen too low. This can be prevented by sufficient preflaring.

Despite careful instrumentation and extensive flushing to reach the final length, work progress is not always smooth. If the instrument is progressing well, we should determine the feeling, how the instrument behaves in the canal. Once the practitioner has the feeling that only the tip reaches into a small opening and that the instrument is progressing slowly, the original, probably slightly narrowed canal, has been found. Then, only patience and a large amount of irrigation helps to instrument the canal to the working length. If it feels like hitting a wall; thus, the instrument should be removed from the canal, the instrument tip prebent, and then the canal should be explored again. In no case a rotary file should be insterted before a reliable and wide enough (iso 15) glidepath to the working length was established.

A rare event deep in a canal is a “deep split”, where the main canal splits up in two independent canal systems in a depth over 13 mm. One more reason to prebend the hand file and to scout the apical region. When in doubt, a wire film shoud be taken to assure the correct allocation of the file in the canal.

Despite all the best efforts, to it is not always possible to prepare the canal system to the working length. The decision-making process, taking all the risks of a possible iatrogenic injury (perforation, via falsa) into the calcualtion, should be done in favor to preserve as much as possible tooth structure.

This, in turn, is due to the pathological condition (apical periodontitis existing/non-exsiting) and the restorative plan of the tooth affected, and decisions should always be made with the patient and consent given.

We also have to remember that after a coronal opening and preflaring of the canal, and soaking with sodium hypochlorite, canal systems that initially appeared to be uninstrumentable with the use of routine methods may be treated successfully. If a canal of a multi-rooted tooth is difficult to access, work should be continued in the other canals, a sodium hypochlorite flooded pulp chamber retained as long as possible, and then later in the treatment, another attempt can be made. In every case a time limit should be set for the development of the obliterated canal so as not to spend too long on one part of the procedure. This saves the practitioner much frustration and from possible perforations, instrument fractures, or unnecessary large dental hard tissue removal, which is a disadvantage for the patient.

Occasionally, there may be difficulties when creating the glide path for the following sized instrument. Problems occur most frequently during the transition from an instrument of ISO size 10 to one of ISO size 15, which means an increase over 50% in instrument diameter. The use of "between" sizes, such as Golden Medium (Maillefer/Dentsply), which include instruments in sizes ISO 12.5, 17.5 and 22.5 may faciliate an instrumentation.

According to the primary instrumentation and installation of the glide path, the final canal preparation and obturation of the instrumented and cleaned canal still remains to be performed. Today's commercially available instruments allow a comparatively simple rotary or reciprocal preparation and shaping of the canal system. Similarly, the obturation is not a major problem; up to now, there has been no indication that an obturation material or technique combination has an effect on the healing of apical periodontitis. In any case, root-filled teeth should receive the necessary protection from unplanned hard tooth substance loss (fracture) and coronal micro-leakage, so that the success of the endodontic treatment may not be impaired because of dental caries and the risk of periodontal disease.

The discharge of the patient at the end of the session may also require some time and caution, as the patient gradually returns back to the sitting position (circulation). In addition, older patients need to be guided as they tend to lose orientation a little and need some time to switch from "treatment" to "normal living" mode again. In short, appointments cannot be rushed and adhered to, and the dental team must be sensitive to responding to the basic physical needs of older patients in terms of comfort, education, and duration of treatment. Thus, compliance increases, however comprehensive.

In summary, we can say that successful endodontics in the elderly can be achieved, with a particular focus on the diagnostics, high-quality radiographs, and a technique for coping with the challenges arising from the calcification of the root canal system without further problems. Also, referral to a specialist for endodontics should be considered.

As long as a tooth plays a strategic role, endodontic intervention in healthy, elderly patients, is indicated and justified. Paying enough attention to the needs of the patient should be given great importance. Performing a root canal treatement with out a long-term plan and good prognosis only driven by the process outcome should not be a reason for the treatement. Overall, the demographic trend toward older patients is obvious; thus, the attitude to dental matters in this group of patients should always receive greater attention.

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Temporomandibular Joint Disorders in the Elderly

5

Marzia Segù and Daniele Manfredini

Abstract

The term temporomandibular disorder (TMD) refers to a heterogeneous group of pathologies affecting the stomatognathic system, characterized by pain and functional limitation within the temporomandibular joint (TMJ) area, the muscles of mastication, and the related structures. TMDs are considered the most common cause of orofacial pain of nondental origin and are currently included within the broader group of musculoskeletal disorders, due to the similarities with conditions affecting other body districts.

The prevalence of TMD signs and symptoms in the general population is high and ranges from 16 to 88%, even if treatment is needed only by a minority of subjects. This observation supports the claim that TMDs are generally self-limiting and the progression toward chronic and disabling forms is uncommon. Notwithstanding that, about one tenth of individuals with TMD develops disabling chronic pain, thus requiring a multidisciplinary approach also addressing the psychosocial component of the disease.

Epidemiological data suggest that the age distribution of TMD diagnoses in patients' populations is quite peculiar, with two distinct age peaks: one at about the age of 30–35 years for subjects mainly complaining of TMJ disk displacements with or without pain and one at about the age of 50–55 years for subjects with degenerative joint disorders. Such observation may appear obvious at first glance, but it was described only recently, since a mean age of about 40 years was usually described for TMD populations as a whole. Thus, while the term "temporomandibular disorders" groups together with some different pathologies featuring common clusters of symptoms, getting deeper into the epidemiology of

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the different TMD diagnostic groups is fundamental for an improvement of knowledge in this field.

Based on these premises, this chapter will overview some general concepts of TMD etiology, diagnosis, and management for the general practitioners and will then focus on the main issues concerning the clinical and imaging picture of TMJ disorders in the elderly.

5.1 General Concepts of TMD Practice: Etiology, Diagnosis, and Management

Temporomandibular disorders (TMD) is a collective term embracing heterogeneous clinical problems that involve the temporomandibular joints (TMJ), masticatory muscles, or both and are characterized by a classically described triad of clinical signs: muscle and/or temporomandibular joint (TMJ) pain, TMJ sounds, and restriction, deviation, or deflection of the mouth opening path.

TMD are the most common orofacial pain conditions of non-dental origin, even though their actual prevalence is a matter of debate, with such a variable range due to the lack of homogeneity in the diagnostic criteria adopted in the various researches.

Based on recent estimates of their prevalence in the general population, TMDs are emerging as a relevant problem in dental medicine and public health. The most frequent symptoms and reasons for patients to seek for advice are pain in the muscles of mastication and/or in the TMJs, joint sounds, and irregularities or limitation of jaw motion.

Patient populations are mainly composed of females, with about a 3:1 ratio. Studies on patients' populations adopting standardized diagnostic criteria showed that muscle pain and TMJ disk displacement are the most common conditions. Age distribution of TMD patients is commonly described as a Gaussian curve, with a predominance of subjects within the 35–45 years age range and a lower prevalence in younger and older people. Nonetheless, it has been recently suggested that the age peak is not the same for all conditions grouped under the term "temporomandibular disorders" and that such average values result from the age distribution of very different conditions. For instance, there is a significantly different age distribution between subjects with disk displacement alone and individuals with inflammatory degenerative disorders (e.g., TMJ arthrosis).

The presence of clinically diagnosed degenerative joint disorders could be a key discriminating factor. On average, joint crepitus, which is the clinical sign that leads to a diagnosis of TMJ arthrosis, is found in patients aged over 50–55 years.

The etiology of TMD is still controversial, but it is now widely accepted that personality traits and psychological factors play a much more important role than the anatomy of dental occlusion. As such, they also represent predictors for treatment outcomes and should be targeted in the management phases. Multicenter studies have shown that a non-negligible percentage of TMD patients (e.g., up to 20%

of individuals) attending tertiary clinics have high levels of psychosocial impairment, leading to suggestions that psychological and social issues may discriminate between patient and general population individuals with similar physical diagnoses.

The most valid pathophysiological explanation for the onset of TMD symptoms calls into cause the relationship between psyche and bruxism, since stress sensitivity and anxiety personality can lead to an emotional overload that, in turn, is mirrored in jaw muscles' clenching and mandible bracing. This can lead to muscle fatigue and TMJ overload and initiate the cascade of events that determine the onset of radiological signs and clinical symptoms. Genetic and neurophysiological factors contribute to upgrade this picture in terms of symptoms intensity and chronicization.

At the individual level, as far as TMJ pain is concerned, it is also noticeable that some patients do not exhibit symptoms that might be expected based on imaging findings. The predictive value of clinical pain to detect magnetic resonance (MRI) effusion approximates 80%. Clinically, this means that some individuals who are seeking TMD treatment due to TMJ pain may have symptoms unrelated with the presence of TMJ effusion or any actual disease within the TMJ. Thus, other factors related to the pain experience may be more important than physical findings to determine clinical symptoms. Due to the importance of psychological factors, such as personality traits, in the pain perception process, such symptoms are thus worthy of being explored from a psychosocial viewpoint, with the aim to assess if there are any other factors that may partly explain the presence of pain. As such, chronic TMJ pain is no different from other chronic pain conditions affecting other musculoskeletal districts.

TMD pain is the second most frequent pain disorder, following low-back pain, as well as the most frequent cause of orofacial pain. The favorable symptoms course with conservative treatment in the absence of psychological impairment and the observation that chronic pain is often associated with high levels of psychological distress suggest that issues related with one individual's psychosocial sphere are very important both at the diagnostic and therapeutic levels. On the contrary, the correction of dental occlusion is no more considered a valid option in the armamentarium for TMD and orofacial pain practitioner, since it is a source of dental overtreatment that has little to do with any therapeutic effects on the TMJ.

Interestingly, there is an absence of correlation between the levels of psychosocial impairment (e.g., depression, somatization, impact of chronic pain on daily activities) and any specific physical diagnoses (e.g., muscle and/or joint disorders).

This means that, at the individual level, other factors related with the pain experience are more important than physical findings to determine the degree of psychosocial impairment. Comorbid pains (e.g., headache, fibromyalgia, irritable bowel syndrome, spinal pain, low-back pain, chronic pelvic pain, and vulvar vestibulitis syndrome, also known as vulvodynia,) are quite present in individuals with chronic TMD. For instance, the prevalence of TMD in headache patient populations is higher than 50%, without any relevant differences between migraine and tension-type headache.

In addition, more than 50% of TMD patients are poor sleepers, keeping the door open to future studies on the correlation between TMD and sleep disorders, such as sleep apnea.

Sex (reproductive status and menstrual cycle) and gender differences (sociocultural and psychological variables) also play a role in etiopathogenesis of TMD, as demonstrated by an increase in levels of depression and somatization in female patients.

Thus, a biopsychosocial illness model is recommended in the diagnosis and treatment of TMD pain, moving from our beginnings based on a dental mechanical model to a medical biopsychosocial model involving cellular, molecular, and genetic mechanisms.

There are several diagnostic systems for TMD.

The American Association for Dental Research recommends that the differential diagnosis of TMDs or related orofacial pain conditions should be based primarily on information obtained from the patient's history, clinical examination, and TMJ imaging, if needed. Such an approach is line with current standard procedures for evaluating similar orthopedic, rheumatological, and neurological disorders. In addition, standardized and validated psychometric tests should be used to assess the psychosocial dimensions of each patient's TMD problem.

The recently published Diagnostic Criteria for TMD (DC/TMD) are the revised version of the RDC/TMD, and its development is well-described in the literature.

The RDC/TMD (Dworkin and LeResche 1992) was the first classification to embrace the biopsychosocial pain model, providing a dual-axis (i.e., Axis I for physical and Axis II for psychosocial diagnosis) assessment. It has been translated into 22 languages and has an overwhelming number of citations in the medical literature.

Since 2014, the DC/TMD are recommended for use in both clinical and research settings. Axis I leads to a diagnosis related to TMD pain conditions (myalgia, arthralgia, and headaches attributed to TMD), as well as to a TMD diagnosis related to intra-articular disorders (disk displacements and degenerative joint disease).

For the new DC/TMD, muscle pain diagnoses are organized into four major subcategories: myalgia, tendonitis, myositis, and spasm. Myalgia is the term that is currently adopted for what was called myofascial pain in the RDC/TMD, and it is further subdivided into three mutually exclusive conditions: (1) local myalgia, defined as pain localized to the site of palpation; (2) myofascial pain, defined as pain spreading beyond the site of palpation but within the boundary of the muscle being palpated; and (3) myofascial pain with referral, defined as pain at a site beyond the boundary of the muscle being palpated.

The Axis II protocol for psychosocial assessment has two options: a brief assessment or a comprehensive set of instruments for an expanded evaluation.

Clinical examination (Axis I) requires a history taking, including questionnaires, and a structured clinical examination. Clinical assessments evaluate pain localization, jaw movement limitations (lateral, protruding, and mouth opening), movement-enhanced pain, TMJ noises, and pain upon palpation of the masticatory muscles and TMJ.

The American Association for Dental Research strongly recommends that, unless there are specific and justifiable indications to the contrary, treatment of TMD patients is initially based on the use of conservative, reversible, and evidence-based therapeutic modalities. While no specific therapies have been proven to be uniformly effective, many of the conservative modalities have proven to be at least as effective in providing symptomatic relief as most forms of invasive treatment. Because those modalities do not produce irreversible changes, they present much less risk of producing harm. Professional treatment should be augmented with a home care program, in which patients are taught about their disorder and how to manage their symptoms.

The clinical management of TMD must be interdisciplinary, conservative, reversible, and "low tech," since there is no need to introduce complex, expensive electronic instruments in the daily routine.

Within this framework, various treatments options can be adopted, including counseling, cognitive-behavioral treatment, physical therapy, pharmacological therapy, occlusal appliances, complementary and alternative treatments, and minor surgery interventions (i.e., arthrocentesis). Major surgery is reserved to very selected cases of severe joint degeneration or TMJ ankylosis, not to say neoplasms.

5.2 TMJ Disorders in the Elderly: Inflammatory Degenerative Disorders

Degenerative disorders of the temporomandibular joint are a frequent cause of orofacial pain. In the new DC/TMD, the terms osteoarthrosis and osteoarthritis are grouped under the broader term degenerative joint disease (DJD).

Arthrosis/osteoarthrosis (OA) is an age-related degenerative joint disease characterized by loss of the cartilage and bone with concurrent remodeling of underlying bone tissue. OA is a progressive multifactorial condition leading to spontaneous pain at rest or during function, decreased range of motion, and articular noise. It has a negative impact on the patient's quality of life.

The prevalence of TMJ OA ranges from 8 to 16% of the general population. Its incidence increases with age, and it is more prevalent in women, possibly suggesting an estrogen-dependent regulation of temporomandibular joint remodeling. It may be unilateral or bilateral.

OA may be primary or represent a second-stage evolution of TMJ disk displacement. In the former condition, etiology is related to macrotrauma, systemic conditions (e.g., generalized osteoarthritis, idiopathic degenerative process), and genetic factors (e.g., G/T polymorphism of the COL1A1 gene). In the latter, prolonged microtrauma and adverse loading (e.g., jaw bracing, joint instability) lead to early signs of joint fatigue and progressive degeneration.

The pathogenesis of TMJ OA changes has been associated with degeneration of collagens and proteoglycans in the cartilage leading to fibrillation, erosion, and cracking in the superficial cartilage layer; subchondral bone changes including inflammation, chondrocyte apoptosis, increased osteoclast, and osteoblast activity; and possible involvement of synovial tissue in chronic inflammation.

The inflammatory reaction that occurs in TMJ OA is partly responsible for the development and progression of the pathology, including high levels of inflammatory mediators in the synovial fluid, such as interleukin 1 beta (IL-1β) and tumor necrosis factor alpha (TNF-α), among others.

Differently to the other synovial joints in the body, which have articular surfaces covered by hyaline cartilage, the TMJ is composed of fibrocartilage. It contains both type I and II collagen fibers, compared to articular hyaline cartilage, which only contains type II collagen.

The TMJ surfaces have a remarkable adaptive capacity. Fibrocartilage is better able to withstand sheer and movement forces; it is less susceptible to the effects of aging; it is less likely to break down over time; and it has a better ability to repair.

Also due to these tissue properties, the natural course of disease is generally favorable, with periods of remission and cartilage regeneration. When the host-adaptive capacity of the articulating surfaces decreases and/or functional overloading of the joint exceeds the normal adaptive capacity, such as in periods of prolonged muscle tension and/or joint immobilization, dysfunctional remodeling is established.

Currently, there is no ground to hypothesize that TMJ osteoarthrosis is related to the defects of posterior dentition, since any empirical clinical suggestions in this sense may reflect an age-mediated association.

Diagnostic criteria include **patient reports of crepitation** from the TMJ during jaw movements and clinical findings that confirm this. Such finding can have a reasonably high sensitivity and specificity for the diagnosis of DJD, as confirmed by computed tomography (CT) scans of the TMJ. Diagnostic criteria for TMJ OA include **radiological detection** (Figs. 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, and 5.10) of at least one of the following changes in condyle morphology: joint space narrowing, sclerosis (a denser area of bone just under the joint

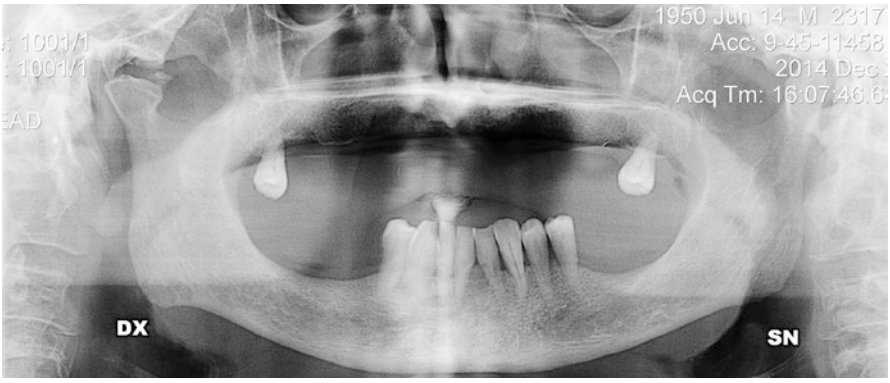

Fig. 5.1 Severe osteoarthrosis can be detected on orthopantomography

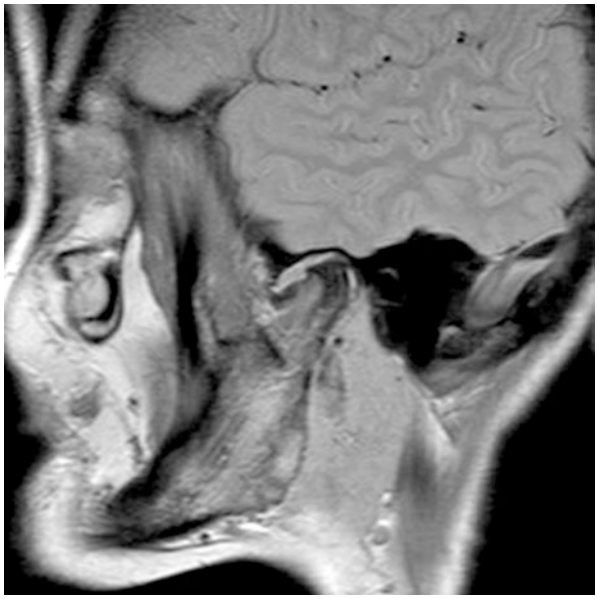

Fig. 5.2 Osteoarthrosis with flattening

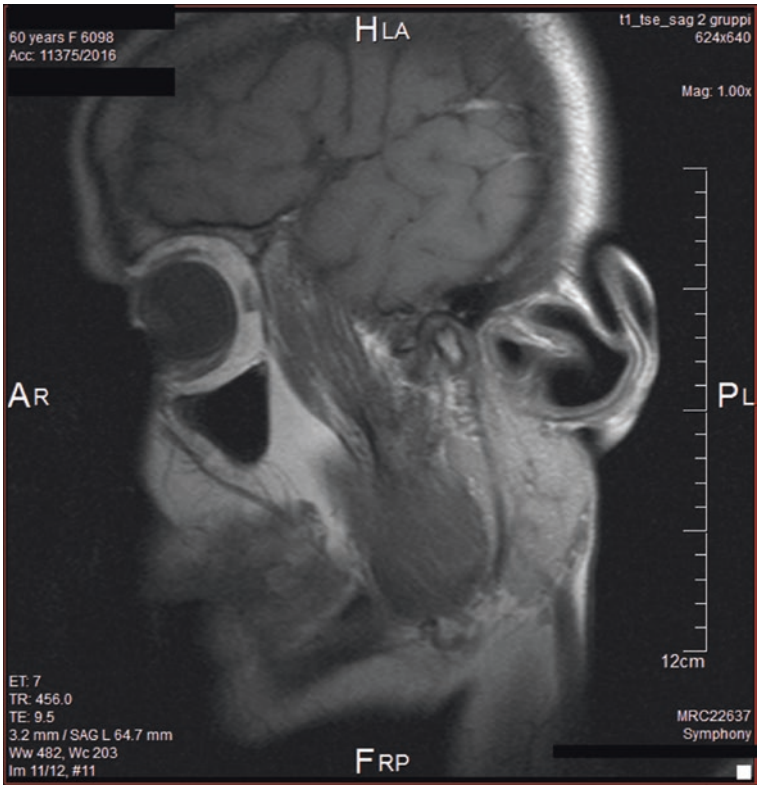

Fig. 5.3 Bifid mandibular condyle

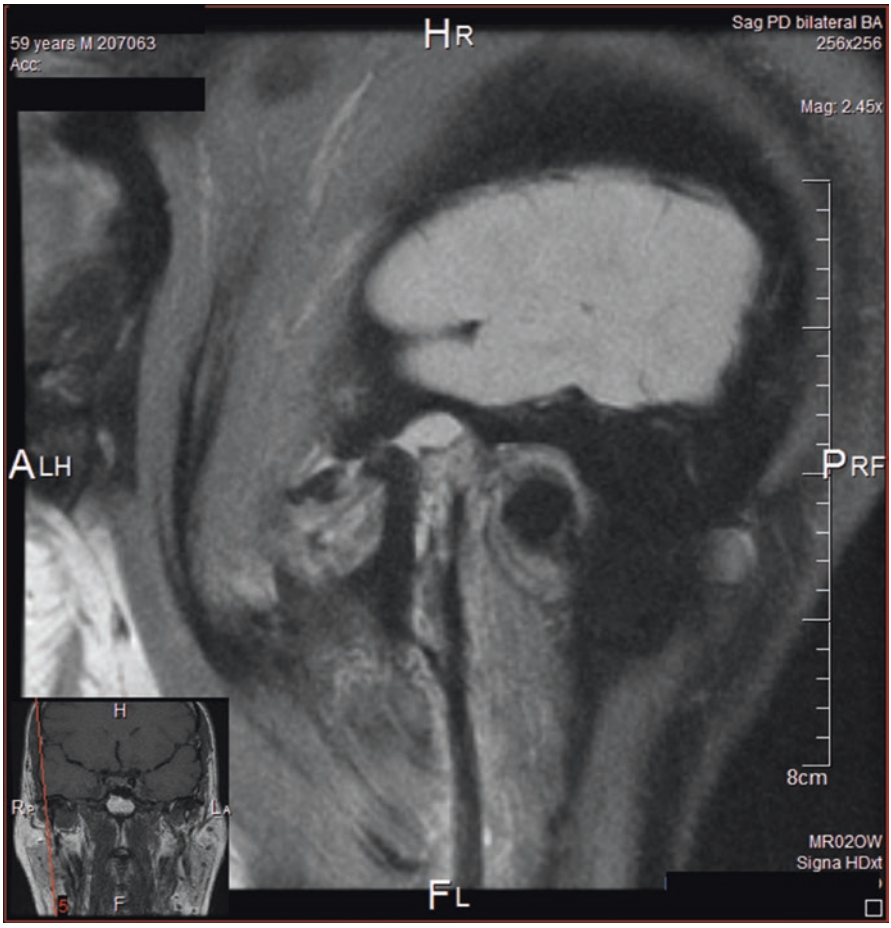

Fig. 5.4 Osteoarthrosis sagittal section of the right side mouth open

cartilage), flattening (loss of an even convexity or concavity of the joint outlines), subcortical cyst (Ely's cyst-rounded radiolucent area that may be just below the cortical plate or deep in trabecular bone), erosion (a cortical break), or osteophyte formation (local outgrowth of the bone arising from a mineralized joint surface) (Fig. 5.11).

These signs of TMJ OA represent different, even if not necessarily progressive, stages of the disease process. As a general remark, erosive lesions and joint space narrowing indicate acute or early change, whereas sclerosis, flattening, subchondral cyst, and osteophyte may indicate late changes in TMJ.

According to DC/TMD, a history of TMJ noise is a recommended criterion for DJD, requiring the patient's report of joint noise (crepitus) during the 30 days prior to the examination, and should be confirmed by the patient's report of crepitus with

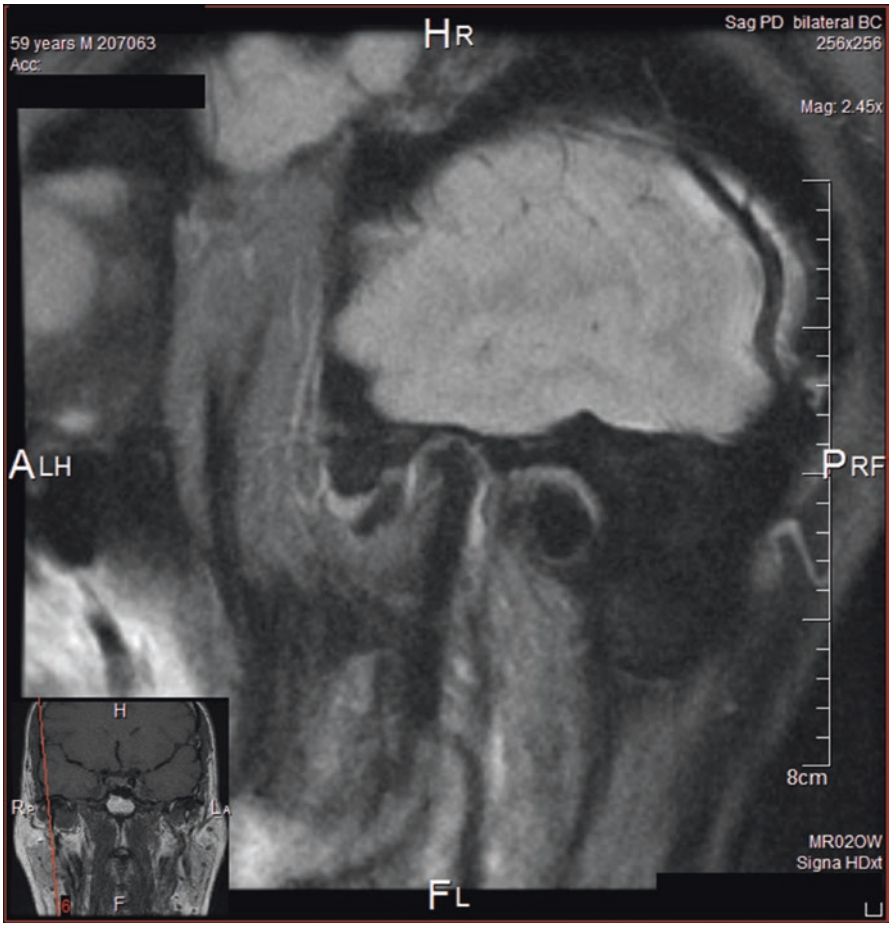

Fig. 5.5 Osteoarthrosis sagittal section of the right side mouth closed

jaw movements during the clinical examination. Establishing a diagnosis of DJD needs for an examiner's detection of crepitus (e.g., crunching, grinding, or grating noises) during the examination. For DJD, no distinction between fine versus coarse crepitus is made.

The hands must be examined for signs of systemic disease (e.g., Heberden's nodes of osteoarthrosis, ulnar deviation of rheumatoid arthritis), which may also involve the TMJ.

Laboratory tests (e.g., complete blood count, erythrocyte sedimentation rate, rheumatoid factor, antinuclear antibody, serum uric acid) are helpful when a systemic cause for TMJ disease is suspected.

TMJ OA is common in elderly individuals with hand and knee osteoarthritis and cervical spine pain, but it is inversely correlated with osteoporosis.

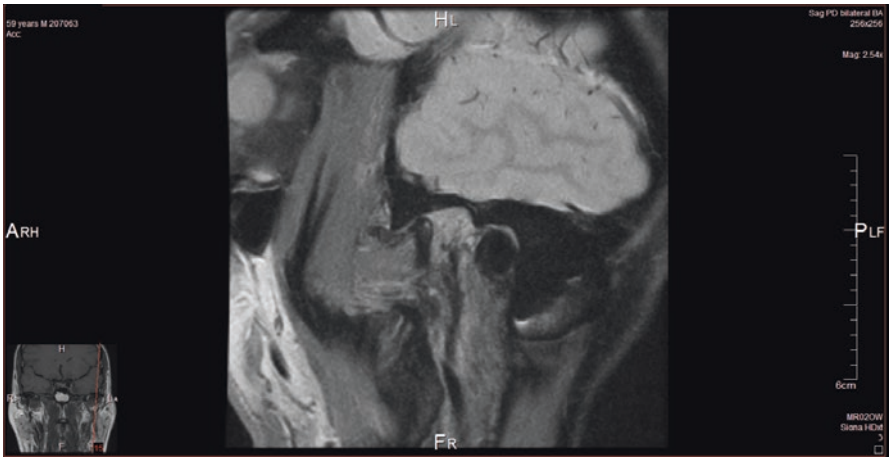

Fig. 5.6 Osteoarthrosis with flattening sagittal section of the right side mouth open

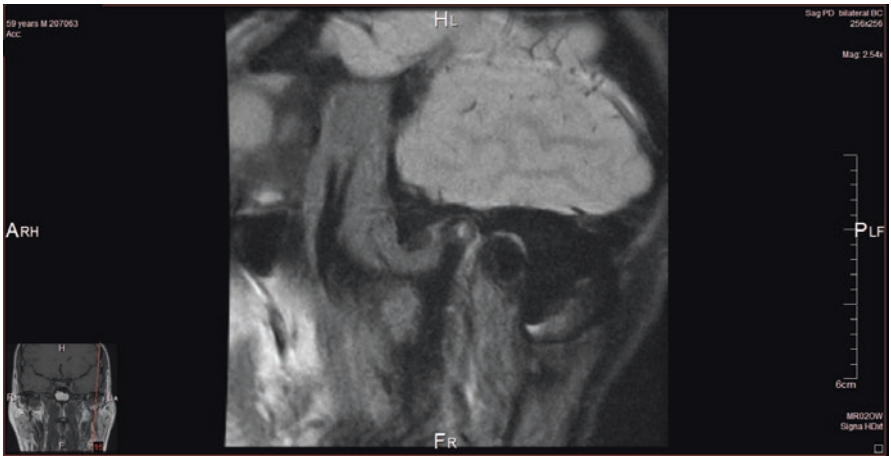

Fig. 5.7 Osteoarthrosis with flattening sagittal section of the right side mouth closed

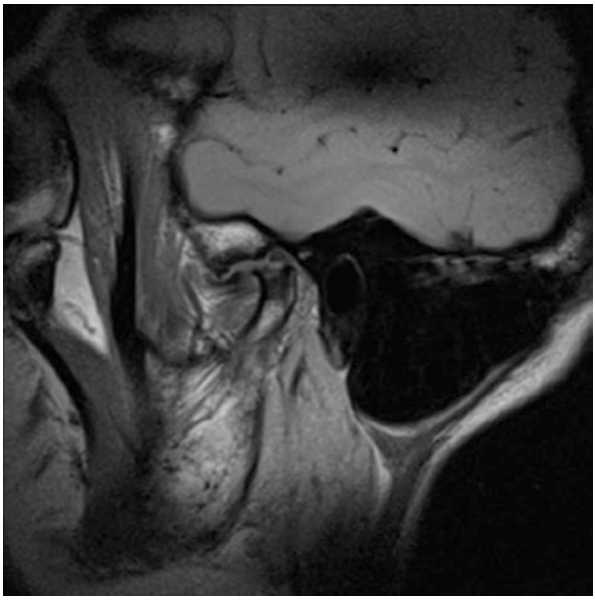

Fig. 5.8 Right TMJ osteoarthrosis mouth closed

Fig. 5.9 Right TMJ osteoarthrosis mouth open

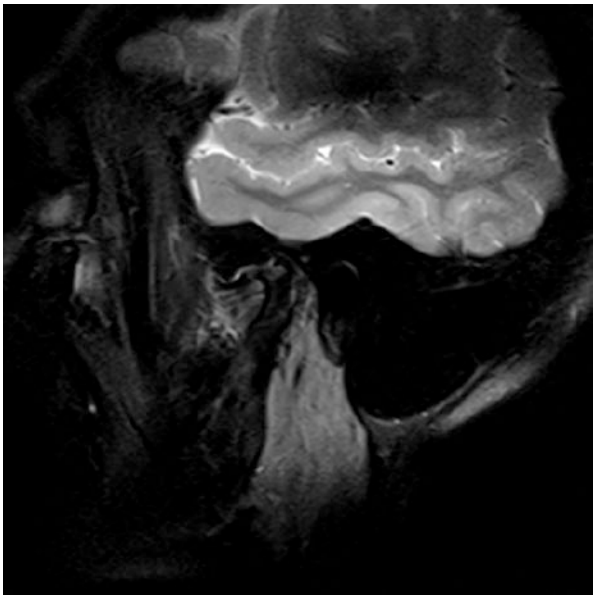

Fig. 5.10 Osteoarthrosis no joint effusion T2-weighted MR

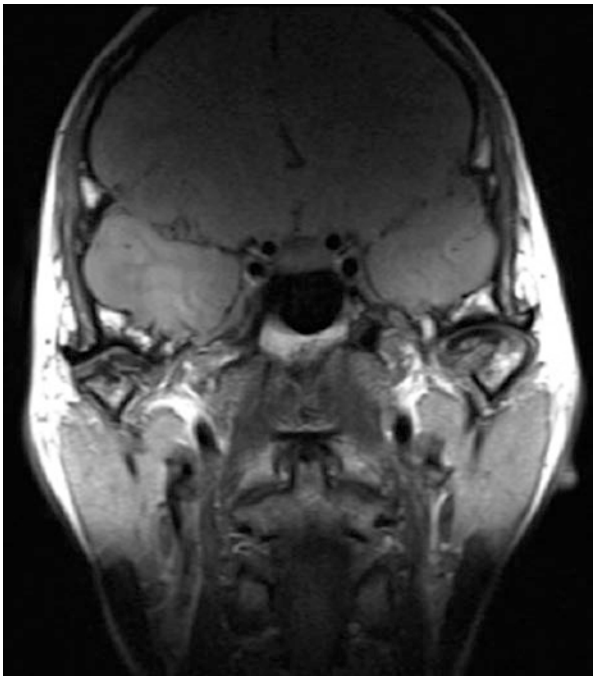

Fig. 5.11 Osteoarthrosis coronal section

5.3 Management Principles for TMJ Disorders in the Elderly

As a general rule, TMD treatment should be delivered in the form of patients' *management* (e.g., the word "management" being used as a synonymous of *symptomatic treatment*, as actually TMD treatment is), with the obvious notable exceptions of some surgery-demanding conditions. Based on that, multimodal therapies incorporating behavioral and educational strategies seem to offer more benefit than a sole approach. Such suggestion is mostly valid for patients with high psychological distress, who can take advantage from the available cognitive-behavioral techniques in their attempt to cope with pain.

Over the years, several approaches, such as physiotherapy, physical therapy, pulsed electrical stimulation, medication, topical ointments, supplements, splint therapy, intra-articular injection, and acupuncture, have been proposed **to manage symptoms** due to such disorders and **to improve joint function**; among those, viscosupplementation with hyaluronic acid (HA) injections has been gaining diffusion. Such strategy has been introduced within the clinics of TMJ disorders as a result of the progressive changes to the classical TMJ arthrocentesis as well as of the increasing knowledge about the potential application of hyaluronic acid to manage osteoarthritis of larger joints.

The term TMJ arthrocentesis (Figs. 5.12 and 5.13) defines the lavage of the upper joint compartment by mean of a liquid, using needles (Fig. 5.14) for the inflow and the outflow (Fig. 5.15). This technique was first introduced at the beginning of the 1990s and derives directly from TMJ arthroscopy, which met much success in the early phases of TMJ minor surgery diffusion thanks to the diffusion of miniarthroscopes and to dedicated miniaturized surgical instruments. Since then, some changes happened due to the fact that findings of studies on the efficacy of arthrocentesis, an extremely low-cost procedure, were very promising.

Indeed, many authors observed that the most effective and successful component of TMJ arthroscopy was the simple fact that the patient was submitted to an intervention and not all the complicated manoeuvers intended to recapture the disk, fix the disk, and remove the adherences within the joint using tiny and sophisticated instruments. The "lysis and lavage" that patients had to go through with arthroscopy was sufficient, independently from any other associated procedure, to reach a favorable outcome. The under pressure flow of a liquid throughout the joint allows by itself the removal of the catabolites, the distension of the joint with breakages of some adherences, and the mobilization of the disk.

Since then, studies on the potential role of joint lubrication impairment as a risk factor for TMJ internal derangements and the subsequent inflammatory degenerative disorders provided a background for TMJ viscosupplementation (i.e., postlavage positioning of hyaluronic acid), which is supported by the clinical evidence of its effectiveness. Notwithstanding that, much information is yet to be defined as far as the most suitable protocols and indications at the individual level are concerned. Several clinical trials have been conducted with the aim to customize

Fig. 5.12 Intra-articular anesthesia

treatment based on the identification of patient- and treatment-related outcome predictors. A five-session protocol of arthrocenteses plus viscosupplementation (Fig. 5.16) was shown to be effective for reducing symptoms of TMJ OA.

Patient education and self-management consist of patient counseling and patient education on the natural course of the disease. The treatment is intended to change oral habits: soft diet, avoidance of excessive mouth opening, and gum chewing are basic strategies to recommend.

Nonpharmacologic therapy often starts with auto-massaging and supervised home-based exercise program that consists of muscle strengthening and range of motion exercises.

Thermal modalities, therapeutic ultrasound, transcutaneous electrical nerve stimulation, and low-level laser therapy are physical therapy modalities often used in osteoarthritis treatment.

Fig. 5.13 Reference line for TMJ arthrocentesis

Fig. 5.14 Instruments for TMJ arthrocentesis

Fig. 5.15 Two-needle arthrocentesis. Salin inflow and outflow

Fig. 5.16 Viscosupplementation after arthrocentesis

As for the pharmacological management, acetaminophen and topical pharmacological agents such as nonsteroidal anti-inflammatory drugs (NSAIDs) and capsaicin are used as first-line treatment. When acetaminophen fails to control symptoms or if symptoms are moderate to severe, NSAID therapy is recommended. Patients taking NSAIDs should be cautioned about adverse effects, which may include gastrointestinal bleeding, renal dysfunction, and blood pressure elevation.

Chondroitin sulfate and glucosamine are popular supplements used to treat the pain and loss of function associated with osteoarthritis, but their efficacy is controversial.

As for oral appliances, the "gold standard" is the stabilization splint, also sometimes referred to as "Michigan splint." It was called stabilization splint because the device is supposed to contribute to occlusal stability (i.e., by simultaneous contacts of the opposing teeth with the appliance surface and stable position of the teeth and the splint). This device is made of hard acrylic resin, typically covers the upper teeth (maxillary appliance), provides full coverage of teeth (full-coverage appliance), and has a flat occlusal surface. Some additional features, such as "freedom in centric" (i.e., flat area of up to 1 mm in diameter that allows smooth slides in the horizontal

plane without a vertical component, designed when a slight intercuspation on the appliance is provided) and canine guidance (i.e., cuspid rise during appliance-guided laterotrusion and protrusion), may be introduced under clinician's judgment.

The stabilization appliance is usually worn at night. If desired, for example, during stressful periods of life, it may additionally be used for a few hours during the day. After delivery, the first checkup is commonly performed within a couple of weeks. Subsequently, the patient should be scheduled on a regular basis (e.g., at least every 6 months) to examine the fit and the occlusal contacts on the appliance. If these requirements are met, the risk of unwanted effects brought about by the appliance (e.g., unintended positional change of individual teeth or the mandible) is extremely low.

Stabilization splint therapy seems to be an effective treatment option for change force vectors and loaded areas, so as to provide symptoms relief and a possible reduction of bone resorption in the glenoid fossa in OA patients. Thus, its effects on the TMJs and jaw muscles have nothing to do with changes and purported improvement of occlusal conditions.

5.4 Conclusions

Degenerative disorders of the temporomandibular joint (TMJ) are a common cause of pain and treatment-seeking behavior in the field of orofacial pain and require careful diagnostic assessment and therapeutic planning. Among the various strategies that have been proposed over the years to manage pain and improve function, viscosupplementation with hyaluronic acid (HA) injections has been gaining widespread attention.

Masticatory Function and Nutritional Status: Considerations for an Ageing Population

6

Martin Schimmel, Laurence Genton, and Gerry McKenna

Abstract

Nowadays, many people retain their natural teeth until late in life as a result of the large success of preventive strategies. However, there is still a very high prevalence of edentulism and partial edentulism especially in elderly patients, and many of these patients are provided with inadequate dental prostheses. In addition, many elderly citizens suffer from systemic diseases leading to increased drug prescription with age. This may have direct or indirect negative effects on the health and integrity of oral tissues like teeth, mucosa or muscles. There is growing evidence that a close interaction between the general medical condition and oral health exists. From a dental point of view, the chewing ability and capacity and its interaction with the nutritional status seem to be especially important. For example, complete denture wearers present a significant oral disability, which often leads to a gradual deterioration of their individual dietary habits. The improvement of maximum bite force and chewing efficiency may be an important prerequisite for an adequate nutrition. Those functional parameters can often be improved by providing functional dental prostheses or by stabilizing complete dentures with endosseous implants. Nevertheless, an improvement of the nutritional status can only be achieved through a close collaboration with dieticians or clinical nutritionists.

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6.1 Introduction

The key factors for successful ageing are described as intact social networks, physical and mental health, and physical and cognitive functionality [1]. The impact of diet or the nutritional status on all of these factors can be considerable. The aim of this review is to discuss the association between masticatory function and nutrition in older adults and the options and limits of dental treatment.

The intake of nutrients depends on different factors; dental status and oral health are only two aspects. Food choice is influenced not only by individual preference, taste, food texture, consistency, colour, shape, size and temperature; but habits formed in childhood, family or regional culture, religious practice, economic status, mobility and general health also play an important role [2]. Most of these points also apply in old age; for example, eating habits formed in childhood and puberty are usually retained until late in life [3].

With age, the number and severity of systemic diseases as well as the number of prescribed drugs often increase, whilst motor and cognitive abilities decline. Grocery shopping becomes difficult when there is insufficient physical strength to carry heavy bags or retirement payment is sparse, and thus money is no longer available for meat, fresh fruit and vegetables. Preparing a balanced diet becomes difficult if vision deteriorates or there is little motivation to cook once the partner has died, for example. A Geneva study has shown that in a representative population sample of people over 80 years of age, 40% had fewer than three food items in stock in their refrigerator and 10% had absolutely none. This was also a significant predictor of hospitalization in the following month [4].

According to Ettinger, the following factors can help to explain the development of malnutrition or undernutrition, particularly in older adults living alone [5]:

1. Low income and a lack of knowledge on how available funds can be used to obtain high-quality food.
2. Physical impairment resulting from acute or chronic diseases leading to exhaustion and weakness rendering shopping and food preparation difficult.
3. Kitchen facilities that are inadequate for meal preparation. This affects physically impaired people in particular.
4. Poor condition of dentures or prostheses leading to avoiding food items that are difficult to chew, with usually no adequate substitute in the dietary plan. Existing dietary patterns that provide inadequate nutrition as a consequence of lifelong unhealthy eating habits.
5. Depression, dementia, boredom, anxiety, loneliness or social isolation, which mean there is little stimulus to prepare a nutritious meal.
6. Multiple medications which suppress the appetite or have a laxative effect or lead to vomiting or nausea.

6.2 Malnutrition

Malnutrition refers to a state resulting from insufficient nutritional intake or uptake that alters body cell mass and decreases fat-free mass and leads to impaired physical

ability, cognitive function and clinical outcome [6]. According to the latest consensus statement of the European Society for Clinical Nutrition and Metabolism, it can be classified into four broad categories, i.e. starvation, cachexia, sarcopenia and frailty, which often overlap, especially in older subjects [6]. Starvation results from a pure deficit of all macro- and micronutrients. Sarcopenia describes the loss of skeletal muscle mass and function occurring in older or immobilized subjects. Cachexia is a complex metabolic syndrome associated with underlying disease, characterized by a weight loss of at least 5% in 12 months and three of the following criteria: low fat-free mass, decreased muscle strength, fatigue, anorexia and abnormal biological markers (CRP >5.0 mg/L, haemoglobin <120 g/L, serum albumin <33 g/L) [7]. Finally, frailty corresponds to phenotypic criteria associated with adverse outcomes and was originally defined by three out of the five following criteria: fatigue, unintentional weight loss, low physical activity, slow walking speed and low grip strength [8]. According to this, older patients who limit their food intake because of reduced masticatory function usually can fall into all classes of malnutrition. Other consequences of malnutrition include low bone density, reduced cognitive functions, poor wound healing and increased rates of hospitalization and mortality [9]. Age-related weight loss, characterized by a loss of muscle mass and free body fat, has been demonstrated in longitudinal studies [10]. The rapid loss of weight and muscle leads to reduced mobility and increases the likelihood of serious falls (Fig. 6.1).

Fig. 6.1 This frail elderly woman lives in a long-term care facility and shows signs of malnutrition. She is bound to the wheelchair because of frequent falls

Despite the declining energy needs associated with increasing age, food is often consumed in an insufficient amount to avoid malnutrition [11]. The reduced food intake along with a decline in the ability of the gastrointestinal tract to absorb nutrients also leads to a lack of micronutrients such as calcium and vitamin D, which counteract the development of osteoporosis. A deficiency of these substances can also lead to increased tooth loss and resorption of the alveolar bone [12, 13]. However, a lack of other micronutrients such as iron, zinc, folic acid and vitamins C and B12 was also described in association with oral and systemic symptoms such as burning mouth syndrome, atrophic mucosa and a weakened immune status and coagulation system [14]. As malnutrition is often diagnosed quite late in general practice, the oral symptoms can provide first clinical evidence.

Malnutrition not only affects institutionalized older adults, but it is most common in this population group with a prevalence of 60–80% [15]. A large cross-sectional study revealed that the prevalence of being malnourished, undernourished or at risk of becoming so can be over 60% in adults over 65 years of age. The study also confirmed previous findings that the percentage is considerably higher amongst residents in care facilities or patients in geriatric hospitals [16, 17].

A Belgian study mentioned swallowing disorders, taste disorders and transfer to a nursing home as examples of risk factors for developing undernutrition or malnutrition [18]. However, oral health and dental status in particular are often not considered in such studies. Evidently, poorly fitting dentures, denture pressure points, caries or periodontal diseases, as well as loose and missing teeth, can have a considerable negative impact on food intake [19].

6.3 Tooth Loss in Old Age

Over recent decades, progress in preventive dentistry and an increasing awareness of 'healthy teeth' have meant that older adults more often retain their teeth well into old age [20, 21] (Fig. 6.2). Although the average number of teeth lost per individual is decreasing, the prevalence of caries and periodontal diseases is increasing, particularly in older population groups [22]. The 1998 UK Dental Health Survey

Fig. 6.2 This 93-year-old lady is exemplary for the older population—more and more people retain their teeth until late in life

Fig. 6.3 Elderly patients that are dependent on care often experience a severe burden of degrading oral health that will lead to infection, pain and tooth loss and thus a negative impact on chewing function

showed that almost 25% of the older adults had 12 or more teeth with a root surface that was either exposed, worn, filled or decayed [23]. The 2009 survey reported that 73% of all adults had exposed root surfaces, and this increased to 90% for those aged over 55 years. The same survey reported that 11% of 55–64-year olds had active root caries compared with 20% of those aged 75–84 years [24]. This affects residents of nursing homes in particular [25] where oral health is often a secondary consideration. Figures from Switzerland illustrate that 43.3% of the population is fitted with removable dentures in the 75- to 84-year-old age group. The percentage increases in those aged 85+ years to 59.7%, and 15.1% of people in this age group are edentulous, rehabilitated with complete dentures [21]; however, in other European countries, these figures can be considerably higher (the Netherland: 27.6% edentulous in the age group 65–74 years) [26]. A cross-sectional study of patients hospitalized in a Swiss geriatric hospital found an even higher percentage of 52% of edentulous patients in the specific population [27]. Accordingly, many older adults have severely impaired oral functions (Fig. 6.3). Although the situation could be improved for many patients by means of endosseous implants, many older people object to such a treatment [28].

6.4 Masticatory Ability and Masticatory Efficiency

As natural teeth are lost, this can impact significantly on patients' oral function. Research has shown that a decreased number of natural teeth results in reduced chewing ability with edentulous patients possessing lower chewing ability compared to dentate patients [29]. An important factor also plays the presence of periodontal disease—the advanced attachment loss accounts for the loss of periodontal receptors and bite force [30]. With a decreased number of teeth or attachment loss, a reduction in chewing ability can result in modifications to food choices. Whilst food choices can be affected by a range of factors, including social, demographic, sensory, economic, cultural and behavioural, the ability to bite and chew is also important [31]. Impaired masticatory efficiency has also been shown to be associated with reduced nutrient intake, poor nutritional status and subsequent health [32–35] (Fig. 6.4).

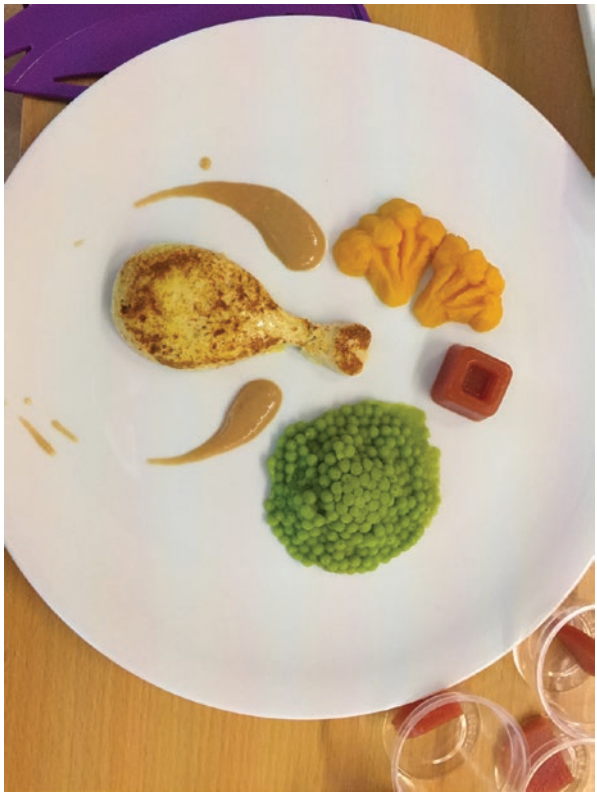

Fig. 6.4 Meals with modified textures can be prepared appealingly in various ways nowadays and are adequate for patients with dysphagia or severe impairment of chewing function. Meal prepared by Raphaël Reinert and Jérôme Hernot

When evaluating masticatory function, the terms masticatory ability and masticatory efficiency must be differentiated. The term masticatory ability refers to the subjective assessment of the masticatory function by the patient and is evaluated using interviews or special questionnaires. Masticatory efficiency is evaluated using objective tests and is defined as 'the effort required to achieve a standardized degree of comminution' [36]. For this purpose, a test food, usually nuts or silicone cubes, is chewed and then rinsed, collected and dried. The degree of comminution d50 is analysed using a sieve system or optoelectronic analysis and is used as a measure of masticatory efficiency [37, 38]. Other methods are based on the analysis of the colour mixing of tow-coloured test foods (e.g. wax, chewing gum) [39–43]. The results from these two-colour mixing tests correlate significantly with the 'sieving method', and they are particularly suitable for individuals with reduced masticatory function [39]. They may also be applied in patients with swallowing disorders because no particles can be aspirated [44]. For patients with severely reduced masticatory efficiency, a combination of objective and subjective evaluations of masticatory function is recommended. The objective methods are based on a previously defined number of masticatory cycles and are therefore not suitable to assess the individual chewing strategies of complete denture wearers, for example [45].

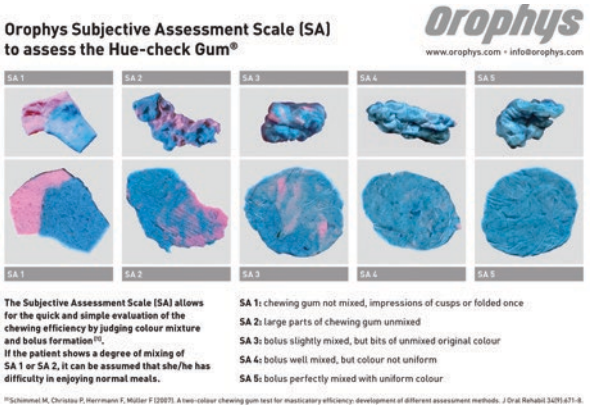

Fig. 6.5 Using a two-colour mixing test, the chewing efficiency can easily be estimated with the scale. SA1 and SA2 would signify a severely impaired chewing function [43]

The colour mixing tests are also suitable for use in private practice, hospitals or geriatric wards since they are cheap, simple and reliable. The patient is asked to chew a multicoloured piece of chewing gum (e.g. Hue-Check Gum ©, Orophys GmbH, Switzerland) for 20 chewing cycles. The chewing gum is then removed from the mouth, placed in a plastic bag and visually analysed using a scale. The shape of the bolus and the degree of colour mixture indicate the individual masticatory efficiency (Fig. 6.5).

If a patient is allocated to grade 1 or 2, it can be assumed that he or she has difficulties when eating foods with a normal consistency. For an even simpler test, the patient might simply bite on the examiner's finger to estimate the available masticatory force [46]. Chewing a piece of raw carrot can also provide initial information which food consistency could be recommended for the patient [47].

Masticatory efficiency is related to the number and distribution of teeth as well as the type and quality of the prostheses. The jaw-closing force and the function of the cheeks, lips and tongue also have a considerable effect. Whilst teeth and dentures serve to crush and grind down foodstuff, it is with the help of the intraoral and perioral muscles that the bolus is positioned between the dental arches and shaped. Saliva plays an important role in the formation of a cohesive bolus, which is then transported by the tongue to the oesophagus [48]. The force and coordination of these structures can, for example, be reduced in stroke a patient, which leads to a decrease in masticatory efficiency [49, 50]. There is also rising evidence that masticatory function is impaired in those suffering from dementia [51, 52].

The ability to crush and grind food is significantly dependent on the area of antagonistic occlusal surfaces [53] and therefore declines with the loss of teeth [37]. Dentures can only in part compensate for this loss. Regardless of age, adults with a complete dentition have the highest masticatory efficiency, but the loss of even a few posterior teeth significantly reduces the chewing function [54]. In one of our own studies, we investigated the masticatory efficiency of edentulous subjects. We showed that those wearing conventional complete dentures had a significantly lower masticatory efficiency than those subjects with full dentition.

Edentulous patients with mandibular implant-retained/implant-supported overdentures show a higher masticatory efficiency than complete denture wearers. These overdenture wearers had a comparable masticatory efficiency to edentulous patients with fixed implant bridges in both jaws. The masticatory efficiency of subjects with a full dentition was not met with any of those prosthetic treatment concepts. This may be linked to the loss of periodontal receptors and impaired jaw movements and reflexes [55].

Older adults often suffer from age-related comorbidities, and with the increasing number of relevant systemic diseases, medications that may inhibit saliva flow are also being prescribed more often. This can lead to a wide range of oral problems. The retention of removable dentures is reduced, and the dentures often cause pain [19]. In addition, the food bolus cannot be formed and lubricated properly, which renders the act of swallowing difficult. The masticatory function is thus significantly affected by the quantity and consistency of saliva [56, 57] (Fig. 6.6).

The ability to crush and grind food is highly dependent on the available maximum jaw-closing force [58]. Muscle mass declines over the course of the ageing process; the jaw-closing muscles are no exception. Additionally, the age- related decline in the muscle cross-section of the masseter and pterygoid muscles is significantly increased in edentulism [59, 60]. Consequently, the maximum force that is available for comminution of food decreases over the course of a lifetime. For patients with mucosa-borne dentures, the maximum force is also ultimately limited by the pain threshold of the mucosa. Newton et al. have shown that overdentures that are supported by natural roots may counteract the waste of the jaw elevators [61]. In patients in the fourth phase of life (adults of both a chronologically and biologically advanced age [62]), it was shown that implant-supported overdentures may prevent or even reverse this atrophy [63, 64]. This emphasizes the preventive benefit of implant-borne prostheses in edentulous patients.

Fig. 6.6 Severe forms of hyposalivation make chewing and swallowing difficult, because the mucosa becomes very sticky

6.5 Dietary and Physiological Aspects

Diet plays a key role in disease prevention in older age, as poor diet has been linked to illnesses such as osteoporosis, atherosclerosis and bowel disease. Poor oral health and loss of teeth can have very significant negative effects on dietary intake and nutritional status for elderly patients [65]. In fact, the American Dietetic Association has stated that oral health and nutrition have a 'synergistic bidirectional relationship' [66]. There is evidence that good oral health generally has very positive effects on nutritional intake of older adults.

The loss of natural teeth can alter older patients' selection of foods. When fewer natural teeth are present, elderly people tend to choose foods that are softer and easier to chew. However, these foods are often low in nutrients including fibre, high in calories and complex carbohydrates [14, 67]. It has been shown that older patients perceived ability to chew foods is closely associated with the number of natural teeth remaining [68]. In addition to the number of natural teeth remaining, the number of occluding pairs of teeth also appears to be very important [69].

Amongst older patients, chewing problems are relatively common. In a study of 1755 people aged 65 years and older, 13% with impaired dentitions said that they 'often' or 'always' had problems biting or chewing in the previous 3 months. Amongst the same group, 10% had experienced frequent limitations in the kinds or amounts of food eaten, whilst 9% always perceived discomfort whilst eating [70]. In another study, one in five older people reported that oral conditions prevented them from eating the foods they would like to choose, 15% took longer to complete their meal, and their enjoyment of food was limited by oral conditions. In addition, 5% avoided eating with other people because of chewing problems. Edentulous subjects were more affected than dentate individuals [71]. Besides the loss of tooth, as people become older, they can chew less well especially harder and elastic food like squid [72]. Other studies have shown that patients with xerostomia, which affects about 20% of older people, also complained of difficulties eating certain foods [73, 74].

It appears that complete denture wearers alter and restrict their diet in the long term because of the prosthetic treatment, due to the development of significant functional impairments, particularly with advanced atrophy of the mandibular alveolar crest [75]. This change in diet can, however, also occur rapidly and may represent a considerable burden for the patient as in the case of a total clearance of the natural dentition. Despite technically flawless preparation of immediate dentures, swelling and pain develop (Fig. 6.7). After several weeks of healing, patients learn, depending on their individual cognitive and neuromuscular adaptability, to manipulate the mucosa-borne dentures and to function with them. It may take up to 6 months after delivering immediate complete dentures before the masticatory efficiency of those who have been wearing complete dentures for many years is reached [76–78]. A study by Millwood and Heath illustrates this, often unnoticed, dietary change particularly well. There, most complete denture wearers only indicated meat as difficult to chew. Closer questioning revealed, however, that fruits with seeds, nuts, carrots, beef, toffee or celery were no longer eaten because of problems with crushing and grinding food. Increased quantities of soft foods such as refined carbohydrates and

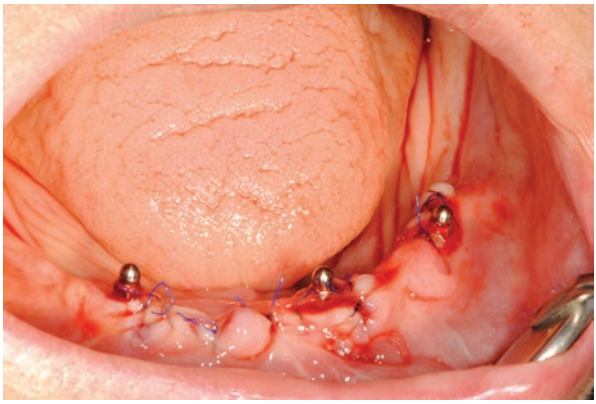

Fig. 6.7 After full clearance of the lower dentition, immediately loaded temporary implants may help to improve in the difficult healing time prior to the reconstructive phase

fats were also introduced into the diet. Foodstuff is often overcooked until being soft, but important micronutrients are destroyed in the process [79].

In a British study, Sheiham et al. investigated the link between the number of natural teeth or edentulism and several nutritional parameters. They showed that the fewer natural teeth the study participants had retained (the most severely affected were complete denture wearers), the lower was the intake of vitamins, calcium, essential fatty acids, proteins and calories [80]. Missing calories were often compensated for with foods containing high amounts of sugar [35]. People with their own posterior teeth also consumed more fruit and vegetables [81]. Having conventional complete dentures accordingly increases the risk of developing a protein-energy malnutrition [82].

A very large US study reproduced these results. A sample of 4442 study participants underwent dental examinations, and a 24-h dietary profile was prepared. This study showed a significant link between dental status and the intake of calories and selected micronutrients, particularly for men. If the results were adjusted for the cofactors age, ethnic origin, education and smoking status, it was apparent that these factors had a greater effect on the nutritional status than the dental status. This result highlights the complexity of individual dietary patterns [83].

Reduced masticatory efficiency in denture wearers also has a critical effect on oral-health-related quality of life [84]. Although foods that are difficult to chew can often be replaced by an equivalent (e.g. fruit by juices) [85] and reduced masticatory efficiency after tooth loss does not automatically result in poor blood parameters, the social components of shared meals and the choice of food are often diminished [86, 87].

6.6 Dentures

In private dental practice, the situation might occur that a primary care physician suggests the provision of a dental prosthesis in order to treat the under- or malnutrition in older patients. The reasoning is often based on the assumption that an increased masticatory efficiency after prosthetic treatment will automatically improve the diet.

However, numerous well-designed studies failed to demonstrate such an effect. McKenna et al. compared the effect of removable and fixed partial dentures on blood parameters such as serum albumin and did not detect any difference between the two groups, even though there were considerable differences in the size of the occlusal contact surface [88, 89]. Previous studies correspondingly failed to demonstrate that partial dentures had an effect on dietary parameters [90–92].

Also, edentulous patients with mandibular implant-supported overdentures who therefore benefited from a significant increase in masticatory efficiency did not show any improvement in their nutritional status if their therapy was not accompanied by nutritional counselling [63]. On the other hand, a large Canadian randomized controlled clinical trial with adequate statistical power compared the diet of edentulous patients with conventional complete dentures and those with implant-supported overdentures. The results suggested that overdenture wearers consumed more fresh fruit and vegetables. However, a positive effect on other nutritional parameters, such as protein, energy and vitamin intake, was not observed [93, 94]. Functionally adequate dentures are therefore an important prerequisite for improving the nutritional status of a patient, but treatment of malnutrition or undernutrition in old age should always be accompanied by nutritional counselling [95–97]. Even elderly denture patients who do not suffer from a protein-energy malnutrition may benefit from nutritional advice and may thus improve their diet [98].

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Carious Destruction of the Remaining Teeth: Diagnostic and Treatment

7

Hande Sar Sancaklı

Abstract

Increase in the life expectancy and the health care has led to the rising of the elderly numbers in the populations. Beside the recent demographic changes, advances in the dental materials and clinical dentistry aided those elder individuals to retain more teeth with reduced loss rates. However, due to the ageing and the physiologic change of the dental structures and their supporting tissues, various risk factors relating to the medical conditions and pharmaceutical therapies constitute elevated caries risk status for the elderly. Regarding the gingival recession rates and decreased salivary flow and content, especially root caries occur as one of the major oral diseases with periodontal changes through the ageing years. The present chapter is dedicated to the caries destruction of the dental hard tissues including the ageing-related changes and the diagnosis, prevention and restorative treatment considerations of the root caries in the elder patients.

7.1 Caries in the Elderly

Nowadays both as a result of the expanding lifespan due to the improved medical care and quality of life on the other side varying regional decline in the fertility rates, ageing people proportion among the global population has raised [1]. The desire to achieve the success on the public health policies and improved socioeconomic status can also be counted to contribute to the longer life expectancy, but still today there are some challenges to maximise the quality of life for the ageing population [2]. Among the essentials of the general health, contemporary

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approach accepts the oral health as one of the main domains of the well-being. As reinforcing the evidence that oral health is an integral of general health, oral cavity stands as a mirror of the whole system [3]. Poor oral health has clearly been shown to correlate with the increased risk for general health problems and compromised status. Especially having a critical impact on the functional, psychological and economic aspects of the overall quality of life of the elderly people, oral health affects the diet and nutrition intake, psychosocial interaction and moreover general well-being. Regarding the improved quality of life aspect, like younger adults, elderly people also desire to have a dentate oral cavity not only to maintain function but also a pleasant aesthetic status [4]. We as dental professionals have the opportunity to serve the best to encourage and keep our patients aged with a healthy dentate for a functional life through the contemporary minimally invasive treatment approach [5].

Today's increasing elderly population retains higher number of teeth rather than the past due to the advancements in the dentistry owing to the improved dental materials and treatment approach [6]. Hence it is obvious to screen most of the dentate elderly individuals having their teeth either carious or restored by filling or crown restorations. Comparing to the past decades, we can consider serious dental problems with the aged dentate patients as a result of more teeth retained more, caries developed (Fig. 7.1 and Fig. 7.2).

Caries and periodontal disease constitute the two major infectious dental problems in elderly patients as seen among the global general population. As today's ageing population remains with an increased retention of natural teeth, dental

Fig. 7.1 Geriatric patient suffering from extended cervical lesions showing both the loss of the dental tissue and cervical caries (Courtesy of Prof. Dr. Olcay Şakar; Istanbul University Faculty of Dentistry Dept. of Prosthodontic Dentistry)

Fig. 7.2 General view of root caries initiation in the elderly

profession will without any doubt face a new caries challenge in older dentate patients. On a specific basis, since the oral cavity provides an entry and retention for the microorganisms, especially bacterial plaque accumulation causing both periodontal disease and dental caries, it has shown to raise the concern of a possible relation between the oral infections and systemic diseases [7].

Together with the contemporary comprehensive conservative and operative treatment approaches, various kinds of progressively developing restorative materials are fulfilling both the functional and aesthetic demands of the patients [8, 9]. Beside emulating the appearance and function of natural teeth, advances in the periodontics and endodontics have also increased dentists' ability to conserve and retain natural dentition throughout the expanded lifetime by stating tooth loss is no longer inevitable [9, 10].

The present chapter will address the aetiology, diagnosis, management, prevention and minimally invasive approach-based treatment choices of the caries lesions of the elderly individuals to maintain healthy dentition through ageing years.

7.2 Dental Caries and Ageing of the Dental Tissues: Is There Any Relation?

Dental caries is a bacterial disease which is defined by a multiple-rationalised, biofilm-mediated, sugar-driven, multifactorial, dynamic disease occurred by phasic demineralisation and remineralisation of dental hard tissues. The dynamic process can occur throughout the life, starting at the primary and permanent dentitions, leading to destructions of the crown and exposed root surfaces through the ageing years [11].

Through the dynamic dentate lifespan, tooth structures have significant physiologic alterations by time. The earliest change occurs in enamel starting immediately by getting into contact with the occlusion and continues as its presence in the oral cavity. Enamel wears due to caries, trauma and several reasons through the lifespan, and meanwhile dentin exposes and starts to produce secondary and sclerotic dentin as a defensive reflection [12]. While the dental hard tissues change over time, the soft supportive and connective tissues also respond to this process by reducing the number of blood vessels in the pulp. These changes may clinically represent a decrease in the sensitivity of pulp especially in conjunction with the reduced enamel thickness exposing dentin by sites. Not only the sensitivity against thermal, tactile or osmotic irritants but also significant pain perception occurs regarding the induction of the sclerotic dentin resulting the shrinkage of the pulp dimension even blocking the root canals [13]. All these clinical symptoms may be explained by the secondary dentin deposition occurring both at the crown part and the root of the teeth. Calcification of the pulp, increase in the collagen fibres, degenerative and diminished nerve supply and external resorption at the gingival area are the most prominent causes of the crown and root pulp volume loss. These changes may also clue why local anaesthesia requirement is low during the restorative treatments in the elderly [14].

Regarding the ageing effects on oral tissues, it is difficult to disseminate a clear demarcation between physiologic ageing and pathological diseases. Most prominent changes can be seen on tooth translucency and surface details such as perikymata and imbrication lines beside abrasion, attrition and erosion seen in ageing years [15]. Both hard and soft tissue loss raising from physiologic gaining constitutes periodontium loss as a common thread for the geriatric patients [16].

Gingival recession resulting from the loss of epithelium attachment and alveolar bone in the elder individuals may cause an increased dental plaque accumulation hindering more susceptible status for periodontal infections. Thus, apical gingival recession exposes the root surfaces exerting the altered root surface caries in the dentate elderly. Although tissue change through the ageing physiologic process does not correlate with severe functional changes, some specific but quality of life-related consequences may occur by time such as salivary gland function, taste, tactile sensation and swallowing [17, 18]. Not only the hard tooth structures and their supporting periodontal constructers but also the oral mucosa and salivary glands as indirect conditions have a crucial role on the caries and periodontal disease existence in the elder patients. Caries and mucosa problems in elderly often develop as a result of xerostomia caused by the medication, the oral motor functional impairment and the conjunction of them interfering insufficient oral clearance (Fig. 7.3 and Fig. 7.4) [19].

Fig. 7.3 Major clinical symptom of xerostomia and changes of the aging oral soft tissue-dried view of the tongue

Fig. 7.4 Changes of the aging oral mucosa of a geriatric patient with xerostomia due to heavy medication

Mainly gingival recession and loss of periodontal structures cause exposure of root surfaces through the ageing years. Plaque removal insufficiency, local abrasion and trauma affect the root surfaces and favour these sites to decay. Furthermore, bad oral health, salivary deficiency, lack of fluoride or other remineralising product use, eroding factors such as gastro-oesophageal acid reflux and most probably dentures accumulating plaque and food remnants constitute the reasons why root surfaces are more prone to high caries risk. Most of the caries lesions progress asymptomatically at the early stages until extreme lesion progression reaches the dental pulp inducing sensitivity and progressively pain and infection [20].

7.3 Root Caries

Addressing specific rationale, root caries is a bacterial disease of a multifactorial, progressive, chronic lesion exhibiting softened, irregular and darkened tissue on the root surface involving occasionally cementum, dentin but rarely enamel close to cemento-enamel junction often seen in the elder individuals [21]. *Streptococcus mutans*, *Lactobacilli and Actinomyces* and species of *Atopobium*, *Olsenella*, *Pseudoramibacter*, *Propionibacterium* and *Selenomonas* are the associated bacteria among the aetiological agents [22].

The most prominent causes are the exposed root surfaces as a result of cumulative gingival recession and the attachment loss through the periodontal challenge. Once the cementum and dentine are exposed, they get more prone to demineralisation which can lead to caries due to low mineral content of the exposed and abraded dentin and the lower pH concentrations of either plaque or oral cavity [23].

Root caries often develops supragingivally on the exposed root surfaces exclusively near the coronal margin and cemento-enamel junction part [24].

Early signs of the carious lesions are characterised by discoloured and slightly softened exposed dentin and can be clearly seen when the superficial plaque layer is removed. Therefore an identical visual examination should be performed only after the root surface is cleaned from any plaque or remnants [25]. There are some substantial differences about the microbiologic invasion intensity between enamel, dentin and cementum. Since the cementum and especially dentin tissues are softer in hardness and have a tubule structure, microorganisms invade faster and initiate lesion very early. However, adequate plaque control and sufficient fluoride uptake would turn active lesions arrested even inactive at this stage [26].

Most of the root caries lesions heal via natural repair and reversal process when bacterial accumulation reduces and the periodontal supportive tissues reach stability by time if the surface becomes non-plaque-retentive area.

Another distinctive characteristic of the root caries seen in the elderly is that the initial caries lesion mostly progresses extensively as discolouration with softened dentin circulating the entire root surface.

The lesion often progresses shallower by encircling the root surface instead of invading deeper. However, severe and advanced lesions may progress towards the pulp and lead to infection. Moreover, the severity of the discolouration does not

Fig. 7.5 Encircling root caries

correlate to the lesion activity since the lesion can get darker by time if the lesion progresses chronically (Fig. 7.5) [27].

Restoration of root caries has some challenging restoring procedures apart from the other anatomical sights of the crown. Due to being a difficult site to restore, the structural characteristics especially being in contact with the gingiva and challenging moisture control, critical adhesion to root dentine and access difficulty of the interproximal or root furcation areas should be taken into account. Cavity size also plays an effective role on the clinical performance since the lesion may extend on a large area even it can circulate the whole root circumference. All these constraints of the lesion make the caries removal and respective restorative material application more arduous [28, 29].

7.4 Detection and Diagnosis

Diagnosis of the caries lesions constitutes the pathway of management of the treatment options. Root caries are the most frequent developing caries on the exposed dentin surfaces of the elder individuals. As the smooth exposed surfaces are prone to root caries for elevated caries determinants widely discussed in the present chapter, they often can be easily detected through visual inspection. However majority of the root caries are seen on the vestibular or proximal sites of the teeth and most probably in the posterior region due to the presence of plaque, proximity to the dentures and gingival recession (Photo). When the root surfaces are exposed, they have the easy access for visual detection. But having a lesion adjacent to tooth or cervical/interproximal restoration, it is quite difficult to reach and detect the lesion. In addition to the visual diagnosis, radiographs even may interfere with the challenging location of the lesion and sometimes can be an obstacle with the precise detection such as burnout effect and the reflection of the existing adjacent restorations such as amalgam or other metal materials.

Detection and diagnosis of root caries have some distinctions apart from the interproximal or pit/fissure caries. Since the caries process of the root lesions does not include enamel, the histologic progression is much faster due to the dentin invasion dynamics. Biofilm often stagnates at the exposed root surfaces and initiates the caries development. Unlike the enamel caries process, primary demineralisation of the root exposes collagen fibrils leading to greater breakdown and volume loss of

dentin [30]. Not only the bacteria-related demineralisation but also root caries may also occur due to hard tissue loss such as erosion, abrasion or abfraction. When the root dentin is exposed without the protective shield of cement, cariogenic plaque bacteria can invade through the dentine tubules without any demineralisation process which can be considered as even contamination of the dentin structure [31]. Regardless of the identical causative factors, on the histologic aspect, root caries has a slightly demineralised dentin surface lesion with bacterial penetration at the surface but a more pronounced demineralised subsurface lesion and translucency at the deep of the lesion body [32, 33]. At the initial phases, the exposed dentin surfaces are usually covered by a cariogenic plaque which must be cleaned for an efficient visual detection.

Root caries as smooth surface lesions are accepted as the most advantageous lesions to detect and hence considered as more preventable by the non-invasive. For an ideal visual diagnosis, teeth should be cleaned with a toothbrush or professional cleaning cup. A ball-ended explorer can also be used to remove any remaining plaque and debris and to check for surface contour or a possible minor cavitation [34]. It is often easy to detect a root caries since there is distinct border with the surrounding sound surface. Sharp explorers should be avoided to detect regarding the risk of damaging the outer surface of the initial caries and may hamper the possible remineralisation of the lesion. Regarding the cavitated root caries lesions, the surface characteristics may differ since the cavity base can be either soft, leathery or hard to probe through. For a gentle and sensitive detection and classification of root caries, a Community Periodontal Index (CPI) probe is also recommended [35].

7.5 Caries Detection Aiding Tools

Most of the criteria used to define diagnosis and clinical decision-making lead clinicians to a subjective judgement. A more precise and objective detection of the lesions would probably guide to draw a prevention-based treatment plan enabling both the treatment and maintenance of the success of the treatment. Especially detection tools validated for the early stages of the caries lesions by detecting the accurate mineral loss can truly heal the lesion activity by the advantage of reversing the demineralisation process.

Today we have various diagnostic aiding tools to detect early stages of the caries lesions and control the disease by monitoring for an objective patient follow-up. As the specific caries lesions detected at the elderly mostly include root caries, some of the commonly used validated diagnostic tools for the coronal caries have not been found relevant for root caries. Despite being sensitive and valid for quantification of demineralisation in enamel caries, quantitative light-induced fluorescence (QLF®) (QLF, Inspektor Research Systems BV, Amsterdam, Netherlands) has not been considered valid for approximal lesion or dentin-exposed root caries yet [36].

Combined use of radiographs and caries detection tools is still the most recommended as sensitive and specific carious lesion diagnosis method [37]. However, visual inspection and diagnosis supported by the radiographic assessment still

remain as the most effective, useful and conventional technique for the final threshold. It should also be taken into account that regardless of the type of the diagnostic tools used, they all should be enrolled through a modern medical approach determining the caries risk status of the patient and management through the medical pattern [38–40].

The DIAGNOdent® and DIAGNOPen® (DIAGNOdent 2095, DIAGNOdent 2190, DIAGNOPen, KaVo Dental, Lake Zurich, IL, USA) use a laser beam at 655 nm wavelength, creating fluorescence in components such as porphyrins that enable to measure the intensity of the emitted fluorescent light [41]. Besides being proposed as simple and economic device to use in assessment of root caries in daily practice, the technique indeed has a good reproducibility and high sensitivity for coronal and occlusal caries compared to visual detection on a clean surface from debris and calculus [42, 43]. Likewise, the complex occlusal enamel shallow root caries surfaces with stains may interfere, and the readings may be confounded. Despite limited validation for its use in root caries, there is an acceptable reproducibility between the measurement of dentin lesion depth and the remaining dentin thickness between the pulp and the readings, and we can face promising data about the use in root caries in the coming years [21].

Originally being an occlusal caries detection and monitoring system, ECM, electronic caries monitor, relies on the electric insulation of the sound enamel on the other side the conductance of the wet and moisturised carious part. The system can measure the increased conductance of the caries lesion compared to sound dentin conductance value which can be a quantitative supplementary to the visual tactic. One of the most advantageous specialties is to give surface-specific readings so that a minimally invasive intervention is possible [44]. Although specific advantages the system has still a limited use in clinical practice due to being operator-sensitive and requiring delicate repositioning of the monitor tip at each measurement for a reliable result [43, 45]. ECM has the highest validation proven by the clinical studies, and all these mentioned capabilities favour this system as a more validated and better supportive choice for the preventive treatment of root caries both on lesion diagnosis and in treatment follow-up intervals in case if an additional quantitative detection aid is required beside the most common visual and radiographic method used in the daily practice [46].

7.6 Lesion Activity: Active or Inactive?

The root caries usually has an obvious and identical colour characterisation. However, detection is crucial whether to identify the lesion as active or arrested (inactive/chronic) considering colour change. As a consequence of the dynamics of the caries process, detection and diagnosis differ from the approximal or pit/fissure caries in regard to managing the diseases [47]. Texture of the lesion, contour of the surface, lesion proximity to the gingival margin and colour of the lesion constitute the threshold for the activity determination of the root caries [48].

If the lesion detected has a matte and chalky or a frosted surface usually covered with a thick plaque, it means it is an active lesion. On the contrary if the dentin is exposed and rather soft, a severe infected caries lesion can be considered. In some cases, if remineralising factors and oral motivation of the patient predominate, the lesion gets inactive spontaneously by time as a natural healing process. Such arrested lesions become shiny yellow-brown colour and mostly show similar hardness to the surrounding sound areas. Even the mildly cavitated arrested lesions get hardened dentin at the surface. All these healing process can be counted as a result of the physiologic repair capacity of the time.

The distinction between an active and an arrested lesion still remains complicated so that clinicians require a practical clinical detection which would easily guide them for the management and treatment of root caries. With the support of microbiological and the clinical evidence in the literature, a new and practical clinical measurement ICDAS II criteria was introduced for detection and classification of root caries. ICDAS II criterion uses the colour, texture, appearance, perception on probing and cavitation parameters to enlighten the clinical detection enabling the entire root surface (facial, mesial, distal and lingual root surfaces). The criterion also includes the lesion activity and the recurrent caries associated with the root restorations (Fig. 7.6 and Fig. 7.7) [49].

Whenever the large exposed cementum and dentin show the signs of active lesion, severe bacterial infection invades through the demineralised dentin along the collagen fibres within the dentinal tubules. On the contrary, inactive or arrested caries lesions are minimally infected so that by only removing the bacterial plaque by toothbrushing can even ensure removing the superficial softened infected carious layer which can inhibit further lesion progression [24]. Thus, regardless of the activity of the caries lesion, it is crucial to keep the exposed surface free from any remnant or plaque to limit the lesion depth.

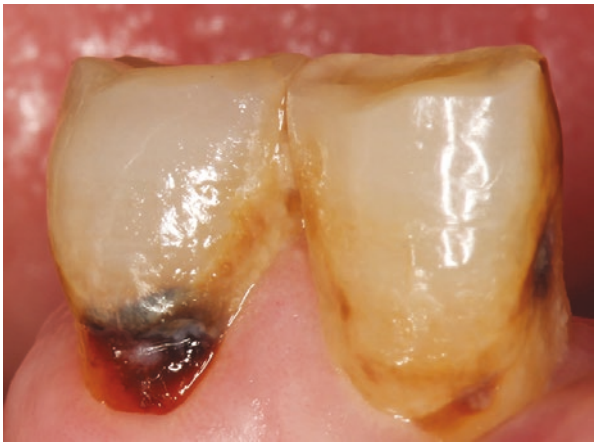


Fig. 7.6 Clinical view of an inactive root caries

Fig. 7.7 Clinical view of an inactive root caries

7.7 Recurrent Caries in Ageing Years

Especially in the dentate elderly, recurrent caries often arises reasons for replacement of the restorations. Recurrent caries adjacent to the existing restorations are generally located at the margins prone to the plaque stagnation. Although diagnosis of the recurrent caries does not differ from the primary caries, sometimes isolated locations may require some additional radiographic techniques. Bitewing radiographs can especially help to diagnose the lesions at the cervical sites of the approximate restorations. Furthermore, in relation to the complicated and hidden lesions at the cervical interproximal sites, it is quite challenging whether to decide if a recurrent caries is active or inactive.

Existing dental crowns play a significant role as reservoirs for cariogenic bacteria and increase the risk of recurrent caries in residual teeth [50]. Especially the imperfect margins, ditches and irregularities around amalgam restorations and discolouration around the composite restorations cannot be considered as judgement criteria for active lesion progression [51, 52]. On the contrary, dentin-invaded lesions requiring radiographic diagnosis may tend to be cavitated and even active exclusively when there is an extended exposed cervical area or a gingival pocket.

7.8 Managing the Caries Challenge in the Elderly

Prevention or management of caries can successfully be maintained if the independent elder individual is capable of the oral hygiene motivation and the required applications. Routine use of fluoridated toothpaste would undoubtedly be the first effective choice to primarily prevent the disease development, whereas other

fluoride products would aid the prolonged oral clearance even more effectively [19]. Novel prevention strategies including the calcium phosphate, nanocrystalline products and various remineralising agents can also be listed as non-invasive treatment choices that could prevent and reverse the caries process successfully [53].

There are several dispositional factors interfering through the caries management process for the root caries lesions in the elderly. Especially related to the existing restorations or the abutment teeth of the prosthesis in the dentate oral cavity, bacterial accumulation near the crown margins, difficulty of plaque control especially at the undercut areas, microleakage and/or potential secondary caries are all arising the need of using antimicrobial agents as a prophylactic regimen for the elderly [54]. Since mechanical retention potential for bacterial plaque at the exposed root surfaces is prominent for the cariogenic activity, surface modification can also be considered to maintain an easy-cleaning area at initial phases. For such cases as an additional professional application, effective use of ozone beside the remineralising agents in early root caries has been shown to be promising to reverse the lesion progress [55]. If the lesion activity can be reversed via the various preventive approaches, the arrested caries would become hard and shiny instead of the dull and porous surface or even brownish-black on the circumferential root surface [56].

Apart from the exposition of the tooth surfaces and the low salivary flow effecting the caries challenge, poor denture design or inappropriate marginal integrity of the existing crown restorations can increase the root caries prevalence [57]. Due to high salivary levels of mutans streptococci colonised around the restoration margins, even clinically 'intact' crowns may enhance the colonisation risk of cariogenic bacteria elevating the risk of root dentinal caries [54]. Thus, all these mentioned particularities of the potential bacterial colonisation near the crown margins, difficulty of plaque control, microleakage and/or potential secondary caries are all arising the need of using antimicrobial as a prophylactic regimen for the elderly [54]. The most common and effective antibacterial agent for dental use is chlorhexidine. Especially for the root caries prophylaxis, high bacterial content of either the plaque over the exposed root surfaces or the bacterial load of the oral cavity can be reduced by chlorhexidine use. Beside their routine use in mouth rinse form, chlorhexidine varnishes are also favoured for the inhibition of root caries development and further progression in the elderly [58]. Another benefit regarding the retention of the chlorhexidine on the root surface is that providing a reservoir effect may elevate the prolonged antibacterial role of the agent against the carious challenge in the elderly. In relation to all these characteristics and to suppress the bacteria-related infection disease, chlorhexidine varnishes should be included either in the cavitated or non-cavitated root caries lesion treatment planning.

An individually driven custom-based preventive care should be provided regarding the patient's risk of developing the disease. At the early stages of the caries lesions, primarily regulation of good dietary habits, appropriate oral hygiene and the daily use of topical fluoride by the high-fluoride toothpaste (5000 ppm F) and regular quarterly professionally applied chlorhexidine and SDF (38% silver diamine fluoride) varnishes in a combined application can be recommended to prevent the initiation and further decrease the progression by inactivating the root caries lesion in the elderly [44, 59, 60].

In addition to the FDA-approved primary caries prevention agents including fluoride, chlorhexidine and silver diamine fluoride varnishes, calcium- and phosphate-containing pastes or creams are also becoming promising choices when used in combination with fluoride in the remineralisation of early carious lesions in the initial stages especially when smooth surface caries are considered [61] (Figure).

Disabled or vulnerable elderly people often suffer from being dependant to caregivers to perform routine daily oral care constituting some limitations for a good oral health [62]. Regarding the frequency of application in the vulnerable elderly, one of the most effective choices is to apply 38% SDF professionally annually or NaF varnish (22,500 ppm) for every 3 months to prevent the root caries. In case professional application is not possible for daily use, high-fluoride content toothpastes (NaF 5000 ppm) and ACP-CCPACP pastes are recommended for an effective prevention regimen.

7.9 Nutrition

Nutrition is one of the most important components of health, functional independence and quality of life in elderly population. Non-communicable diseases determined as cardiovascular disease, hypertension, cancer and diabetes are the major causes for the mortality for the elders and are mostly caused by the imbalanced or inadequate nutrition. Thus, the contemporary trend of raising wellness and quality of life maintenance highlights the dietary regulations in conjunction with the traditional treatments to regulate the symptoms and progress of most diseases. Beside all the causative relations between the common risk factors of these diseases, nutrition has a potent effect on the oral health.

Elder patients often suffer from higher caries occurrence arising from medical complications and their related medications beside the above-mentioned caries risk factors. Beside inadequate nutritional uptake seen in the elderly, dental caries majorly reasoning the tooth loss can also be considered to effect the chewing function and consequently malnutrition. However, different medical conditions such as depression, eating disorders, dementia and malnutrition may also directly influence salivary balances and lead to an increase in the caries formation.

Nutrition may act as a determinant factor in most of the oral diseases. Saliva, nutritional status and oral health have been defined to interact with each other as a causative cycle, whereas the relation between poor nutritional status and reduced salivary flow rate in the elderly is much more evident [63].

Salivary flow rate reduces in malnourished elderly as a consequence of poor nutritional uptake, and this status can further affect the salivary glands and even can cause atrophy of the gland which makes the caries process inevitable [64]. Low salivary flow rate and low buffering capacity and decrease in pH induce the caries risk in the elderly especially by the retentive food debris remnants on the exposed tooth surfaces due to the decreased flow rate. Especially, overcooked or mashed high-energy dietary supplements with high amounts of sucrose in the elderly diets induce

ruining the retained tooth very easily [65]. Cariogenic bacteria in such situation may initiate dental caries by fermentation of the carbohydrates, and furthermore the process accelerates by the low total calcium levels attributing to the demineralisation process due to increased caries activity in case of malnutrition [66]. Salivary flow-inducing foods with low cariogenic increased alkaline content such as the dietaries with calcium, phosphate and casein will assist for an improved remineralisation and prevention.

As dental clinicians and a secondary wellness coach, our goal should be to maintain elder patients having adequate dentition with most possible appropriate salivary flow to chew more and consume higher amounts of fibre in their diets to improve their oral health and status of the general health.

7.10 Does the Restorative Treatment Plan Differ from the Adults?

The high prevalence of tooth loss due to caries has been the reflection of the fact that most of the caries-affected teeth had been extracted up to date. But today contemporary conservative approach requires to remove the least possible amount of carious tissue and favour even non- or minimally invasive treatment protocols using remineralising agents and adhesive solutions to maintain more sound tissue possible. Thus, by conserving the maximum tooth tissue and natural dentition, the quality of life of the elderly would be improved retarding or even avoiding the use of fixed prostheses [67]. Although the epidemiological data on oral health in the elderly is not very encouraging and there are imbalances among the countries and regions, the treatment approach should be including the novel minimally invasive and conservative restorative choices to improve the well-being level [68]. Differing from the adult population, older adults often have the increased caries risk arising from cariogenic diets and xerostomia mostly raised from the multiple medication and further reduced manual dexterity [69].

Caries risk assessment would help the practitioner determine the frequency of routine radiographs, level of preventative care required and when to restore the carious lesions [70]. Most of the dentate older patients present with numerous large restorations due to caries lesions but probably resulting from repeated replacements throughout the restorative spiral [70]. Thus it is gaining more importance to provide individual caries risk assessment and effective prophylaxis strategies through the conservative approach to keep the teeth sound or minimally restored.

Restorative caries treatment planning of the elder patients should be majorly in conjunction with the evaluation and assessment of the related risk factors. As the history of medical conditions and medication plays a major role on the caries risk progression, the diet history and habits have to be elicited too. Being the most prominent indicator of the elevated caries risk factors, salivary parameters such as volume and buffering capacity should also be taken into account.

Since all these mentioned parameters have strong evident role on the development of the dynamic caries progression, the treatment planning can be based on two dependent phases: restorative phase and the preventive maintenance phase which were mentioned earlier in the present chapter.

7.11 Restorative Treatment Options for Root Caries

Compared to the restorative techniques in younger patients, the restoration alternatives do not majorly differ for the caries lesions of the elderly. Since there are many advantages of the direct adhesive restorations performed for the caries lesions such as being an economic option beside capability of repair or replacement, the main consideration should be to select an adequate restorative material choice to maintain the survival against the high caries activity. All these determinants address direct treatment choices to be the primary choice unless the cavity configurations are complicated [71, 72]. Owing to the time required for an indirect restoration that usually takes multiple sessions, treatment schedule may constitute obstacle especially for the functionally dependent patients.

7.11.1 Adhesive Restorative Materials

Today with the latest technologic advances and material variability in the evolving adhesive dentistry, there are numerous material choices to adhere the dental substrate. Resin-based materials including composites, composers, resin-based glass ionomer materials and CAD-CAM resin-based block materials enable clinician to drive the best available treatment planning for the hard tissue loss cases.

Contemporary adhesive materials have a good potential to bond the enamel and dentin, and reliable long-term survival rates for so many clinical conditions have been clearly shown in the literature. However considering bonding durability through the ageing simulations, controversial results have been demonstrated either bonding deficiency or considerable deterioration in bond strength values after ageing for both self-etch and etch-rinse adhesive strategies [73]. Adhesive-tooth interfaces are both prone to mechanical-chemical degradations in the oral cavity. Principally not only the masticatory forces but also the thermo-mechanical changes that occurred in the oral cavity largely compromise the bonding strength of the resin-based moreover polymerising adhesive materials [74]. Considering the physiological characteristic of the remaining dentin tissue of the root caries lesions, both the moisture content and organic components can jeopardise the adhesive bonding capacity [75]. A worse scenario would be if the bonding substrate is the caries-affected cervical dentin. In such cases, challenging adhesive bonding can occur between the adhesive agent and softer dentin with mineral deposits in its tubular structure which means insufficient resin tag formation through a weak hybrid layer [76].

Most of the contemporary resin-based restorative materials have technique sensitivity due to their applications on the dental tissues. Likewise, oral cavity

dynamics and the physiologic ageing of the dental tissues may encounter this integrity [77]. However, studies also showed that the aged dentin tissue did not lower the bonding strength since hybrid layer quality is more efficient to reach higher adhesion effectiveness [76]. Through all these critical evaluations regarding the root caries, the most hazardous ambient is that to bond the wet dentin which can interfere with moisture tolerance of the adhesive. Novel adhesive agents so-called universal bondings are launched to be less technique sensitive and moisture tolerant. Promising results have been published by the in vitro and in vivo studies to encourage clinicians performing long-term successful restorations with better outcomes [78, 79].

Taking into account the basis of the bacteriological aetiology of the root caries and consequently the recurrent caries odds especially in the high-caries-risk group, some attempts have been elongated through the recent years. A self-etching monomer-derived antibacterial component MDBP has been found to inhibit the progression of root surface caries in vitro through its antimicrobial activity and bonding capacity of the demineralised dentin [80]. MDPB-impregnated adhesive agent has also been presented to be strongly effective against *Actinomyces* which is often associated with root caries [81].

Not only the bacterial challenges but also the durability of the bond strength constitutes predictive results on the bonding performance especially the substrate-sensitive cases. CHX gluconate is nowadays known via its MMPs inviting activities in addition to its legendary antimicrobial property. Thus favouring both advantages today, there are promising evidences that CHX application would counteract the age-associated bonding destructions exerted by the adhesive agents [82].

Despite the extreme developments in the monomer chemistry and even the latest adhesive material advances, most of the current resin-based restorative materials include some deficiencies and deprived bonding efficiencies for the root caries restorations regarding their substantial characteristics and isolation problems. Glass ionomer materials can be both used for root surface protection and as conservative restorative material especially in the caries management of the high-caries individuals due to its chemical-binding characteristics and fluoride release potential. Sealing the dentin surface effectively, adhesion strategy of GI materials relies on the chemical adhesion to the mineralised dentin via calcium bonds [83].

Polyacid-modified resin composites so-called compomer and giomer materials have also the advantage of fluoride release. Although the fluoride release is less than that of glass ionomers, considering their aesthetic characteristic, they are used in the root caries restorations with an acceptable success [84]. Giomers are one of the latest adhesive materials hybridised by the glass ionomer and composite resin carrying the benefits of both as the aesthetic and physical characteristics of the composites and the fluoride-releasing and fluoride-recharging property of the glass ionomers [85]. The unique hybrid characteristics of giomers can be an option for the root caries restorations for their elevated fluoride release and durability (Fig. 7.8).

Fig. 7.8 Root caries lesion restored with resin-modified glass ionomer restorative

7.11.2 Atraumatic Restorative Treatment (ART) in Elderly

Integrating the minimally invasive dentistry in the contemporary clinical practice has emerged many new methods for the cavity preparations and suitable dental materials to apply, respectively [86]. The the main objective of the atraumatic restorative treatment lies on the caries treatment alternative for those who are in underserved communities where oral health services access are rarely available [87]. However, it has been a promising approach for elder adults having limited access to routine dental care and considered at a higher risk of developing caries [88]. Especially vulnerable elder people with physical disabilities majorly have difficulties in plaque control and extended dental treatment collaborations [89].

According to the minimally invasive and ART approach as the first attempt for arresting dental caries, high-fluoride preparations are recommended. For the restorative ART interventions, caries lesion is usually removed by hand instruments and consequently restored by a glass ionomer-based restorative or cement [90]. Either for reducing the marginal integrity problem and caries development at the restoration margins or for an improved effective carious dentin removal, chemomechanical methods have been considered for the ART [91]. Restorative treatment modalities for the root caries have some alternative preparation techniques, special instrumentation and material choices due to the challenging requirements of the lesion characteristics. Most lesions can be removed and prepared by rotary instruments or in conjunction with the hand instruments, whereas the softened carious dentin can be removed by hand instrumentation. Hand instrumentation may work for most of the softened infected root caries lesions as mentioned in ART approach. The advantage of a more minimally invasive intervention specialty of ART, not only the vulnerable patients with mobility issues but also healthy elder patients, may benefit such conservative and simple techniques.

7.11.3 Repair

Repair of the existing restorations can be considered to avoid further tooth substance loss or more invasive complicated requirement restoration within the conservative approach [92]. In the elderly, most of the carious lesions progress secondarily rather than growing primarily. Thus within today's minimally invasive treatment approach, repairs are becoming more favourable in the contemporary dental practice [93]. Since the commonly used restorative material in the previous century and the recent years has been amalgam, it could be reasonable that the 93% of the recurrent caries detected are associated with amalgam occurring at the gingivoproximal sites of class II restorations or crowns [94]. Clinicians may benefit from the adhesive and particularly fluoride-releasing materials for advanced and conservative repair applications.

How to assess the *caries risk* in the elderly?
Ask about:
- Caries experience
- Salivary flow
- Oral hygiene status
- Diet
- Exposure to fluoride
- Periodontal disease risk level or status

Root caries risk determinants:
- Unique caries type of the elderly
- Associated with exposed root surfaces due to gingival attachment loss
- Xerostomia (physiological, systemic disease complication or polymedication induced)
- Cariogenic diet
- Old restorations with irregular marginals
- Retentive partial dentures

Caries prevention dynamics for the elderly
- Promoting salivary flow
- Adequate mechanical plaque removal
- Low cariogenic diet
- Good oral hygiene
- Reduced cariogenic/pathogenic bacterial-antimicrobial use
- Increased exposure to fluoride
- Use of additional remineralising agents

More Teeth, More dental problems, More caries

3I for dentate elderly

- Ideal oral hygiene
  - Bacterial plaque removal
  - Bacterial control
- Ideal salivary flow
  - Mechanic stimulation (chewing and food intake induction)
  - Salivary substitutes
  - Adequate water drinking
  - Reducing the mucosal tension due to the dryness
- Ideal restoration/prosthesis integrity
  - Proper fitting
  - Hygienic margins

Minimal invasive treatment concept for root caries in the elderly

-Major domains-

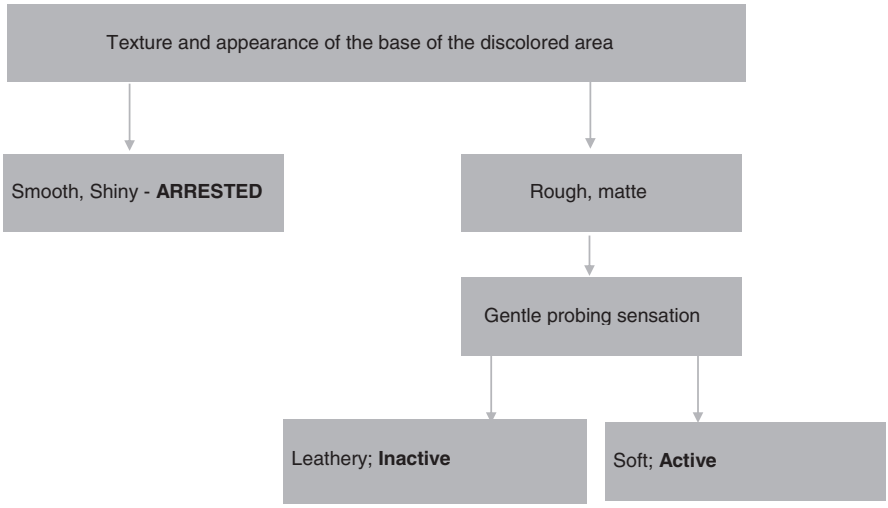
- Early detection
- Prevention through fluoride and remineralising agents
- Bacterial control—CHX varnish
- Less intervention—more caries preventive measures
- Favour ART approach (hand excavation, chemical removal technique, adhesive materials)
- Repair rather than replacement

FDA-approved main caries prevention agents:

- Fluoride varnish
- Chlorhexidine varnish
- Silver nitrate/silver diamine fluoride (SDF)

Arrested/inactive caries lesion; non-cavitated Glossy white-yellow • Prophylactic intervention • F varnish-gel-toothpaste • CPP-ACP crème	*Active caries lesion; non-caveated* Chalky-irregular plaque accumulated surface • High concentrated F therapy-varnish/gel • F toothpaste (5000 ppm) • CHX varnish • SDF varnish • ACP, CPP-ACP
Arrested and slight cavitated caries lesion Glossy white-yellow • Prophylactic intervention • F varnish-gel-toothpaste • CPP-ACP crème • F-releasing materials were required	*Active and cavitated caries lesion* Light to dark brown leathery consistency Restoration F-releasing materials recommended

Restorative material selection criteria:
Size of the lesion
Aesthetics
Patient oral health motivation
Parafunctional or behavioural habits
Clinical performance of the material due to special conditions
Isolation and working area conditions
Operator skill



ICDAS decision tree for root caries activity

An ideal root caries restorative material requirements:
1. Acceptable adhesion to cervical root dentin
2. Adequate bonding strength for resistance and occlusal stresses
3. Cariostatic properties to prevent secondary caries
4. Easy to apply and manipulate
5. Less technique sensitivity
6. Resistant to dry mouth conditions
7. Good wear and abrasion resistance
8. Good polishability
9. Repairable
10. Biocompatible
11. Long-lasting survival
12. Acceptable aesthetic
13. Economic

An ideal root caries restorative material needs to require:

1. Acceptable adhesion to root dentin
2. Good flexural strength for resistance and high bond strength for tensile and compressive occlusal stresses
3. Cariostatic properties to prevent secondary caries
4. Easy to manipulate and apply
5. Technique-sensitive-free regarding moisture contamination
6. Less technique-sensitive steps
7. Short setting time
8. Resistant to dry mouth conditions
9. Good wear and abrasion resistance
10. Biocompatible
11. Long-lasting survival
12. Acceptable aesthetic
13. Economic

1. Acceptable Adhesion to Root Dentin
2. Good flexural strength for resistance and high bond strength for tensile and compressive occlusal stresses
3. Cariostatic properties to prevent secondary caries
4. Easy to manipulate and apply
5. Technique-sensitive-free regarding moisture contamination
6. Less technique-sensitive steps
7. Short setting time
8. Resistant to dry mouth conditions
9. Good wear and abrasion resistance
10. Biocompatible
11. Long-lasting survival
12. Acceptable aesthetic
13. Economic

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Minimalistic Approach for Conservative Restorations

8

Michel Goldberg

Abstract

The traditional restorative treatment of a carious decay implies traumatic preparation. Cleaning the softened demineralized dentin using manual or mechanical methods leads to geometrical preparation of cavities displaying flat surfaces (cervical and/or pulpal), at right angles from each other. Taking advantage from the geometry of the cavity, horizontal and plane surfaces contribute to preparation of cavities according to GV. Black's principles (1908). Ultimately, the cavity is filled with a biocompatible material. All these successive steps refer to old concepts, as they were developed in textbook or in manuals published in the previous century.

The recent evolution of the preparation of cavities, adhesive properties of resin-containing cements or glass ionomers, and the biological properties of adhesive-containing materials leads to improve adhesion and promote atraumatic restorative treatment (ART). This is based on clinical decisions linked to caries risk assessment (CRA). The aims of minimal invasive therapy are oriented toward the reduction or evolution of carious lesion. These methods are focusing on the enhancement of methods of prevention, keeping the teeth functional for the whole life. These methods constitutes a whole set of investigations, avoiding unnecessary preventive measurements. Minimal approaches associate enamel and dentine carious lesions, linking the various stages of the lesion to the depth of the dentin decay.

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Initial enamel caries: The initial enamel lesions are barely visible (white spots) and generally undetectable. Fissure lesions, white spots located on enamel surfaces, and cervical areas, covered by dental plaque contribute to the formation of the initial lesions (Fig. 8.1). Arrested white spots become brown spots, under the influence of bacterial pigments underlining the enamel lesions. Under an apparently well-mineralized surface zone, the body of the lesion increases in thickness, and gains pigmentations. A cavity is gradually formed between the outer surface zone and the inner dark and/or translucent borders (Fig. 8.2). Tubules connect the outer surface with the inner lesion, linking the enamel surface with a zone implicating that the lesion is located more centrally. This is the place where demineralization is mostly occurring.

Enamel carious lesion remains invisible, starting from the very early beginning and transformed obviously into pathologic lesions. Caries crosses the whole thickness of the enamel layer, associating the formation of tubules, Retzius striae, and sub-surface alterations. At later stages of the carious lesion, lesions develop in the sub-surface, before any evidence for cavitation can be detected [1, 2].

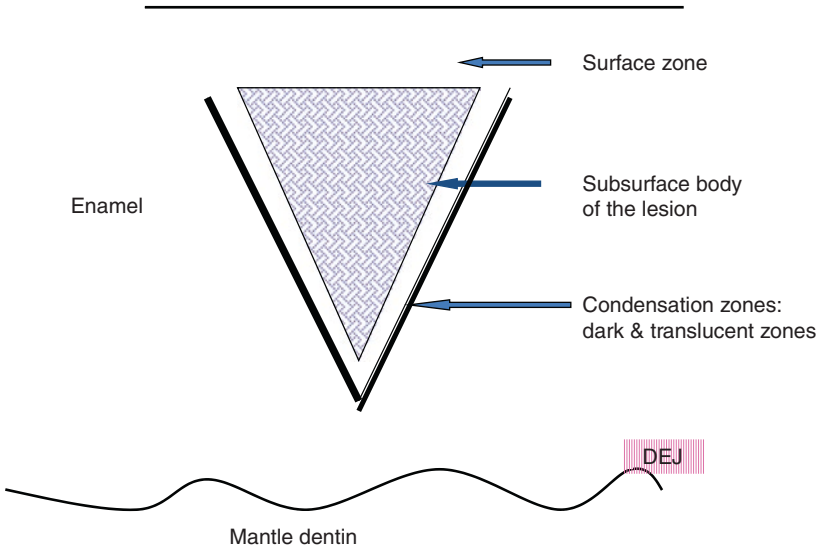

Fig. 8.1 Initial enamel carious lesion including the different zones

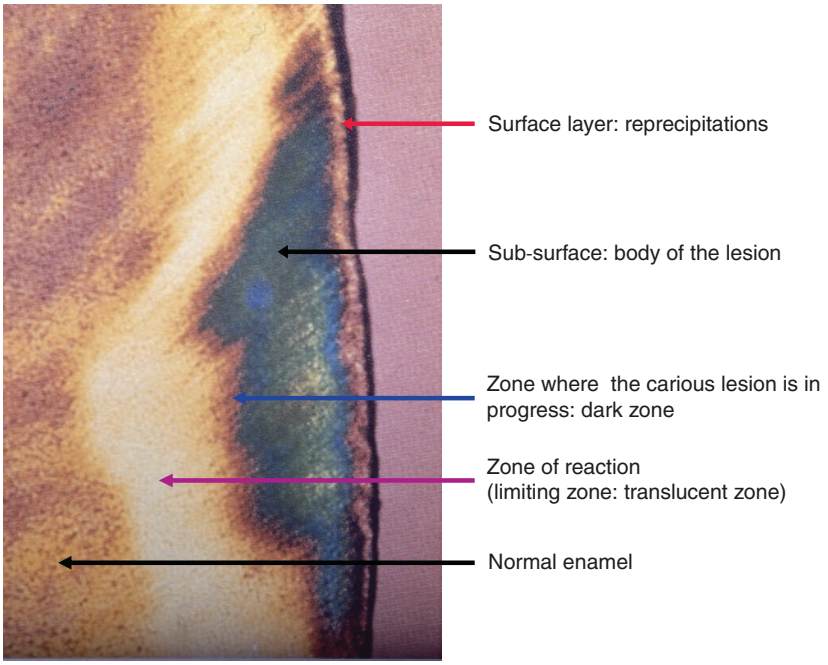

Fig. 8.2 Section of a white spot lesion: initial enamel carious lesion including the different zones

The carious lesion displays a triangular shape, oriented toward the dentino-enamel junction (DEJ), with a sharp summit (arrowhead) reaching the DEJ. Then, the carious decay spread along the DEJ, enlarging this junction, and destructing the outer surface of the mantle dentine. The enlarged DEJ favor bacterial penetration, and support dissociation between the enamel layer and mantle dentine.

Superficial carious dentin lesion: Visible cavitation or carious lesion into dentin becomes visible on radiographs. They are correlated with frequent meal snack of sugars/cooked starch, inadequate saliva flow, deep caries and fissures or developmental defects. They are negatively correlated with antibacterial therapy, interproximal enamel lesions or radiolucencies [3].

Prevention implies factors inhibiting the development and limiting the volume of the carious lesion. Located at the surface of dentin, two layers have been actually identified in dentin carious lesion (Fig. 8.3):

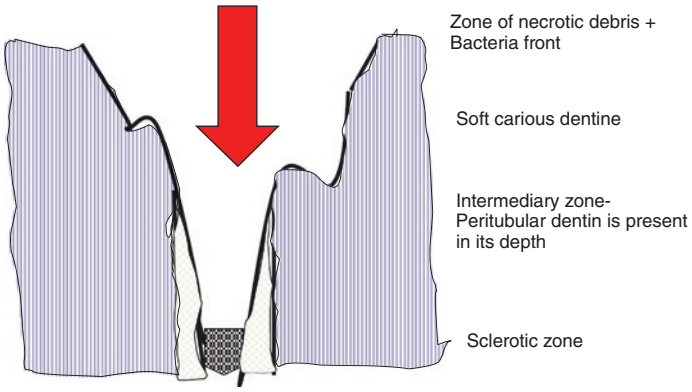

Fig. 8.3 Initial carious lesion in dentin: schematic representation of the different carious layers (necrotic debris, soft carious dentin, intermediary zone: a mixture of soft carious dentin and empty tubules, above the sclerotic zone

1. An *infected* layer, where the DEJ is enlarged, occupied by colonies of bacteria invading the junction between enamel and dentine, and degrading the superficial mantle dentine. Dentine tubules are enlarged, bended and filled by bacteria. At the DEJ, an infected layer is located within the enlarged superficial dentin junction.
2. Beneath this outer zone, an *affected* zone is found. The mantle dentin displays reduced thickness. In the affected zone, globular and interglobular spaces are altered. Tiny tubules are filled with bacteria, whereas enlarged interglobular spaces do not contain bacterial colonies. Intertubular spaces are unfilled and don't contain the dentine-specific non-collagenous proteins. In contrast, proteoglycans and non-specific molecules accumulate in interglobular spaces.

It is quite clear that minimally invasive therapy keeping the lesion within a small size, contribute to limits the growth of the lesion. Fluoride may be used in close association with toothpastes, varnishes and drinking water. Fluorides prevent the growth of the carious lesion. Prevention also allows identifying risk factors. Clearly, prevention implies four successive steps [4].

Primary prevention may concern the family as a whole. Secondary prevention has to be considered both at a population and individual levels. Tertiary prevention aim to prevent further complications and integrate treatment failures. Quaternary prevention helps to control the economic and human costs.

Education, tooth brushing, dietary counseling are parts of protective factors including the biological and therapeutic components preventing early colonization and including tooth brushing, mouthwashes, varnish gels. Non-fluoridated agents, such as xylitol, contribute efficiently to prevention. Chlorhexidin, CPP-ACP may also be implicated in a series of tools that plays role in prevention.

From the initial carious enamel lesion to the development of coronal dentin lesion, structurally, the mantle dentin in the crown, and Hopewell-Smith translucent zone in the root, the carious lesion increase in depth. After a superficial non-carious dentine, a degradation zone is found, containing food debris, residual vegetal and animal, which are unable to remineralize. The subjacent zone is demineralized, containing enlarged tubules, peritubular dentine being eliminated during the first steps of the carious attack. Tubules contain bacteria, non-apatitic precipitations, calcium phosphate, and other re-precipitations, closing the lumen of tubules. Infected and affected tubules contribute to bacterial invasion. Peritubular dentine gradually re-appears. The subjacent layer is formed by sclerotic dentin. In the transparent zone of dentine, sclerotic dentine is located at the surface of a densely mineralized layer. Beneath this layer, dentine displays a "normal" appearance. The deepest part of dentin has a variable thickness, covering a residual layer, over the dental pulp. Odontoblasts, the subjacent sub-odontoblastic layer (also named the so-called Hoehl's layer), and the central pulp constitute the inner parts of the dental pulp.

8.1 The Different Layers of the Carious Lesion

The control of caries implies that 55% is located in the outer third of dentin, 10% in the middle third and 5% in the inner third of dentin. Oral streptococcal microorganisms promote caries. Three phases have been reported in the published literature:

1. Initial interaction between the dental plaque and the tooth surface, mediated by adhesins.
2. Accumulation of bacteria in dental biofilm and production of glucose and glucanes by the bacterial enzyme glycosyl transferase.
3. The formation of lactic acid.

Anatomically, the lesion vary between E0 (no lesion), E1 lesion located in the outer half of enamel, E2 lesion developing mainly in the outer half of enamel, D1 lesion arising in the outer third of dentin, D2 (middle third of dentin) and D3 in the inner third of dentin. There is a variety of approaches for minimally invasive treatment (Fig. 8.4). The control of the disease implies replacement therapy and caries vaccine, allowing the control of caries.

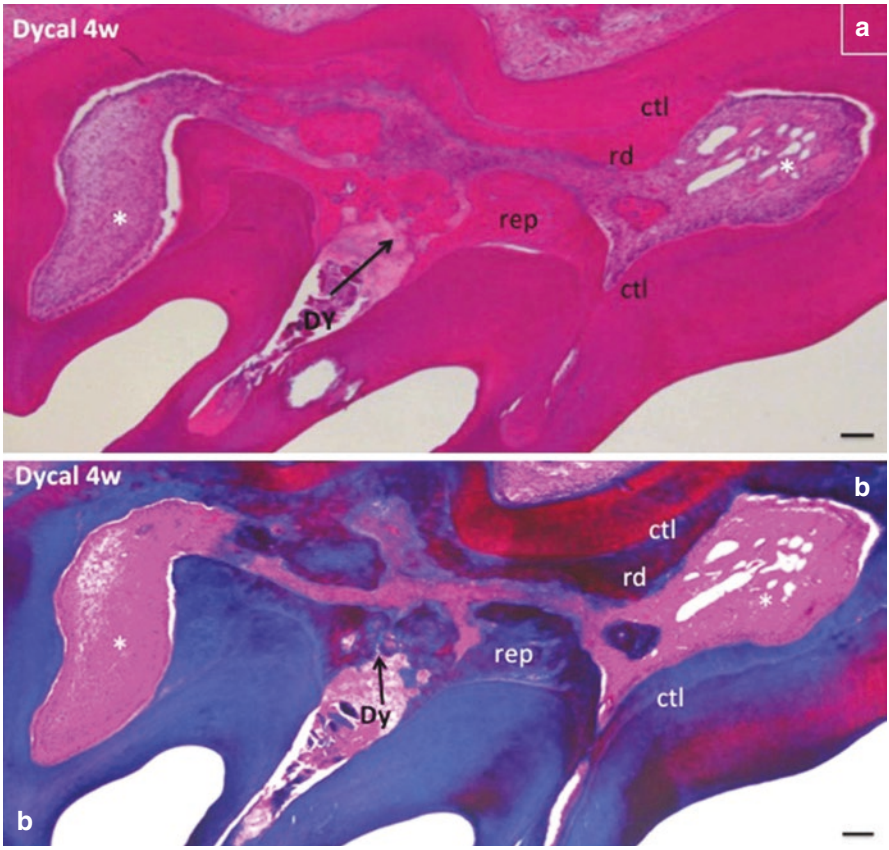

Fig. 8.4 *rd* reactionary dentin, and rep: reparative dentin after pulp capping with Dycal after 4 weeks. CTI is the calciotraumatic line at the junction between secondary and tertiary dentin

8.2 Principles and Objectives of Minimal Intervention Dentistry

MID implies a modern medical approach, art and science of restoring teeth altered by dental caries, prevention of disease and its early interception.

Minimal caries excavation strategies depend on patient's caries risk, lesion-pulp proximity and vitality, the extent of remaining supra-gingival tooth structure and clinical factors. MID is promoted by the management of caries, caries risk assessments, early prevention and interception of the disease [5].

Mechanisms	Dental substrate affected	Tooth-cutting technology
Mechanical, rotary	Sound and carious enamel and dentine	
Mechanical non-rotary	Sound or carious enamel and dentine	Hand instruments, air- abrasion, air-cutting, ultrasonic, sono-abrasion
Chemomechanical	Carious dentine	Caridex, Carisolve, Papacaries gel, pepsin-based solution or gel
Photo-ablation		Lasers
Other bacteria		Photoactive disinfection, ozone

8.3 The Development of Minimal Invasive Treatment (MIT)

MIT implies four different points:

1. Recognition of potential caries risk, saliva testing and plaque diagnostic tests.
2. Reduction of carious factors eliminates or minimizes caries risk factors by increasing the pH of the oral environment.
3. Arrest or reverse incipient lesions, using appropriate topical agent including fluorides and casein phosphopeptides - amorphous calcium phosphates.
4. Repair retaining tooth structure (Fig. 8.4: *rd* reactionary dentine, *rep* reparative dentine; *ctl* calciotraumatic line).

International Caries Detection and Assessment System allow a scoring system for enamel lesions. Score 0 is related to sound enamel. Early caries allows to score the first visual changes in enamel (score 1–2). The established caries ascertain a localized enamel breakdown (score 3–4), follows by a lesion in the underlying dentine. The shadow score goes from 4 to 6, and the severe caries leaves distinct to extensive lesion [6].

8.4 Traditional Treatments: Black's Concepts

For many years, following Black's classification, mechanical rules were applied to teeth preparations. Small areas of subsurface demineralization were formed beneath the superficial dental plaque. Drilling creates large cavities prepared according to geometrical requirements. This is needed imperatively for the stabilization of cavities, prophylactic extension, and preparation of flat or perpendicular walls. *Mutans streptococci*, *S. sobrinus* and *S. lactobacilli* produce lactic acid and appear in the dental plaque before any caries could be clinically observed. Recent spectacular evolutions of dental materials, namely the adhesive properties of resins and glass

ionomers, have revised the general concept. As a consequence, these changes are leading to Minimal Intervention Dentistry. However, different available concepts are nowadays determining the rules of **M**inimal **A**dhesive **R**estorations or on what is sustaining the preventive concepts implicated in the treatment of carious diseases.

Dental caries are bacterially based diseases. Bacteria are responsible for acid production. Dietary fermentable carbohydrates contribute to the dissolution of enamel hydroxyapatite. Due to fluoride intake or to crystal remineralization, the prevention or development of dental caries constitutes a major step for dental caries prevention. Since the pioneer work of GV Black on operative dentistry [7], carious lesions are anatomically classified in five classes. The shape and preparation of cavities are related to the anatomical localization of the lesion.

We can establish a firm diagnosis of the carious decay, allowing determining if prevention will be the predominant non-treatment (non-operative/preventive) or if we are following the traditional rules of conservative/restorative dentistry. Indeed, the lesion may need to be cured, following conventional methods routinely used in operative dentistry. The two options may be alternatively used, depending the depth and evolution of the carious lesion.

Usual caries therapies imply mechanical (curettes, excavators, or hand instruments) or drilling preparations (low or high speed). Beneath the proximal contact area, enamel lesions expand. Class I concerns exclusively occlusal fissures and infiltrated carious lesions. Thin diamond burs enlarge fissures, and open simultaneously the lesions located on the two outer enamel surfaces. These mechanical or drilling preparations allow enlargement of fissures and sealing lesions with resin-containing material or glass ionomer-cement occlusal cavities, releasing fluorides. Class II develops in the proximal aspects of molars and involves also occlusal junctions. Class III interferes with the proximal surfaces of incisors and canines. Class IV comprises the proximal surfaces associated with occlusal destructions. Class V lesions are mostly located in the cervical zone. Class V develops at the collar of teeth, at the junction between enamel, cementum and dentin. In this particular zone, the dental plaque accumulates, mineralizes and contributes to demineralization of the cervical collar including the region where enamel covers cementum. Enamel is overlapping cementum, and/or is located where enamel displays a gap between the superficial dentin, and the cementum/enamel junction.

Some rules were adopted during the preparation of cavities, suppressing enamel overhangs, and restraining easy access to the cavities. The limits of cavities extend up to zones where the cleaning and hygiene of the tooth surfaces may be controlled. They follow architectural rules where only solid dental walls are kept. For decades, these mechanical/biological considerations were mostly related to the filling of cavities lesions, using gold foil, casted inlays, and silver amalgam restorations. Nowadays, adhesive composite resins and glass ionomers have modified the overall concepts, and Black's rules are no more considered as mandatory. It is considered that preventing early colonization of enamel by bacteria is a general rule in minimalistic dentistry.

8.5 Infiltration with Resin Materials, New Concepts for the Treatment of Carious Lesions [8]

Following the evolution of the concept of cavities preparation, the concept of Minimal Intervention shifted from Black's concepts and became "filling without drilling". It favors the penetration of resin into the very small pores of the enamel lesion. Pores size in mature enamel range between 2 and 10 nm between the crystals. The periphery of prisms is up to a micron or so in width. The pore zone appears to be in the range of 0.1–1%.

Fissure may be sealed. Penetration/infiltration is limited to the enamel surface, and to a 4–10 μm layer. Penetration of resin is quite limited, but obviously the surface zone is an effective barrier to infiltration.

The infiltration material should be hydrophilic and finally polymerized. Hydrophilic or water-based materials are desirable. The material should be surface active and possess a low-viscosity. This would permit easier access to the lesion, filling extremely small pores sites, and ideally should be a surface-active material. The material should be bactericidal or at least bacteriostatic. The material should be tolerated by the dentin/pulp complex and also acceptable by adjacent oral tissues. The material should be self-polymerizing. It should present a mechanical support. Occlusion of lesion pores is desirable or mandatory, and in any case cosmetically acceptable. The application should be easy, and at low cost.

A number of resins have been used for infiltration: e.g. Resorcinol-Formaldehyde; Methacrylate-based Resins. They have been used successfully. Scotchbond, Gluma 2000, All-Bond 2 and Amalgambond plus allow deep penetration in the pores of the lesion. Such resins tend to become viscous. The physical properties can be selected. They improve the penetration into the small pores of the lesion.

All the work concerning infiltration of caries lesions indicate that the current materials are a prerequisite for a necessary successful infiltration. Resin appears to occupy the body of the enamel prisms. It opens possibilities that self-infiltration treatments are a possibility in the minimal treatment of carious decay.

8.6 Engineering a Dental Pulp: Minimalistic Approaches for Conservative Restorations

A variety of stem cells are found in the dental pulp. Embryonic, post-natal and adult, monopotent or totipotent, immortalized and induced pluripotent cell lines have been identified and they were used specifically as tools for engineering the dental pulp [9, 10]. During embryogenesis, reciprocal interactions between the oral epithelium and neural crest-derived ectomesenchyme lead to the initial formation of dental placode and guide through sequential morphogenetic events the building of a tooth. Tooth patterning also involves a spatio-temporal control of signaling pathways that sustain interdependent inductive interactions and signal exchanges between epithelial and mesenchymal cells. Ectomesenchymal cells give rise to

odontoblasts, which synthesize the dentin extracellular matrix (ECM), and guide the terminal differentiation of dental pulp cells [11].

In 2004, murine tooth structures were successfully bioengineered after implantation of dissociated rat tooth bud cells-seeded scaffolds in ectopic site and/or after combination of non-dental mesenchymal cells with embryonic oral epithelium. Recombining the tissues lining the oral stomodeum and the mesenchyme seems to mimic developmental events and leads to the formation of tooth structures with a similar morphology as a natural tooth, when combined with a suitable scaffold. Recombining the tissues lining the oral stomodeum and the mesenchyme specifically located within the first branchial arch, stem cells-based murine teeth were successfully bioengineered. Some authors put emphasis on the importance of the epithelial cell layer lining the stomodeum, whereas others were focusing mostly on the effectiveness of the condensing connective tissue as a key factor of success. Regeneration of an organ or a tooth involves cells expressing a complex cascade of genes, structural molecules, transcription and growth factors, associated with specific scaffolds [12].

In the dental pulp, stem cells are scarce. These unique cells endowed the dual capacities to ensure self-renewing and generate the differentiated cells types requiring specialized functions. They are implicated in the repair and regeneration of deficient tissues and organs [13, 14].

Initially, embryonic stem cells acquire the final cell phenotype and become secretory cells, a process followed by the mineralization of the tissue. The major difficulties focus on how to obtain functional stem cells. It is quite unrealistic to use stem cells located within the embryonic blastula, even amplified by cell culture. More realistic, hematopoietic progenitor cells are present in umbilical cord blood. Placental blood (PB), previously considered as waste product, constitutes nowadays an alternative source of hematopoietic stem cells for bone marrow reconstitution.

8.7 The Origin of Post-Natal and Adult Stem Cells (ASCs)

Initially, embryonic stem cells (ECSs) are totipotent cells, clonogenic, and capable of self-renewal. At later stages, adult stem cells have been shown to undergo asymmetric cell division, one daughter remaining in the stem cell compartment, whereas the other daughter cell undergoing further cell division gives rise to differentiated cells. They may differentiate into each of the more than 200 cell types of the adult body. Stem cells are also present in adult organism, maintaining tissue homeostasis and ensuring tissue repair after a lesion. Postnatal or adult stem cells (ASCs) are no more totipotent. They divide and differentiate into diverse specialized cell types. They have been used extensively in the field of repair and regeneration. Stem cells display multilineage differentiation potential. When they are activated, they are maintaining the capacity to self-renewal and “stemness”.

After isolation, expansion, and characterization of the multipotent human mesenchymal stem cells, 5–7 days after initial plating, committed progenitor cells displaying a restricted potential were evaluated by Pittenger et al. [15] as being about 0.001–0.01% of the grand total of cells. According to Sloan and Waddington [16], the subset of undifferentiated cells can represent in the dental pulp as little as 1% of the total cell population. Side population (SP) cells in human deciduous dental pulp were evaluated as 2% of the total cells. According to Kenmotsu et al. [17] approximately 0.40% of the pulp cells may be stem cells or side population when they are found in young rats, whereas only 0.11% is found in old rats.

Pluripotent adult stem cells display a restricted lineage potential. Interestingly, mesenchymal stem cells (MSCs) derived from bone marrow display an odontogenic potential. Co-culture of these non-dental stem cells with oral epithelial cells derived from embryos renders the MSCs able to express odontogenic genes such as Pax9, Msx1, Lhx7, DMP1, and DSPP. The transplantation of such cell mixture in murine renal capsule resulted in the formation of tooth-like structures. The MSCs may thus represent an autologous source of cells for tooth regenerative research. Alpha-SMA-expressing perivascular cells represent dental pulp progenitors in vivo, namely during reparative dentinogenesis [18].

8.8 Diversity of Adult Dental SC

Since 2000, several adult stem cells have been identified in tooth. Many type of dental stem cells have been recognized in this context. Dental pulp stem cells (DPSCs) are derived from the pulp of the human permanent third molar. Other cells have been isolated from exfoliated deciduous teeth (SHED). Apical papilla stem cells (SCAPs) cells are derived from the apical part of the papilla of growing tooth roots. In vitro, SCAP have been shown to exhibit dentinogenic and adipogenic properties. In addition, they also express neuronal markers. We have reported that in the open apical papilla, some cells have the capacity to multiply, as shown by the Proliferating Cell Nuclear Antigen immunostaining (PCNA labeling). They migrate from the central part of the pulp to the lateral sub-odontoblastic boundaries. Then, they slide from the root toward the coronal part of the pulp where they underwent terminal differentiation [14].

At the chair side, adult stem cells are easily accessible from extracted wisdom molars or from their surrounding tissues. All these heterogeneous cell populations have the ability to differentiate in vitro into odontoblasts, osteoblasts and adipocytes, and into neuron-like cells. A few stem cells are also found in the periodontal ligament (PDLCs) and dental follicle (DFSCs) (Table 8.1).

Hence, instead direct pulp capping by implanting in the coronal pulp calcium hydroxide in a pulp exposure, or inserting a few pulp stem cells, apical progenitor cells may contribute to pulp regeneration. Apparently stem cells are not easily

Table 8.1 shows the origin of adult postnatal stem cells

Stem cells permanently present in the adult tooth:
– Dental pulp stem cells isolated from the pulp of permanent teeth
– Exfoliated deciduous teeth stem cells and immature dental stem cells from deciduous teeth
– Apical papilla stem cells
Stem cells present in periodontal tissues:
– Periodontal ligament stem cells
– Dental follicle stem cells, differentiating in odontoblast-like cells or endothelial cells
SM taking origin from other tissues
– Induced pluripotent stem cells
– Hematopoietic stem cells
– Neuronal stem cells

Sonoyama et al. [19]; Huang et al. [20]; Honda et al. [21]; Silvério et al. [22]; Hynes et al. [23]; Vidovic et al. [18]

accessible, they are still difficult to detect and isolate. These cells are rare, and in addition, they may de-differentiate after a limited number of passages.

8.9 Induced Pluripotent Cell Lines

In this context, the strategy involving Induced Pluripotent Cell Lines (IPs) was developed, expecting to obtain large clusters of stem cells and cell collections allowing easier implantation within the dental pulp [23]. By over-expressing some transcription factors, including Oct3/4, Sox2, Nanog, Klf4, c-Myc, and Lin28, it was shown that adult somatic cells may be reprogramed, even if they were previously differentiated. The iPS can de-differentiate, and further re-differentiate according to the site where the cells are implanted. It appears that any adult differentiated cell has the potential to step back to an embryonic stage. Many dental cells such as DPSCs, exfoliated deciduous teeth stem cells, SCAPs, periodontal ligament and gingival fibroblasts have been used to generate iPS. These cells provide a promising unlimited source of autologous cells for regenerative dentistry. However, it comes out that after preliminary differentiation, iPS does not keep a stable terminal phenotype.

8.10 Immortalized Cell Lines

Another strategy was used to establish immortalized and stable cell lines. A few were obtained either after spontaneous transformation, but more were got from virally transformed cloned 3 T6 cell lines. Immortalized bovine dental papilla cells, or viral transformation of MO6-G3 odontoblast cells were also used successfully [24]. Cells immortalized by telomerase as well as cells modified by human telomerase transcriptase (hHTERT) gene were exploited in the course of such investigations [25]. These cell lines were employed to characterize dental pulp progenitors and elucidate the molecular and cellular mechanisms governing their differentiation. In our laboratory, we have obtained clonal cell lines from tooth germs of day

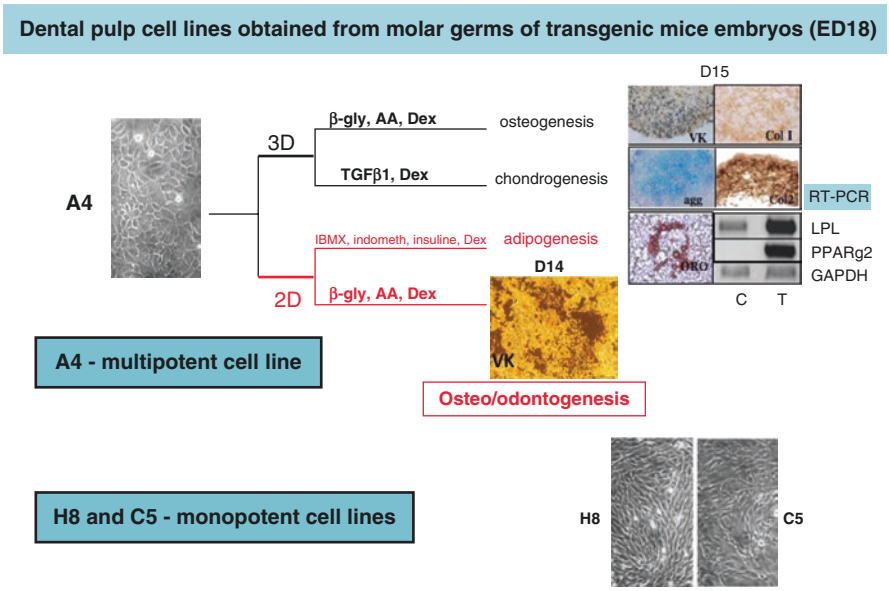

Fig. 8.5 Multipotent cell line may differentiate into bone (osteogenesis), cartilage (chondrogenesis), fatty tissue (adipogenesis) and odontogenesis. H8 and C5 are monopotent cell lines that do not display any change in their phenotype

18 mouse embryos transgenic for an adenovirus-SV40 recombinant plasmid (pK4). Transformed odontoblast cell lines were created with high proliferative capacity, allowing ultimately studying the regeneration and dentin repair [26] (Fig. 8.5).

Among the cell lines that were obtained, A4 cells appear to be multipotent. In the presence of glycerophosphate (GP), ascorbic acid (AA) and dexamethasone (Dex), three-dimensional cultures of A4 cells differentiate into osteoblasts. In contrast, after the addition of TGF1 and dexamethasone to the culture medium, the 2D cultured cells expressed a chondrogenic phenotype. In addition, using some other culture conditions (IBMX, indomethacin, insulin and dexamethasone), the A4 cell lines were implicated in adipogenesis, whereas GP, AA and Dex induce an osteo/odontoblast phenotype. Two other cell lines, C5 and H8, were monopotent and displayed a restricted odontoblastic program. We demonstrate the coexistence of multipotential and restricted-lineage progenitors in the dental pulp [27] (Fig. 8.6).

After a surgical exposure, following in vivo implantation of cells in the dental pulp of rodent incisors, osteodentin was massively formed in the lumen of the pulp. In the molar, the mesial horn of the dental pulp was filled by osteodentin. This evidence that cell implantation may be a tool stimulating the synthesis and secretion of ECM molecules, followed by pulp mineralization.

Embryonic and adult stem cells, totipotent and monopotent immortalized cells, implanted within the dental pulp release extracellular matrix molecules, transcription and growth factors, influencing the control and efficacy of inflammatory molecules. Implicated in the synthesis and secretion of ECM, the SIBLINGs are actual

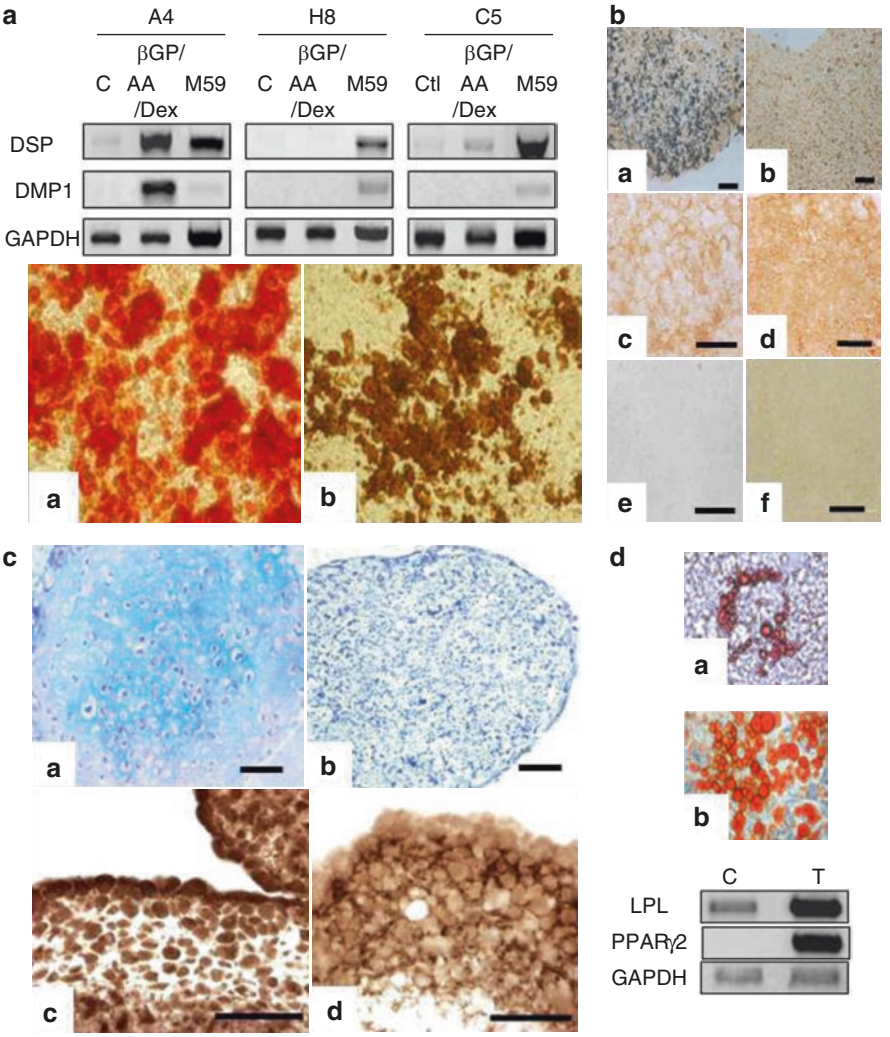

Fig. 8.6 The cell line A4 express DSP and DMP1, in contrast with the H8 and C5 cell lines which are not reactive. B: Bone differentiation C: Immunovisualization of proteoglycans D: Lipids are expressed as LPL and PPAR gamma 2

components of the dental pulp that play a role in pulp mineralization. Conversely, MEPE, which is another member of the SIBLING family, has a more ambiguous role. Acting as mineralization promotor, the C-terminal (ASARM) and the central domain are also performing mineralization inhibition.

Pluripotent adult stem cells display a restricted lineage potential. Interestingly, mesenchymal stem cells (MSCs) derived from bone marrow display an odontogenic potential [20]. Co-culture of these non-dental stem cells with oral epithelial cells derived from embryos renders the MSCs able to express odontogenic genes such as Pax9, Msx1, Lhx7, DMP1, and DSPP. The MSCs may thus represent an autologous source of cells for tooth regenerative research (Fig. 8.7).

The nature of the pulp cells implicated in such processes remains open. After a given number of asymmetric cell divisions, fibroblasts (or pulpoblasts) divide and differentiate toward a phenotype characterized as odontoblast and/ or osteoblast. Following the formation of clusters, pulp mineralization takes place. Interactions between the feeding pulp cells and structural fibroblasts contribute to the release of a series of differentiation factors, which may influence the number of stem cells, also named side population cells. They behave as autonomous cells, which are primarily responsible for engineering a pulp inside a root canal, which further underwent mineralization.

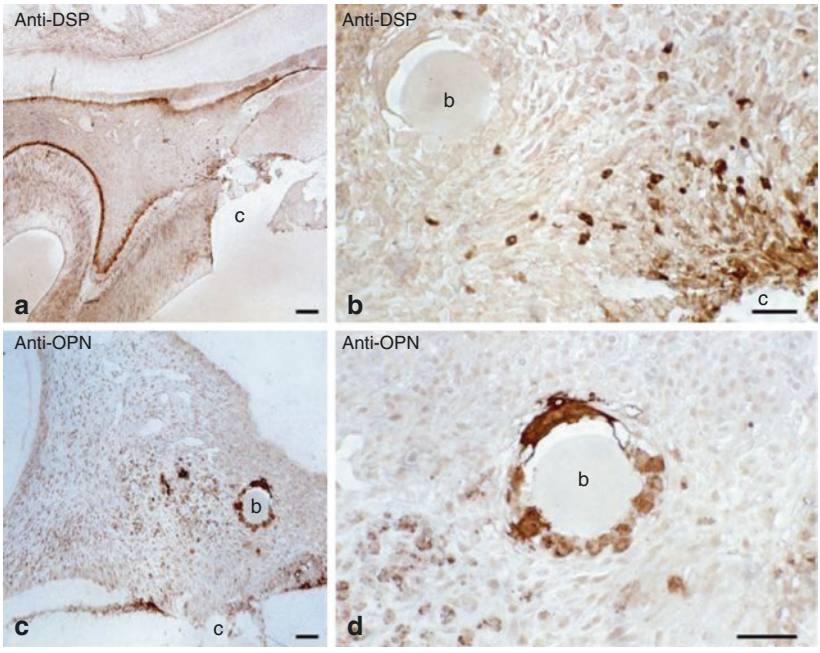

Plate 5

Fig. 8.7 (**a** and **c**) Anti-dentin sialophosphoprotein (DSP) immunolabelling. (**c** and **d**) Immunolabelling was carried out with an anti-osteopontin (OPN) antibody. The anti-BSP shows extensive labelling nera the pulp perforation, but no around the agarose bead (**b**). Anti-OPN labeling is strong around the agarose beads, acting as a carrier for the protein

Stem cells constitute the major factors concerned by pulp healing and renewal. We are far from the complex regeneration of a tooth, still problematic. We focus here on the first step for tissue engineering, restricted to the restoration of dentin or a dental pulp, followed afterward by the root canal mineralization. This phase may provide a good substitute for endodontic treatment. Altogether, many questions arise in this emerging field of tissue engineering that are not yet answered, but pave the way for the future.

8.11 Dental Pulp Stem Cells

The post-natal dental pulp contains heterogeneous cell populations responsible for its maintenance, defense and capacity of repair: stromal fibroblasts, odonto-osteoprogenitors, neuronal and vascular cells as well as inflammatory and immune system cells such as dendritic cells, neutrophils, macrophages, lymphocytes. The ability of the pulp to respond to a variety of pathological conditions and injuries by deposition of a reparative dentin by pulp "progenitors" is well recognized but the origin, localization and precise identity of odontogenic stem cells remain largely unknown. Identifying cells mobilized in response to pulp injury is a prerequisite to design alternative strategies for capping and endodontic treatment, using stem cells.

A decade ago, a population of odontogenic progenitors, inferred as dental pulp stem cells (DPSCs), was isolated from the pulp of human permanent third molars. Populations of DPSCs possesses (1) generic mesenchymal stem cells-like properties (MSCs), (2) colony forming ability and (3) were shown to express in vitro osteoblastic, adipogenic, chondrogenic or even neuronal markers. DPSCs share many similarities with mesenchymal stem cells of the bone marrow (BMSCs), which are the most studied stromal stem cell populations. More than 4000 human genes are expressed either by BMSCs or DPSCs. Dental stem cell populations also express different panels of stem cell surface markers such as 3G5, STRO-1, CD44, CD106, CD146, CD90 and Sca-1 used to characterize hematopoietic stem cells. However, it is important to note that DPSCs and BMPCs have not the same embryonic origin and that cells derived from the human or animal dental pulps have not been able to support hematopoiesis in transplantation assays. DPSCs are thought to contribute to reparative dentin formation, and it appears that they may correspond to heterogeneous populations of precursor cells or represent distinct differentiation stages along the odontoblastic lineage.

The presence of cell populations displaying stem cell properties within the pulp has opened new paths for considering more conservative therapies. Nevertheless, the formal demonstration that pulpal resident stem cells are actually the reparative dentin-forming cells recruited in response to injury is still lacking. The hypothesis that a subset of stem cells carried by the vasculature replenishes the pulp after lesion can not be totally excluded [18]. In the pulp, as in most tissues, the size of the pool of stem cells is very small (<1%) and little is known about their anatomical sites within the pulp. Moreover, the responsiveness of the pulp provides a dynamic system for tissue repair that may imply migration of stem cells from their resting places to the site of

injury. Undifferentiated mesenchymal/mesectodermal cells present in the stroma, perivascular cells such as Rouget's pericytes or fibroblasts have all been proposed as potential progenitors mediating pulp repair after destruction of the odontoblasts and the Hoehl's sub-odontoblastic cell layer. Advances in imaging technology and identification of stem cell markers are still needed to visualize stem/precursor cells in situ.

8.12 Where Are the Dental Pulp Stem Cells Niches?

Stem cells are rare cells that are uniquely capable of both reproducing themselves and generating the differentiated cell types that are needed to carry out specialized functions. Stem cell behaviour is regulated by inputs from their local environment often referred as the "stem cell niche". Niches are defined as specific anatomic locations that provide structural support, trophic support, topographical informations and the appropriate physiological cues to control the maintenance, quiescence, self-renewal, recruitment towards differentiation and long-term regenerative capacity of stem cells. Hallmarks of a niche may include: the stem cell itself, stomal supporting cells that interact directly with the stem cells via secreted factors and cell surface molecules, extracellular matrix (ECM) that provides structure and mechanical signals, neuronal inputs and vascular network that carry systemic signals and represent a conduit for recruitment of inflammatory and circulating cells into the niche. In teeth, as in the adult blood system, multiple niches may exist and specific markers allowing the definitive identification of stem cells within the pulp are lacking [28].

Some data suggest that pericytes could differentiate into osteoblast-like cells, so odontogenic stem cells may reside in a perivascular niche. In this context, it is interesting to mention that many hematopoietic stem cells (HSCs) and neuronal stem cells (NSCs) are localized close to the vascular network; this could be important to communicate "insult" and expose stem cells to signals activating their recruitment. Besides, alterations in ECM components and matrix elasticity related to damage or ageing may also provide mechanical signals that could have a profound impact on stem cell activity. Thus, it appears that the distribution of tissue stem cells is not random and, within the dental pulp, there are potentially several distinct niches of stem/progenitor cells. Nevertheless, still little information is available regarding their topological organization and the inputs that recruit osteo-odontogenic stem cells to form reparative dentin. In contrast to other tissues known to have a constant regeneration potential, such as intestine and bone marrow, dental pulp stem cells will react to form reparative dentin only after injury. This implies that signals ensure their survival and prevent their differentiation while maintaining their responsiveness following pulp damage. Whether an endogenous pool of stem cells associated with supportive stromal cells are mobilized at the site of injury and/or whether attraction of migrating stem cell is necessary to repopulate a niche and expand precursor cells at the appropriate site for dentin repair is unknown. In addition, the alteration of the dentin-mineralized matrix promotes the release of bioactive molecules including high concentrations of Ca2+, which locally may also contribute to stem cells proliferation and differentiation in the post-injury pulpal environment.

Another approach reported in our laboratory suggests that platelets plays important role in the recruitment of dopamine and serotonin implicated in tooth repair. A functional interplay was evidenced between functional stem cells and platelets [29]. We provide evidence that stem cells are recruited according to the levels of dopamine We show that injury-activated platelets are the source of systemic 5-HT and DA necessary for dental repair since natural dentin reparation is impaired in two rat models with monoamine storage-deficient blood platelets. We used Fawn-hooded rats whose platelets are deprived of bioamine storage dense granules, a disease analogous to that of the human Hermansky-Pudlak syndrome. Fawn hooded rats are the sole available animal model with monoamine storage-deficient blood platelets. Moreover, selective inhibition of either D1, D3, 5-HT2B, or 5-HT7 receptor within the pulp of wild-type rat molars after lesion alters the reparative process. Altogether our data argue that 5-HT and DA co-released by pulp injury-activated platelets are critical for stem cell-mediated dental repair through 5-HT and DA receptor signalings.

8.13 Minimal Bioactive Material

In addition to the bioactive cells and materials mentioned above, it has been shown that some bioactive molecules display antibacterial effects. Minimal invasive dentistry displays benefits and the display different challenges. Some antibacterial effects have been identified; leading to reduce affected and/or infected caries decays [30]. Along this lines of evidences, restorative materials should be « bioactive » and display antibacterial effects.

An antibacterial monomer (12-methacryloloxydodecylpyridinium bromide: MDPB) demonstrates cavity-disinfecting effects. Incorporation of 1% chlorhexidine gives antibacterial and physical properties, and reduce bacterial in affected and infected dentin in vivo [31].

Conclusions

Altogether physical and chemical tools may contribute to pave the way for minimalistic approaches for conservative restorations. The concepts derived from Black's classification and derived technologies obviously need to be renewed. This was leading to minimalistic approaches of restorative dentistry. The preparation of cavities, including the removal of carious lesions limited by the sclerotic zone, was firmly modified, and the concepts of geometrical preparations were abandoned. The adhesive properties of new biomaterials have modified the current thoughts, developing more conservative and minimal approaches for the benefit of the patient.

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Evaluation of Transitional or Immediate Complete Dentures

9

Alexandre Mersel

Abstract

Twenty years ago, numerous publications indicated that the aged population will reach about 20% in 2020. Now, the profession and the health authorities have to challenge this situation. Of this cohort, about 50% constitute what is termed the old-old frail and handicapped persons who suffer from drastic physiological and psychological changes that increase the difficulties with classical and traditional dental and prosthodontic treatments. Globally, the shift from a dentate to an edentulous condition has shifted from 55- to 75-year-olds.

9.1 Clinical Considerations

Twenty years ago, numerous publications indicated that the aged population will reach about 20% in 2020. Now, the profession and the health authorities have to challenge this situation [1]. Of this cohort, about 50% constitute what is termed the old-old frail and handicapped persons who suffer from drastic physiological and psychological changes that increase the difficulties with classical and traditional dental and prosthodontic treatments [2]. Globally, the shift from a dentate to an edentulous condition has shifted from 55- to 75-year-olds [3].

9.1.1 Status Changes

The increase in the life span strongly influences the oral status of this population in respect of their health, social and behavioral conditions. It is admitted that consequently the new edentulous patient will not lose their teeth only because of neglect,

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but rather because they have outlived the life span of their fixed and partial prosthetics [4]. The treatment of the elderly and compromised patient should be specific because it has to cope with changes in the oral conditions initiated by ageing and consider important social and psychological aspects. These create different demands and needs compared with the other cohorts [5].

9.2 Medical Conditions

General health conditions and the medications involved interfere with the oral rehabilitation treatment plan. Systemic diseases usually require special care and prohibit an invasive procedure.

9.3 Oral Status

Aging is characterized by important changes in the human organs.

These changes, in conjunction with age-related pathological conditions lead to the consumption of multiple medications.

When using a large number of drugs, various side effects may appear:

Xerostomia, or mouth dryness, is a common phenomenon that affects eating, swallowing, and taste reduction. A drastic diminution of the saliva flow results in poor retention for the removable prosthesis and burning mouth pain.

Taste alteration, or taste diminution, directly influences dietetic habits, usually with significant consumption of sugar or salt.

Oral diseases and pathological conditions such as cancer are frequent and there is an essential need for an integrative approach concerning the management of oral conditions paying attention to systemic implications [6].

9.3.1 Oral Findings in Diabetic Patients

This systemic disease results in a higher prevalence of caries and especially root-caries. Also, the periodontium is severely affected and even leads to the loss of intact teeth.

9.3.1.1 *Candida*

Candida is a silent host that affects a large number of elderly people, mainly in the oral cavity and **in the removable prosthesis**. The ability of *Candida* to adhere both to the mucosa and the dentures plays a principal role in the pathogenesis. One of the main reasons for elderly mortality is *Candida* infection [7].

9.3.1.2 Mental Status Evaluation

During the first examination and before any diagnostic, prognostic, and treatment planning, it is compulsory to carry out a slight evaluation of the patient's mental status, namely speech, hearing, and language difficulties. The *FROMAJE test* is an easy and quick mental evaluation test. FROMAJE is an acronym for: *function, reasoning,*

orientation, memory, arithmetic, judgement, emotional state. A total score provides approximate information about the risk of delivering a successful treatment.

9.3.1.3 Patient Denture Satisfaction

One of the aims of our oral rehabilitation therapy is the complete satisfaction of our patient. Patient satisfaction with complete dentures depends on various factors such as prosthetic and functional quality of the dentures, personality traits, appearance and esthetics, and the patient's behavior and attitude toward dentures [8].

Age is a questionable factor, but gender is not significantly correlated with the acceptance of the dentures. Moreover, religion is an important factor in the adaptation of the new set of dentures [9] as numerous patients are in anxious anticipation of their complete dentures; dentists with clinical experience and adapted skills are achieving more successful results [10]. In any case, there is often a discrepancy between the quality of the prosthodontic treatment and the complaints of edentate patients [11]. Research has indicated that the prosthesis was the most frequent specialty in litigations within the ethical scope and in civil law. Therefore, the dentist should always be aware of minimizing errors during prosthetic treatment and treatment planning [12].

9.3.1.4 The Necessity of a Bioethical Attempt

To manage an easy transition from the dentate to the edentate condition, several techniques and prosthetic devices may be used.

Immediate Dentures

A complete denture fabricated for immediate placement following the removal of the remaining teeth. This procedure requires laboratory support and numerous long chairside appointments without certainty of a good result. Of course, multiple extractions may present a clear contraindication for systemically compromised and frail elderly [13].

Interim or Provisional Prosthesis

This is a prosthesis enhancing the patient esthetics, stabilization, and function *for a limited time, after which it has to be replaced by a new restoration. It is recommended to be utilized as the basis for the future transitional prosthetic if properly constructed on a metal base* (Fig. 9.1).

Transitional Denture

This is usually a removable partial denture (RPD) used as an interim prosthesis on which artificial teeth are progressively added after extraction or loss of the natural teeth. This transitional denture becomes an interim complete denture in the last step when all the remaining teeth have been extracted.

Immediate Dentures

The classic immediate dentures present a number of difficulties for elderly and handicapped patients.

On a psychological level: from a psychological aspect, the patient ignores the appearance of the new denture, which can contribute to the patient's stress, and even to rejection of the new prosthesis [14].

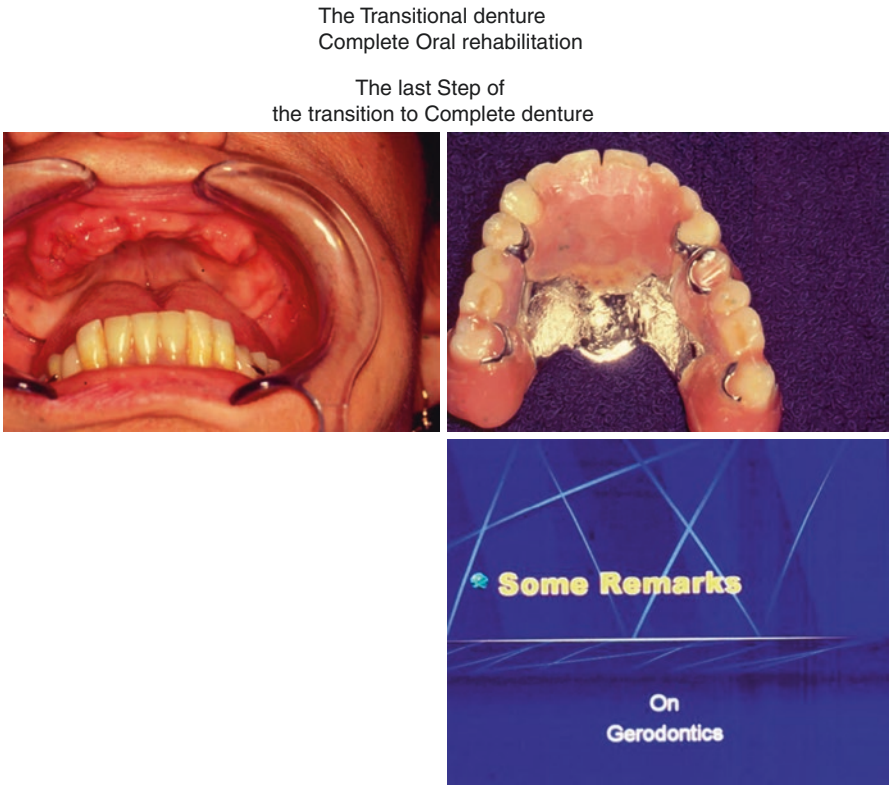

Fig. 9.1 The transitional denture in complete denture rehabilitation

On a functional level: there are often major discrepancies between the impression and the final aspect of the ridge after surgery creating a bad fit of the base and a loss of retention of the denture. Consequently, there will be problems with phonetics when the patient starts speaking.

On the adaptation capacity: adaptation to a new denture immediately after serial extractions is very traumatic; there is a risk that the frail elderly could not cope with the pain and swelling. In several cases, the patients will have difficulties inserting and removing the new dentures.

At the surgical level: in several cases, surgery has to be performed in a hospital This procedure requires close cooperation between the oral surgeon and the prosthodontist. Sometime the assistance of the family is necessary.

In conclusion, immediate dentures are in general painful, stressful, and have no guarantee of acceptable esthetics and good functional achievement. From a social point of view, the patient is isolated from social activities and a normal quality of life.

9.3.2 Minimally Invasive Procedure: An Adapted Approach

For geriatric and handicapped patients, transitional dentures constitute a recommended approach, presenting several advantages [15].

In a first step, old, existing, removable, and partial dentures may be refitted.
In a second step, the vertical dimension is re-evaluated and restored.
Finally, the occlusion is examined, and a new occlusal balance created.
When this stage is reached, a period of mucosal healing is necessary.

- Surgery has to be well planned and allows the removal of a small number of teeth, generally two to three, reducing the trauma significantly.
  - Immediately adding the prosthetic replacement teeth using a simple chairside technique allows quick recovery of function and esthetics. The dentist has good control of the esthetics and the patient has no complaints about his appearance [16].
- For a physiological consideration, adaptation is easier when there are minimal changes for the tongue space, mastication, speech, and nutritional habits.
  - During the healing process, a strict follow-up should be ensured with the necessity for several rebasing and occlusal corrections.

9.4 Rebasing Relining

This is a very important point but is often neglected by both the patient and the dentist.

9.4.1 Problematic

Because of the modern style of life, no patient is currently able to accept being without dentures after surgery. Usually, the dentist is tempted to use the old denture as a transitional denture until the definitive rehabilitation is achieved. Consequently, a significant time-delay is necessary from the beginning of the intervention to the new denture insertion. This problem is solved by using a soft-tissue lining or tissue conditioner. The uncontrolled use of relining for a long period could represent a severe inconvenience (Fig. 9.2).

9.4.2 Comprehensive Relining System

1. *Most of the soft –lining products are porous after 6–7 days and contaminated by micro-organisms as* Candida.
2. *The consistence and softness of these products change quickly, and then the lining is cracked, hard, and can injure the supporting soft tissues*
3. *Because of these changes, the prosthesis loses retention and stability, thereby causing discomfort and decreased function.*

Healing Process :
Soft and Medium Relining

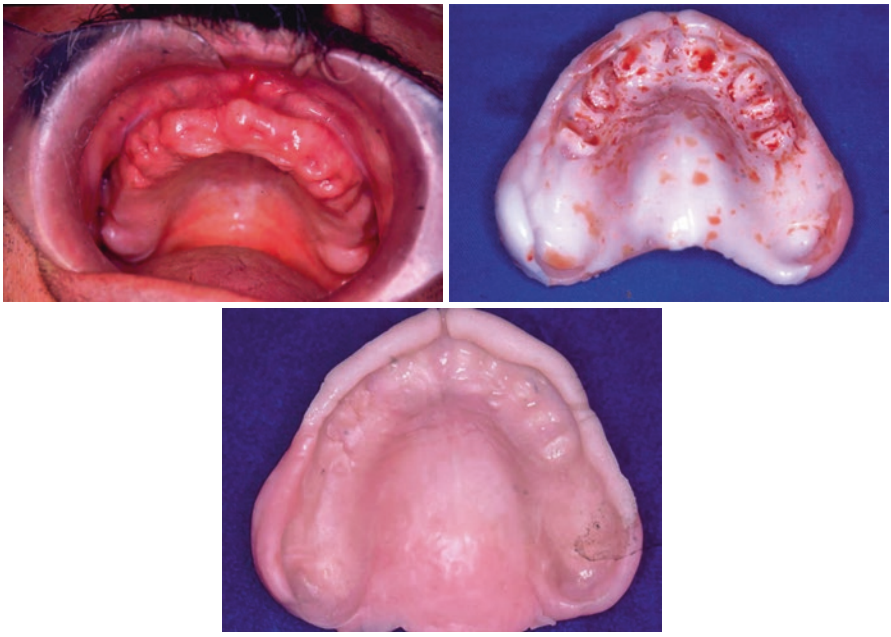

Fig. 9.2 Healing process soft and hard relining

Therefore, the dentist should set up with the patient a timetable to control the quality of the relining material and the healing process. The patient must be aware that this follow-up system is an integral part of the treatment and that for these important services he has to **pay corresponding fees.**

Two types of product are necessary if the dentist is to provide his patient with maximal comfort and success.

9.4.2.1 Soft Relining

Soft relining is necessary about 15–21 days after the surgical procedure, in fact two chair-side soft relinings are necessary. When the sutures are removed and the gingiva seems healed, a more consistent relining product is then needed.

9.4.2.2 Medium Relining

The healing of the hard bone tissues is expected about 90–100 days after the extractions. Medium relining can be maintained for 2–3 weeks with its initial qualities. Medium relining provides the patient with comfort and function without frequent visits to the dental office. Usually, 3–4 medium relining procedures are necessary before the dentist starts the prosthetic rehabilitation.

9.4.2.3 Medium Relining During the Prosthetic Restoration

A certain amount of time is necessary for the laboratory to achieve a perfect prosthetic reconstruction; in the meantime, there is some adaptation between the

dentures and the hew situation. Soft lining is not recommended in this case, because it is too soft and unable to absorb the masticatory stresses. Medium relining remains the best solution in these cases.

The dentist should pay attention to the fact that their patient is confused on this issue. Therefore, he has to emphasize that **relining** is the readaptation of the tissue surface of the denture by the addition of a layer of a new base material. This is mainly a chair-side session. **Rebasing** is the replacement of the existing base of the denture with a new base after new impressions have been obtained. In this case, the dental laboratory may take a while. Of course, there is a significant cost difference.

9.5 Psycho-Geriatric Behavior and Dental Anxiety

In conclusion, before starting such a traumatic intervention, the dentist should bear in mind that dental anxiety (DA) is a severe, stable, and highly prevalent dysfunctional condition, with a long duration. Socio-economic factors are also determined at the level of satisfaction of the elderly patients [17].

9.5.1 Clinical Case Report on Immediate Complete Dentures

The patient: a 75-year-old man who had retired with cardiac problems presented with a bad periodontal situation. It was necessary to extract all his teeth from the upper maxilla (1-21-22-23) and three (33-34-35) from the lower maxilla (Fig. 9.3). *An alginate impression was obtained and the reexamined teeth were enveloped in a metal X-ray folio to avoid a premature extraction of 23* (Fig. 9.4). *The functional impression was obtained utilizing an individual tray; after border molding, a first wash was accomplished and a hybrid impression of the upper teeth was finalized* (Fig. 9.5). *The next step was the determination of the vertical dimension and the centric relation* (Fig. 9.5). *The following session was devoted to the checking of the*

Preparation of the tray
Alginate (milk) anterior Impression

Fig. 9.3 Alginate impressions

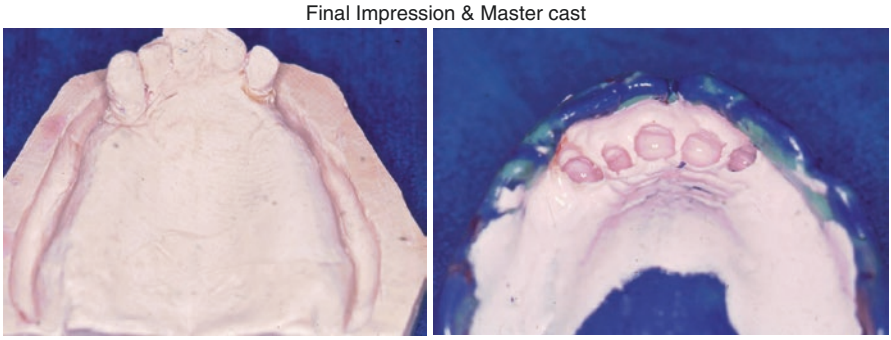

Fig. 9.4 Master models

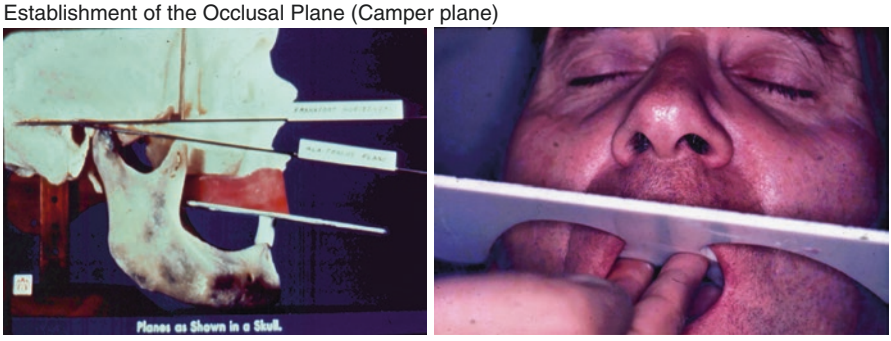

Fig. 9.5 Establishment of an occlusal reference plane; Camper

arrangement of the teeth and the occlusal relationship. Note the two orthodontic clasps on 11 and 23 to maintain the stability of the upper denture set-up (Fig. 9.6). *Materials used include alginate, iso-compound, pericompound (G-C Corp) and Xantopren Green and Xantopren Blue (Bayer).*

In the final session, the dentist extracts all the residual teeth and inserts the new dentures (Fig. 9.7).

Clinical consequences are bleeding, pain, swelling of the upper lip, no perfect esthetics, difficulties speaking and eating, and the necessity for a close follow-up and numerous soft lining sessions. Overall, it is impossible to predict the final result.

Transfer to the Articulator with the Face-bow

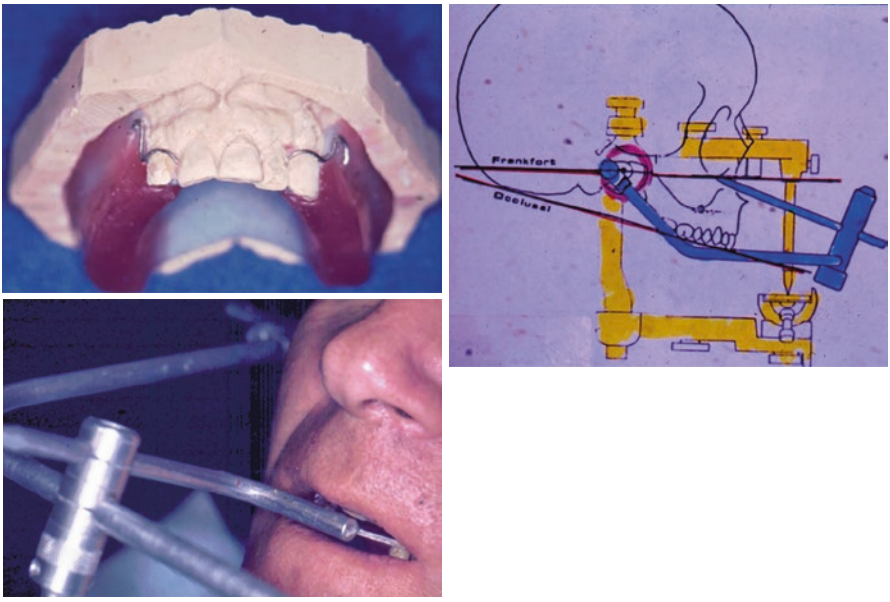

Fig. 9.6 Transfer to the Articulator with the Face-bow

Try –in & Balance

Fig. 9.7 Try in and balance

9.5.2 Clinical Case Report with a Transitional Complete Denture

The patient: a 68-year-old healthy woman, a busy CEO. Concerning the upper maxilla, she had a partially removable metallic frame denture Kennedy class 1, and a bridge from 15 to 25. This bridge dropped down several times.

There were no proper root treatment, no reconstitution, deeply carious teeth, and consequently all the remaining teeth should be extracted.

With the agreement of the patient, a timetable was set-up. ***The strategy*** *was to proceed with a minimally invasive intervention and immediate replacement of the extracted teeth.*

This treatment plan and the timing were fully explained, and after discussion and approval an alginate impression was obtained. The upper RPD was pulled out, and three teeth removed from the model. Corresponding acrylic teeth were also prepared (Fig. 9.8).

In this way, on the day of the extractions of 21-22-23 and separation of the upper bridge into two parts, the dentist was able to replace the extracted teeth. Because the shade and the shape had been selected before surgery, the esthetic result was perfect (Fig. 9.9).

Fig. 9.8 Wax up of the two dentures

Fig. 9.9 Extractions, sutures, and insertion

No functional problems or speech difficulties were noted.

In the same way, step-by-step, segment-by-segment, teeth were extracted and immediately replaced.

The first step was: extraction of 21–22–13 (Fig. 9.10).

The second step was: extraction of 25 (Fig. 9.11).

The third step was: extraction of 1-12 (Fig. 9.12).

The fourth step was: 13-14 (Fig. 9.13).

The fifth step was: relining the transitional upper denture (Fig. 9.14).

Of course, between the surgical steps it was necessary to deliver follow-up and relining/rebasing care.

Fig. 9.10 The first step was extraction of 21–22–13

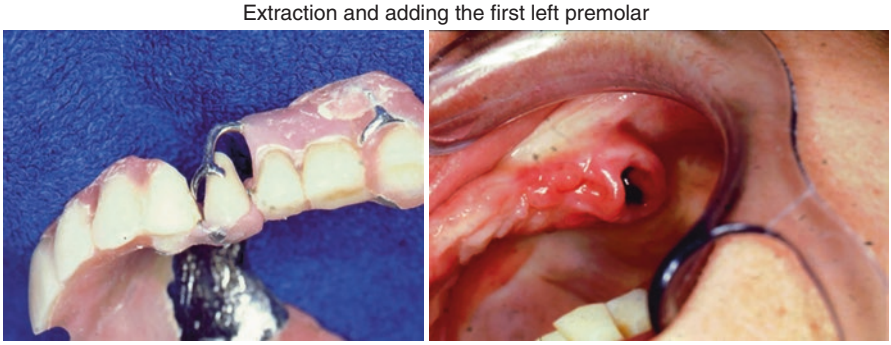

Fig. 9.11 The second step was extraction of 25

Healing Process, removing sutures adding buccal flange

Fig. 9.12 The third step was extraction of 1-12

Extraction and adding upper right anterior segment

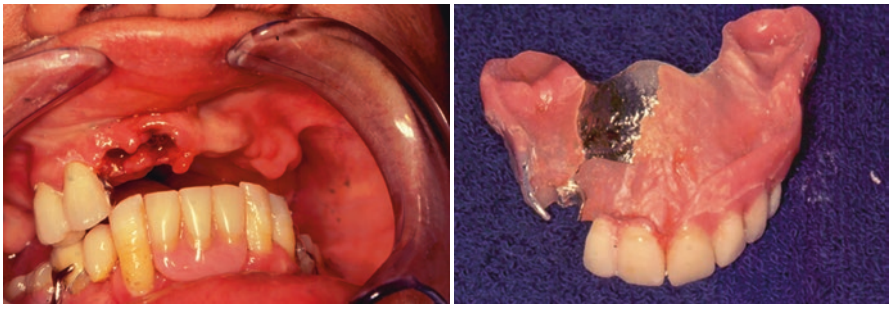

Fig. 9.13 The fourth step was 13-14

The Transitional upper C.D.
The last Step of the transition to Complete denture

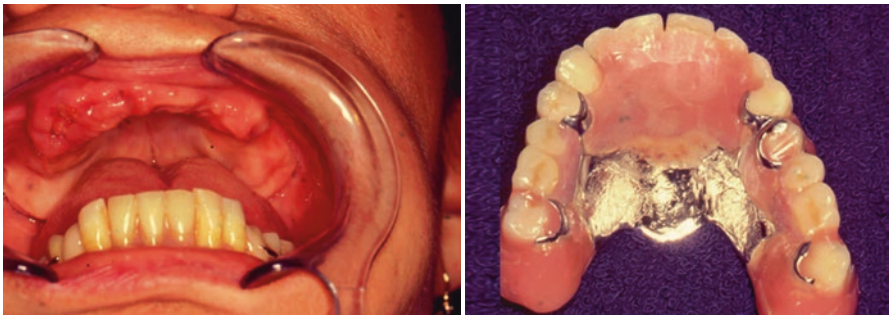

Fig. 9.14 The fifth step was relining the transitional upper denture

9.6 After-Care and Prevention

This is often a forgotten element of the treatment. The dentist may be considering that after successful insertion, his duty is done.

On the contrary, the anxious patient has a perpetual need to be examined and to be assured that all is in order [18]. ***For this elderly population a recall is necessary every 2 months to check oral hygiene, pathological symptoms, and any new behavioral difficulties*** [19].

Another point is the popularity of implants in dentistry; this **"implantomania"** is now the subject of endless questions, thereby creating an atmosphere of suspicion [20].

A flexible management is compulsory, including social and financial aspects, to avoid conflictual situations [21].

Conclusion

The recent data demonstrate a huge increase in the elderly population, thereby creating a significant need for dental services.

Dental education tends to favor an intervention policy. The minimal intervention approach will be better adapted to the demands and needs of frail patients and will help to reduce inequalities in oral health care.

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Limits of Complete Denture Rehabilitation

10

Alexandre Mersel

Abstract

Demographic studies indicate a constant increase in the elderly population. The overall number of people aged over 60 years is expected to double, from 605 million to 2 billion from 2000 to 2050 (WHO 2013a).

10.1 Introduction

Demographic studies indicate a constant increase in the elderly population. The overall number of people aged over 60 years is expected to double, from 605 million to 2 billion from 2000 to 2050 (WHO 2013a).

The greatest increase will take place in the developed countries, where the number of elderly people will reach 1.7 billion by the year 2050. Taking into account this phenomenon, several countries are creating adapted policies to deal with this challenge [1].

The reasons for this trend are the consequences of several factors:

- Amelioration of the health condition and health services
- Increase in the education level
- Promotion of better oral hygiene
- Changes in nutrition concerning quality and quantity
- Social and public health care adapted for the elderly, such as better housing conditions with expanded possibilities for handicapped people [2]

The treatment of senior patients must be specific, because they have to cope with peculiar changes in oral conditions with ageing, with consideration of the social and

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psychological aspects. This creates different demands and needs compared with other cohorts [3].

10.2 Medical Conditions

General health conditions or medical involvement may define oral rehabilitation [4]. Systemic diseases are frequent, requiring special care and prohibiting any invasive procedures [5].

The most common diseases and the major causes of mortality are mainly: heart diseases, cancer, cerebrovascular problems, arteriosclerosis, diabetes, impaired lung diseases, and neuropsychological conditions such as Parkinson's and Alzheimer's.

10.2.1 Mental Status Evaluation

During the first examination of the patient, and before starting any diagnosis, prognosis or treatment, it is essential to establish the mental status. Dementia is a common brain illness among elderly patients. The practitioner has to realize that the elderly, who appears to have dementia, is in actuality suffering from pseudo-senility syndrome and, in reality, has communication disorders; therefore, often, ageism contributes to the over-diagnosis of dementia. It is essential to have a good knowledge of the cognitive status: speech, hearing, and language difficulties, in addition to knowing how to evaluate a patient who has suspected dementia.

10.2.2 Oral Status

Aging is characterized by important changes in the human organs. The conjunction of these changes with age-related pathological conditions leads to the need for multiple medications to maintain the patient's quality of life. There is a danger, when a large number of medications are used by the elderly, of provoking undesirable side effects. Mouth dryness, or xerostomia, is a common phenomenon. The consequences of xerostomia are numerous, and affect eating, swallowing, taste, thereby impairing the nutritional status. A consequence of the diminution of the saliva flow is poor retention of the removable prosthesis, and burning mouth pain [6].

Symptoms such as burning mouth, dry lips, altered speech, and ulcerated mucosa are the consequences of hypo-salivation and xerostomia. It is estimated that, currently, about 30% of the elderly suffer from hypo-salivation and xerostomia [7].

Taste alteration, mouth dryness, and teeth staining are often side effects of the medication taken by the elderly. A survey from Helsinki demonstrates the relationship between drug intake and xerostomia, that is, the greater number of medications, the greater the probability of mouth dryness. The diminution of taste influences the dietetic habits and provokes significant consumption of salt or sugar.

Oral cancer has high morbidity and mortality [8]. The 5-year survival rate is only 17%, whereas for lesions with distant metastasis it is 75% for local lesions.

The direct causes are: tobacco, alcohol, infections, and chronic irritation due to very sharp teeth or a prosthesis. The indirect causes are: nutritional deficiencies, poor oral awareness, and poor access to oral care for prevention and early detection.

Oral diseases are frequent and there is a need for an integrative approach concerning the understanding and management of oral conditions, paying particular attention to the systemic implications [9] (oral diseases, oral and dental diseases).

10.2.2.1 Dental Findings in Diabetic Adults

Diabetes mellitus is a major threat to health and is the fourth leading cause of death by disease. As for systemic disease, elderly diabetics may be affected in both the quality and length of their life. Several studies reported a higher prevalence of caries, in particular, root caries.

Also, the periodontium is severely affected and even leads to the loss of intact teeth.

10.2.3 *Candida*

One of the most silent hosts is *Candida*, which affects a great number of elderly people, mainly in the oral cavity but also in the removable prosthesis.

It was mentioned that one of the main reasons for mortality in the elderly is *Candida* infection: oral candidiasis is a sign of impaired local or systemic defense mechanism. The carriage rate of *Candida* depends on the age and health of the patient. In a study of the elderly in Japan, *Candida* was detected in 67% of the patients. *Candida* is the fourth most common cause of hospital bloodstream infections in the USA.

10.2.3.1 Pathogenesis

The ability of *Candida* to adhere to the mucosa and the dentures plays an important role in the pathogenesis.

10.3 Complete Edentulousness

10.3.1 Edentulism

Edentulousness is a debilitating and irreversible condition.

Concerning complete dentures, a disappearance of complete denture prosthodontics was predicted [10]. Although the prevalence of tooth loss has declined, edentulousness remains a major disease among the elderly, with great variation depending on the country.

Nevertheless, the need for complete dentures remains essential for a large proportion of aged patients, especially in the cohort of the “old-old.” Obviously, the transition from partial to full dentures has shifted to a more advanced age (70–80) (Fig. 10.1).

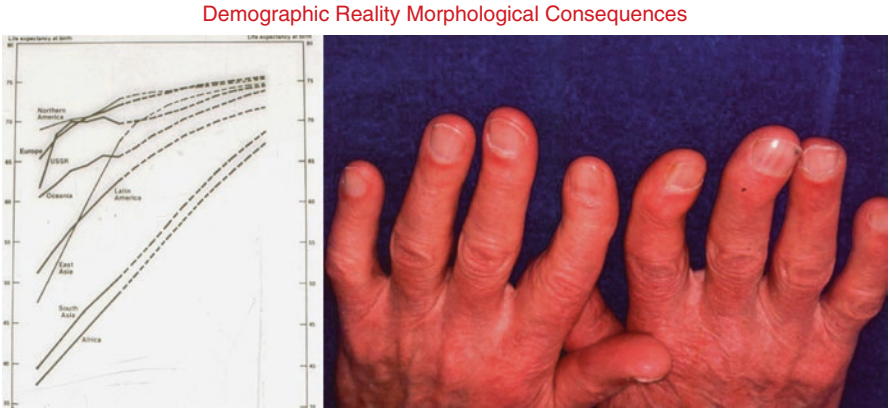


Fig. 10.1 Demographic reality

In Switzerland, 85.9% of persons aged 85 years or above are reported to wear a removable prosthesis and amongst them 37.2% are totally edentulous. In the USA, it is predicted that there will be 37.9 million elderly people by 2020, age: 70–80. Among them, nine million will be totally edentate [11].

Therefore, if complete dentures are to be progressively eliminated from the standard dental education curriculum, the result will be that millions of patients will be forced to find alternative providers for their prosthesis. A complete denture remains a difficult form of oral rehabilitation because it needs to challenge significant physiological and psychological problems.

Because aging is not a pathological condition but a permanent decrease in the individual faculties, the practitioner should face the implications of ageing in the oral cavity. Genetic and biological factors, in addition to social and behavioral issues, may play an important role.

10.3.1.1 The Necessity of a Bioethic Attempt

Despite the fact that the dentist applies the rules he/she was taught, he/she may be very disappointed by the results. Unfortunately, there are dogmas that dragged down for senior patients the prosthetic restoration to pitfall (Figs. 10.2 and 10.3).

Since geriatric dentistry is not a priority in the basic educational syllabus, the profession is not able to face a growing minority of persons with atypical or unusual requirements looking for prosthodontic treatment who present outstanding features or variations from the norm. Therefore, these handicapped patients, described as "denture cripples," are unable to receive conventional treatment or often cannot wear the dentures completed by the dentists [12].

The classical approach is devoted to the treatment of typical or normal patients, but for old-old or atypical patients, special diagnostics and solutions are recommended.

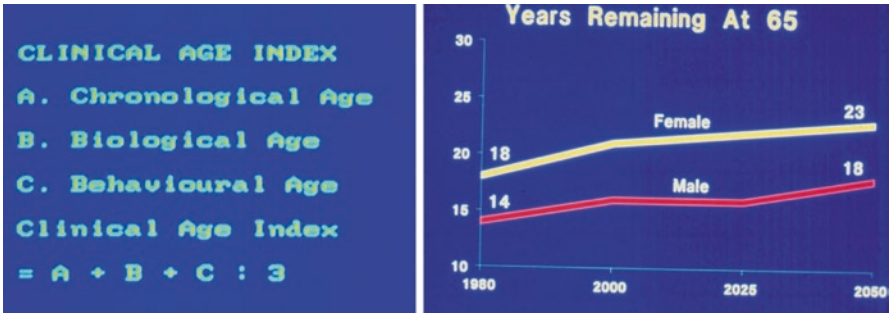


Fig. 10.2 How old are you?

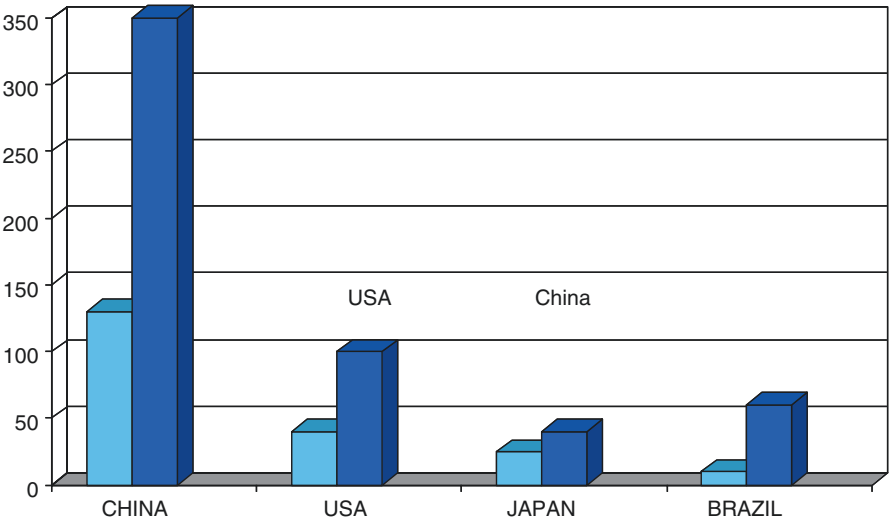


Fig. 10.3 Elderly 2002–2050

A typical or conventional patient can be categorized by the following characteristics:

1. A patient who comes to the dental office for prosthodontic treatment after or about the loss of his natural teeth.
2. His expectation of the dental care is to be provided with a set of removable dentures that will partly replace the functions fulfilled by his natural teeth.
3. He agrees to the treatment and collaborates with the dentist during the clinical procedures and the necessary adjustments that follow the delivery of the dentures.

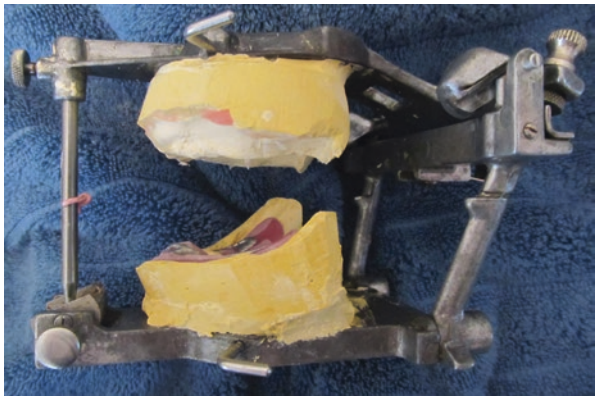


Fig. 10.4 Edentulous ridges in an articulator relationship

4. He does not present any severe systemic or physical limitations for the treatment and for home self-care.
5. The masticatory muscles and the temporo-mandibular joints are reasonably healthy with no functional limitations.
6. The residual ridge and adjacent structures are of normal size and form, and able to provide a stable functional foundation for the dentures.
7. The soft and hard oral tissues are healthy and properly lubricated by the salivary flow.
8. The tongue and the tongue attachments are of normal size and position and allow the insertion and proper function of the mandibular prosthesis.
9. There is minimal or non-existent gagging reflex at the posterior region of the maxilla during the treatment and after upper denture insertion.

   At a physiological vertical dimension at occlusion there is adequate denture space for the construction of the denture bases and the setup of the artificial teeth.

   The special occlusal relations between the edentulous ridges permit the setting of the artificial teeth on top of or close to the residual crests and allow harmonious arrangements (Fig. 10.4).

   The patient shows a reasonable and positive attitude, acceptance, and the ability to adapt following delivery of the dentures.
10. Last but not least: there are no symmetrical patients as educated in the conventional textbooks. Because the left and right sides are not symmetrical, the teeth arrangement does not respect the patient's physiology.

In conclusion, with aging there is no ideal patient who presents all the described criteria.

Hereafter, the most frequent features:

1. *Systemic patients:*

   the great majority present one or two systemic diseases. The most common are hypertension, cardiovascular problems, and diabetes.

Aside from this, there are also critical neurological systemic situations such as Parkinson's, Alzheimer's and different kinds of depression. Various forms of cancer are also frequent.

2. *Psychological behaviors:*

   the most difficult obstacles to successful treatment are often psycho-geriatric attitudes and behavioral disorders [13].

   Aside from the classic organic brain syndromes there are also paranoid states and affective disorders.

   These factors will barely compromise treatment planning.

3. *Economic limitations:*

   with increases in the life span and economic difficulties, an economic gap has appeared, and consequently a diminution of financial possibilities.

   Physiological evolution with aging:

   there is a change in the physiology of elderly patients with aging; a change in the supporting structures, the muscles and the natural or acquired reflexes. In particular, bone resorption and the important differences between the maxilla and the mandible were studied. A growing difference between the right and the left side should be noted [14].

   Nevertheless, very few studies were found on the fundamental asymmetrical condition of the great majority of individuals.

   Usually, one side is shorter than the other. Often the middle of the maxilla does not correspond to the middle of the face.

   This is in total contradiction with what was thought in the majority of textbooks (dogmas).

   In the same way, the condylar guidance is different between the two sides, providing an unequal occlusal climatic. In general, the ridge resorption is centripetal in the maxilla and centrifugal in the mandible, causing a problematic cross-bite (Fig. 10.5).

   Numerous pieces of research have indicated the asymmetry of the chewing cycles, thereby inducing a special occlusal balance system.

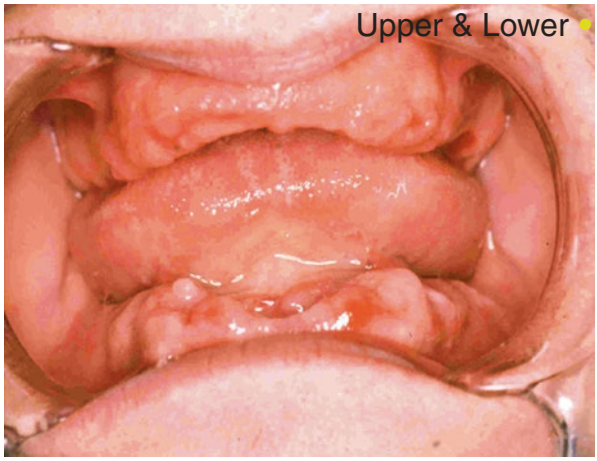


Fig. 10.5 Mandibular chewing cycles

Another important fact is the acquired para-function caused by poor prosthetic restorations, creating a serious obstacle to the stability of the new dentures. When considering an adapted treatment plan for the old-old patient, this asymmetric factor must be taken into consideration.

10.3.1.2 Satisfaction with Complete Dentures

In the cohort of the elderly, there is an important group of people who constantly have great difficulty in adjusting to and wearing dentures. Therefore, they have a reduced quality of life and are dissatisfied, causing dentists considerable problems. Identifying these patients before treatment will give the practitioner the possibility to modify the approach and to help the patient to adopt more realistic expectations. There are a wide variety of factors involved in the dissatisfaction [15].

1. Past denture experience is better related to denture satisfaction than age.
2. Comfort is a decisive factor, because the patient is always comparing the new with the old dentures, in terms of the dentures' design, the occlusal system, the freeway space, and the phonetics.
3. Usually, the criteria for conventional dentures are: an accepted esthetic, good retention and stability, an ability to chew properly, and an acceptable phonetic. A failure of one of these conditions will led to the failure of the whole oral rehabilitation.
4. Switching abruptly from an old to a new denture is often the reason for destabilization of the geriatric patient. In this situation, the patient will never accept the new restoration.
5. This underlines the importance of psychological aspects in the treatment of the elderly patient. In the same way, the influence of the systemic condition and the medication has an impact on the tolerance of dentures.
6. Only a step-by-step treatment plan, with evaluation possibilities, is recommended. These transitional steps are the *conditio sine qua non* for comprehensive and tolerated changes.

10.4 Limitations of the Complete Denture

10.4.1 Rehabilitation

Total edentulousness is a condition determined by the loss or extraction of all the natural teeth. However, the inferences of edentulousness are deeper and more lasting than the wound healing and tissue resorption. It is well known and documented that edentulousness affects to several degrees and at different levels the surrounding muscles, ligaments, temporo-mandibular joints, adjacent mucosa, facial appearance, masticatory and speaking function, in addition to the psychological status of the patient.

Edentulousness can be a debilitating handicap, and the majority of patients are described as "denture cripples". The construction and the delivery of a set of

well-fitting complete dentures achieved following the principles and techniques described in the prosthodontic text books are able to bring back the capabilities lost as the consequences of the extraction of the natural teeth.

The complete denture will partially rehabilitate the patient on a functional, esthetic, and emotional level. These statements are true, globally, for the vast majority of patients, where objective in addition to subjective conditions fall into the normal or rather typical category of edentulous patients.

However, there is a growing minority of geriatric or elderly persons looking for prosthodontic treatment for unusual features or variations from the norm who are unable to receive conventional treatment or cannot wear the dentures as completed by the dentist.

This situation calls for an attempt to provide classification and procedures for these extreme and unusual cases in which the classic approach, methodology, and techniques cannot provide an acceptable prosthodontic solution for the patient. To achieve such a classification, it is imperative to first define what typical of edentulousness the patient has. A typical edentulous patient can be categorized as one with the following characteristics.

Normality:

1. A patient who comes to the dental office for prosthodontic treatment after losing or about to lose all his natural teeth.
2. His expectation of the dental care is to be provided with a set of removable prostheses that will partly replace the functions fulfilled in the past by his natural teeth.
3. He is agreeable during the treatment and collaborates with the dentist during the clinical procedures and the adjustment period that follows delivery of the dentures.
4. He does not present any severe systemic or physical limitations for the treatment and for home self-care.
5. The masticatory muscles and the temporo-mandibular joints are reasonably healthy and have no functional limitations.
6. The residual ridges and their adjacent structures are of normal size and form and are able to provide a stable functional foundation of the denture.
7. The soft and hard oral tissues are healthy and properly lubricated by the salivary flow.
8. The tongue and the tongue attachments are of normal size and position and allow the insertion and proper function of the mandibular prosthesis.
9. There is a minimal or non-existent gagging reflex at the posterior region of the maxilla during the treatment and after upper denture insertion.
10. In the physiological vertical dimension of occlusion, there is adequate denture space for the construction of the denture bases and the artificial teeth.
11. The special occlusal relations between the edentulous ridges permit the setting of the artificial teeth on top of or close to the respective residual crests and allow harmonious occlusal arrangements.
12. The patient shows a reasonable and positive attitude, acceptance, and ability to adapt following delivery of the dentures.

There is no ideal patent who presents with all the criteria described at the optimal level. However, most patients seeking complete denture restoration will have an acceptable degree of most of these qualifications.

The elderly edentulous patient or situation is not only a qualitative condition, but mainly a quantitative one, best illustrated when the most common edentulous feature is evaluated.

10.4.1.1 The Geriatric Status: the Handicaps

1. *Systemic patients:*
   the great majority of these patients present one or two systemic diseases. The most common are hypertension, cardiovascular problems, and diabetes.
   There are also critical neurological systemic situations such as Parkinson's, Alzheimer's, and all types of depression. Aside from these sicknesses, cancer is also frequent.
2. *Psychological behaviors:*
   behavioral disorders and psycho-geriatric attitudes are well known and present one of the most difficult obstacles to successful treatment [16].
3. *Economic limitations:*
   with the increase in the life span and decrease in the economic situation, a growing economic gap illustrates the diminution of the financial resources.
4. *Aging physiology: complete edentulousness:*
   the evolution of the physiology for the elderly patient is a function of the aging of the supporting structures, the muscles and the natural or required reflexes.
   Bone resorption has been studied for a long time and the research indicates a strong difference between the maxilla and the mandible. There is also a difference between the right and left sides.
   There are very few studies on the fundamental asymmetry of most individuals. Usually, one side is shorter than the other, the middle part of the maxilla does not correspond to the middle part of the face. The condylar guidance is different between the two sides, causing an unequal occlusal cinematic. The ridge resorption is centripetal in the upper maxilla and centrifugal in the lower one, thereby creating the cross-bite situation (Fig. 10.6) [17].

Fig. 10.6 Posterior cross-bite

The chewing cycles are also asymmetrical, inducing a special occlusal balance system. In particular, para-function acquired due to poor prosthetic restorations remains an obstacle to the stability of our complete denture prosthodontics, especially considering the old-old patient. Asymmetry has to be taken into account when elaborating an adapted treatment plan.

10.5 Physiological Design of Complete Denture

10.5.1 Conservative Approach

As it is very difficult to correct physiological changes, the practitioner must respect these basic elements maximally, mainly to register the function and para-function of the tongue and the peripheral muscles.

The dentist must take proper impressions of the soft tissues and ridges, avoiding any exaggerated pressure.

The practitioner must also evaluate the correct vertical dimension, taking into consideration the fact that for the elderly patient, the free space should be more important. All the mentioned parameters create the denture space. In fact, the design of the complete denture, a non-invasive denture, is the *sine qua non* of stable prosthodontic rehabilitation.

10.6 Method and Materials: Satisfaction

10.6.1 Modeling Technique for a Physiological Complete Denture

A traditional anatomical and functional impression is obtained. Then, proper vertical dimension and a centric relation are established using wax rims. The rims are transferred with a face-bow to a semi-adjustable articulator, and the upper and lower teeth are mounted on a polymerized acrylic base.

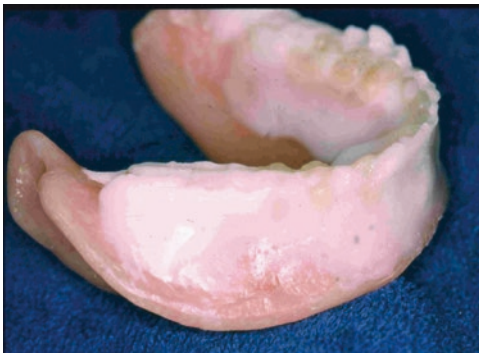
At this stage, when checking the denture, good retention of the upper denture versus a very poor retention and stability of the lower one can be observed. Therefore, in this study we focus the technology on the mandible. As there are three main denture aspects, a nonpolished surface, an occlusal surface, and a polished surface, only the polished surface can be changed.

Fig. 1. To register the denture space in this way, the polished surface is recovered with a soft lining material (G. C. Soft Liner) and the patient is asked to perform functional movements such as speaking and swallowing.

Fig. 2. After setting the material, the new design of the prosthesis appears, reproducing not only the symmetrical aspect, but also the physiological denture space.

Fig. 3. Before the final polymerization, the dental technician should remove a number of teeth and utilize the registration material as a model of the denture's polished surface. In several cases, there will not be enough space for the second lower molar conducting to a short arch (Fig. 10.7).

Teeth set-up using the Nijmegen approach [18].



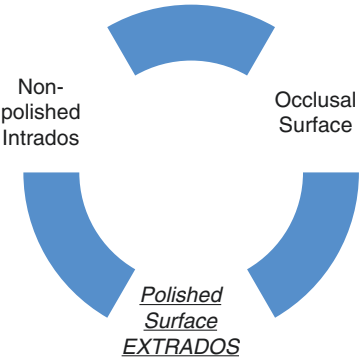


Fig. 10.7 Rationale of phonetic impression

A number of publications reported several variations of the method, under the concept of respect for the neutral zone, or piezography or phonetic impressions [19].

10.7 The Study

The aim of our study is to explore the validity of this registration in terms of comfort, stability, retention, phonetics, and satisfaction. For this purpose, 46 edentulous geriatric patients were rehabilitated using this method. In total, 21 men and 23 women with severe lower maxilla atrophy, a group of 51 elderly patients with classic dentures, and another group of 46 elderly patients with the modified physiological dentures, were examined. They were kindly asked to report their answers to the practitioner (Table 10.1).

In addition, there was a follow-up to register the number of sore points and how many visits were necessary to obtain a satisfactory result (Table 10.2), and to see the general satisfaction of the patients concerning their comfort, esthetics, mastication, and retention of the new dentures.

Table 10.1 Satisfaction with conventional dentures

Total number	Satisfied	Not satisfied
51	22	29
Percentage	43.2	56.8

Table 10.2 Satisfaction with physiologically designed dentures

Number	Satisfied	Not satisfied
46	31	15
Percentage	65.3	34.7

10.8 Results

In this study, the main target was to ascertain that the physiological method was promoting more satisfaction than the conventional one, in terms of comfort and fewer sores and to have a good positive follow-up (Table 10.3).

65.3% of the patients were in favor of the Physiological Method, whereas 43.2% were in favor of the conventional technique.

Concerning the comfort parameter, the physiological design denture was the most appreciated: 76% versus 24% for the conventional dentures.

Also, the number of visits because of sores was lower, especially in the mandibular dentures (Table 10.4).

There were no significant differences concerning the phonetics issue.

10.9 Discussion

In this atypical situation, an adapted solution was the result of a correct diagnosis and the making of the appropriate clinical decision.

The clinical technology was relatively simple and non-invasive; the results, in the short and long term, excellent. The other solution proposed was not realistic when taking into consideration the capacity of the patient to undergo a surgical approach. The main problem in the atypical cases is that the dentist is usually educated as a surgeon and trained to eliminate the defect or the lesion, and after that to start the reconstruction phase. The dentist should act more like a physician, trying to eliminate the illness. In the related case, the dentures were utilized as physiotherapy devices.

Implants are broadly recommended over dentures as a consensus solution. Nevertheless, with the growing gray population, there are some strict limitations, especially systemic diseases, neurological disorders, psychological factors, and financial conditions. In several cases, it is simply the fear of invasive treatment (Figs. 10.8, 10.9, 10.10, 10.11, 10.12, 10.13, 10.14, 10.15, 10.16, and 10.17).

Table 10.3 Comfort appreciation

Appreciation	Good (%)	Poor (%)
Conventional dentures	38	62
Physiological design	76	24

Table 10.4 Number of visits due to sores

Visits	Upper maxilla	Lower maxilla
Conventional dentures	3	6
Physiological design	3	3

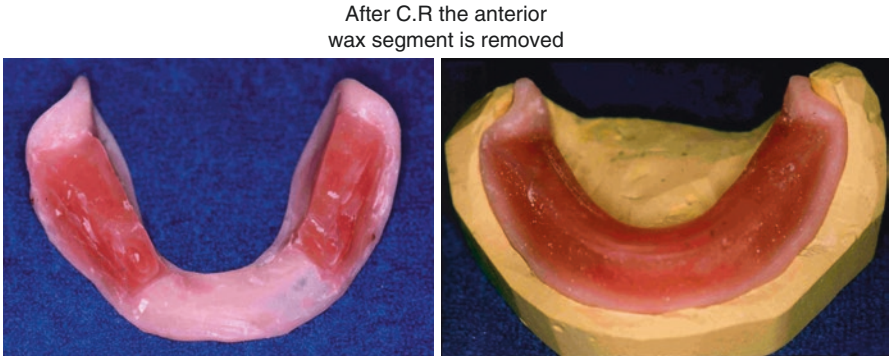


Fig. 10.8 Anterior registration

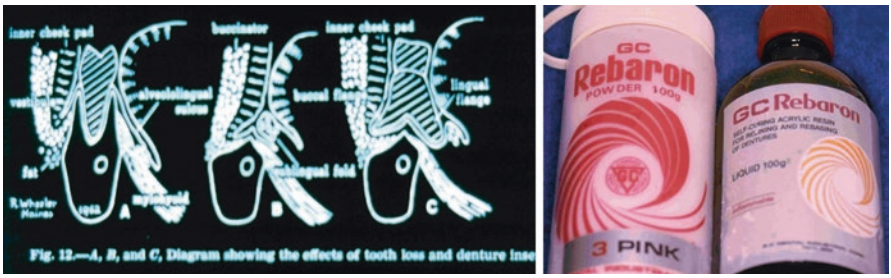


Fig. 10.9 Registration procedure with rebasing acrylic

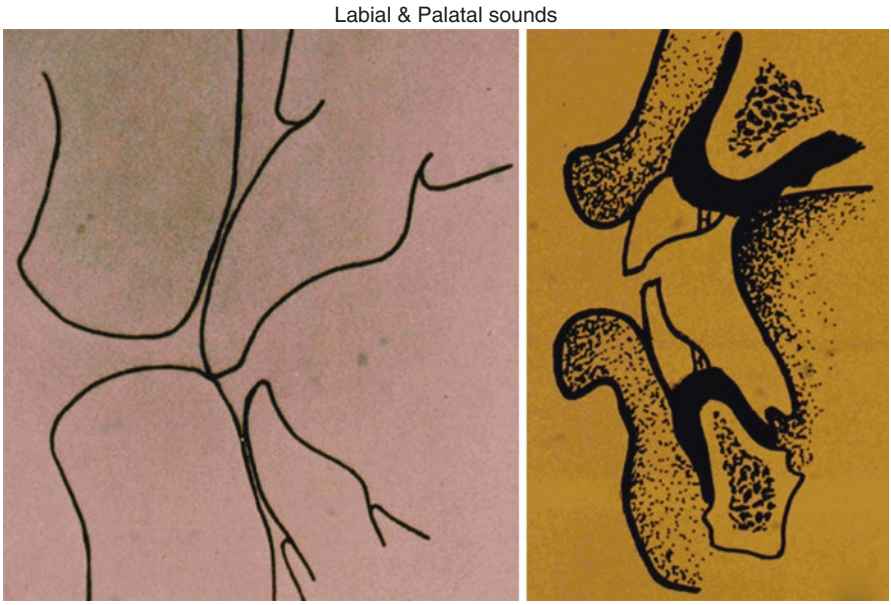


Fig. 10.10 Phonetic sound during the setting

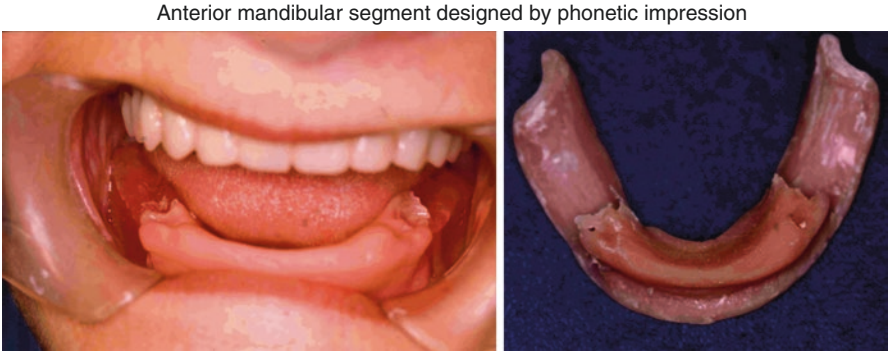


Fig. 10.11 Anterior segment designed by phonetic impression

Fig. 10.12 Piezography of the right posterior mandibular segment

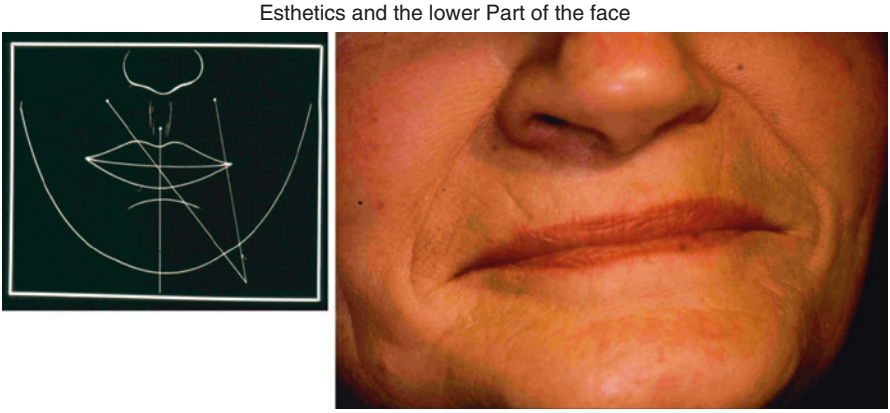


Fig. 10.13 Esthetics of the lower part of the face

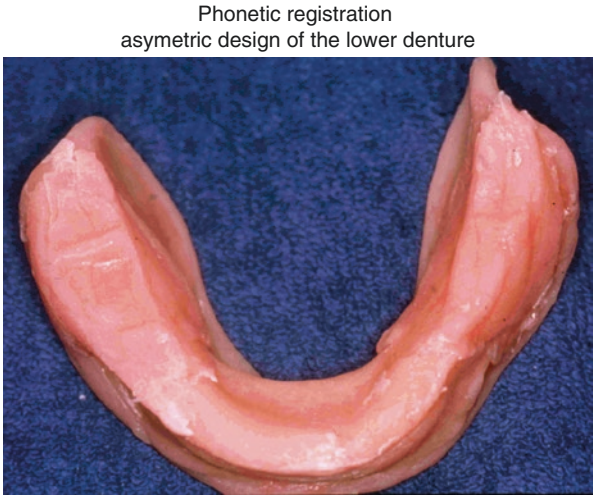


Fig. 10.14 Phonetic asymmetric registration of the lower denture space

Fig. 10.15 Perfect fitting of the lower denture

10.10 Occlusion for Complete Dentures: An Adapted Approach

10.10.1 The Inter-Maxillary Relationship

10.10.1.1 The Vertical Dimension

The determination of the vertical dimension (VD) is the key issue for correct oral rehabilitation. This is also the starting point to find out the vertical dimension of occlusion (VDO). The vertical dimension of rest is registered when the patient is in a full resting position (vertical dimension of rest, VDR) It has been admitted that the difference between the two measurements gives the freeway space (FWS): VDR – VDO = FWS. Usually, the VDR is determined when the patient is sitting in a vertical

Fig. 10.16 Teeth setting in respect of the denture space registration

Fig. 10.17 Function and esthetics 50 years later

position, the old upper denture or the new polymerized final base and the wax rim in place. It is not recommended for to wear the lower denture. Phonetic tests are then performed until the mandible is stabilized in its resting position. During this important procedure, it is important to observe a silent atmosphere (Figs. 10.18 and 10.19).

10.10.1.2 The Occlusal Plane

Before starting to deal with the occlusal plane, the dentist should establish the occlusal plane of orientation (OPO). This intermediary step allows the construction of the occlusal rim on the vertical and horizontal aspects.

As a guideline, there are two main approaches:

1. The classical plane of Camper; anatomical landmark. Camper was a Dutch anatomist at the end of the seventeenth century. A line is drawn between the upper part of the tragus and the lower part of the ala of the nose. In the horizontal plane,

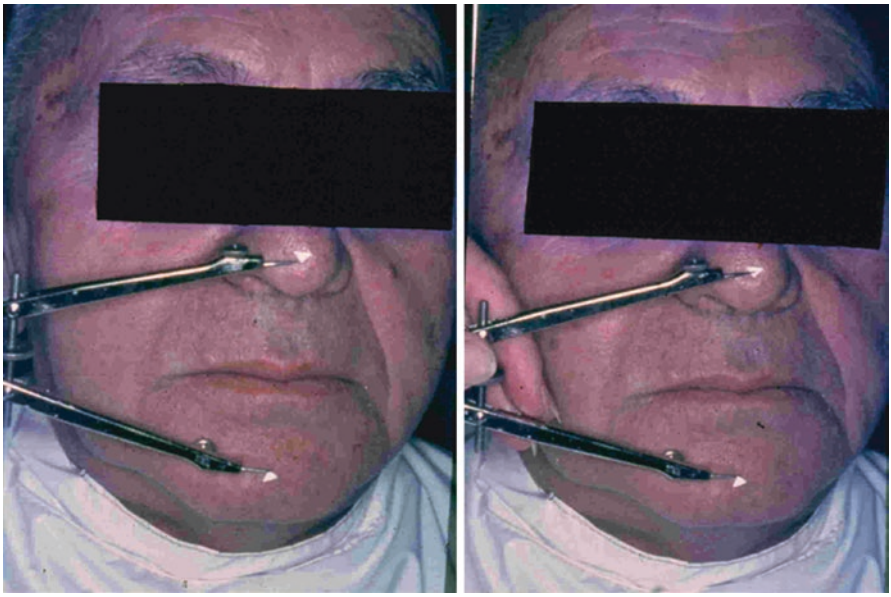


Fig. 10.18 Vertical dimension of rest (VDR)

Fig. 10.19 Vertical dimension of occlusion (VDO)

the rim is trimmed in a line parallel to the inter-pupillary line. The occlusal plain is mainly determined by the upper skeletal anatomy. Therefore, a number of authors reject this procedure (Fig. 10.20) [20].

2. A physiologic landmark: it is obvious that the tongue is the main partner in the oral rehabilitation process. Ignoring this important fact will lead to failure. Therefore, in the construction of the lower rim, the landmark will the 2/3 retromolar pad and the corner of the lower lip, taking into consideration that the dorsal surface of the tongue at rest is parallel to this plane. Doing so a second time, the maxillary rim is adjusted to the lower rim contrary to the Camper line

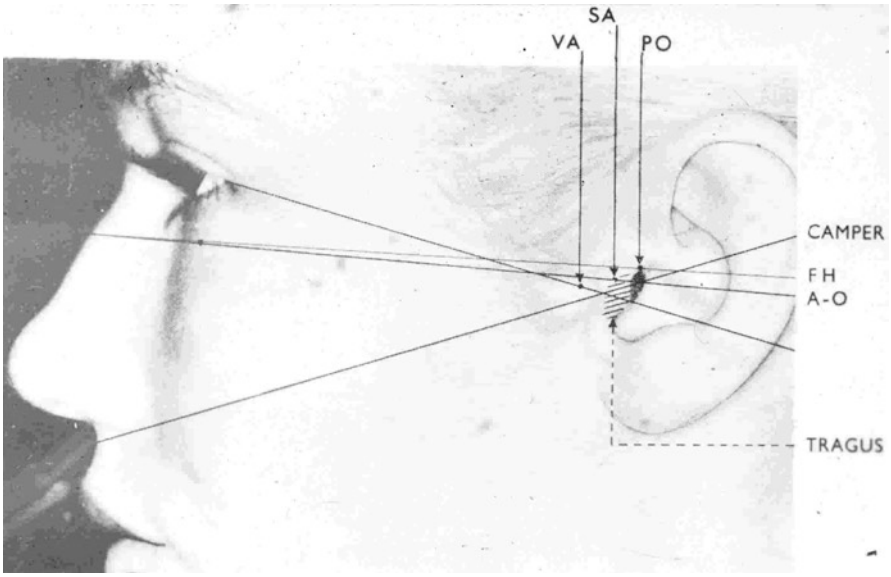


Fig. 10.20 Hinge-axis, anatomical or physiological

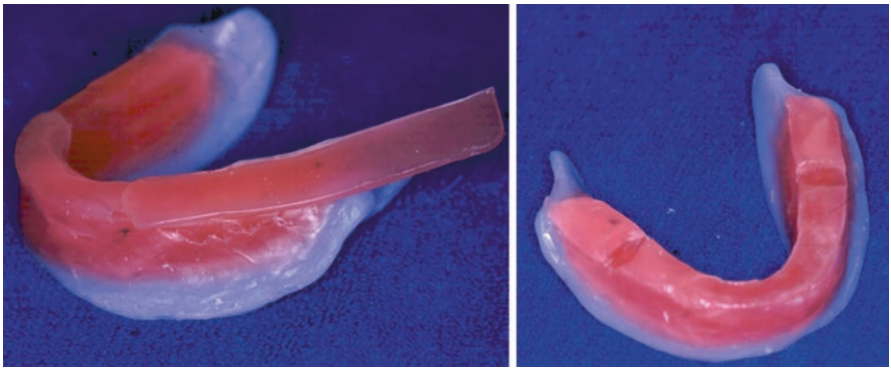


Fig. 10.21 Realization of a mandibular lingual occlusal reference plane

registration where the lower rim is referred to the upper rim (Figs. 10.21 and 10.22). A study performed on the difference between these two approaches indicated an average of 8°, or 2 mm in the posterior part of the lower rim [21]. This change in the occlusal plan has an influence on the establishment of a balanced occlusion (Hanau's quint).

10.10.1.3 Anterior Teeth Arrangement: Esthetics

Obviously, esthetics is a very complex factor in dental practice. There are often important differences between the perceptions of the dentist and the patient.

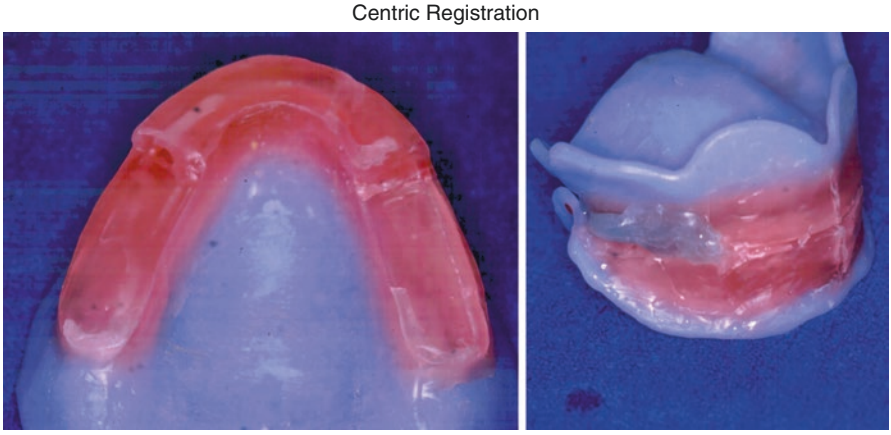


Fig. 10.22 Centric relation registration using this plane

Therefore, it is advised to progress step-by-step following the classical concepts; old photos could be helpful in these cases (Figs. 10.23 and 10.24).

1. The profile: the dentist is generally working "on face" and forgets to look at the profile. The support of the lips is crucial. During speech, the appearance of the acrylic pink base is often ugly. The skeletal relationship between the upper and lower jaws often shows a lower prognathic situation, giving the patients an unconventional aspect (Fig. 10.25) [22].

   The analysis of the nasolabial angles is extremely relevant for the upper tooth position [23].
2. The midline: this landmark is supposed to be the median limit between the right and left sides of the patient's face. In reality, because every individual is asymmetrical, the two sides are not equal. Under these circumstances, the midline is a compromise among several factors such as the inter-pupillary line, the vermillion of the upper lip, and the nose. The maxillary incisive papilla is not an acceptable unique landmark (Fig. 10.26) [24].
3. The choice of the teeth: the color choice is crucial and requires the participation of the patient. Usually, presenting several sets of maxillary teeth and not a simple tooth sample is recommended. The shape is also important, based on the anatomy of the maxilla, the size of the residual ridge and the shape of the face. The form of the teeth is guided by the dentist, who is able to test the smile and the speech function.
4. The centric relation: this strategic point commands maximum intercuspation, as a departure from the eccentric movements to the right, the left, and the protrusive relation. For young or middle-aged patients, this point is relatively easy to find, but it will be a difficult challenge for elderly patients who have been functioning under suboptimal circumstances for a long time. In these cases, the prosthodontists should find a free centric relation, thereby enabling a comfortable restoration.

Fig. 10.23 Discrepancy between the upper and lower midline

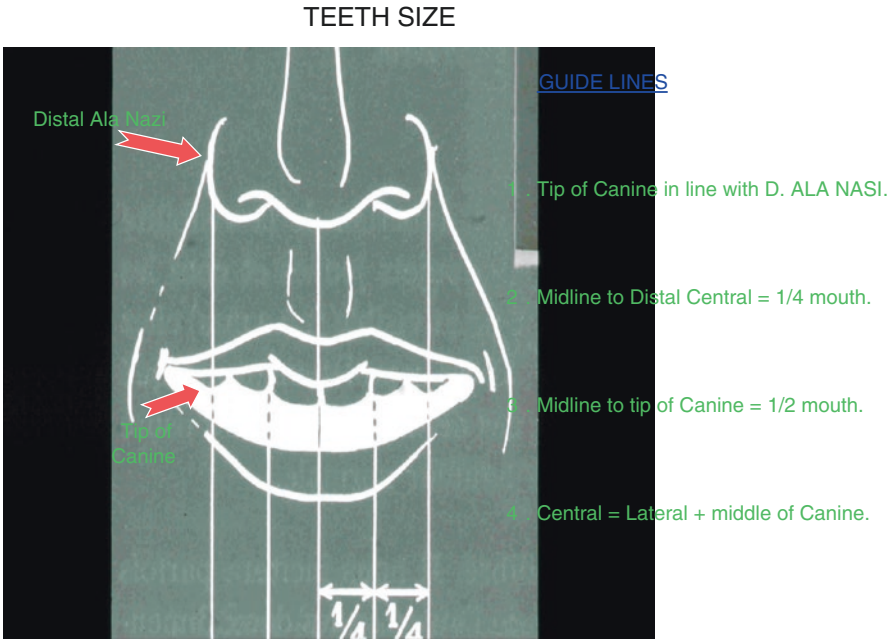


Fig. 10.24 Relationship of the anterior teeth set-up and the face

10.10.2 Bilateral Balanced Occlusion

The aim of this procedure was to deliver an articulation system obtaining simultaneous contact of all teeth. This dogma occurs only when the patient is a bruxist, but not in normal individuals [25]. Some authors recommend a bilateral balance occlusion without anterior contact to avoid dislodgment of the upper

Fig. 10.25 Nondental factors in treatment planning

NON DENTAL FACTORS

AGE
MEDICAL STATUS
PATIENT UNCOOPERATIVE
INABILITY TO TOLERATE RESTORATIVE PROCEDURES
INABILITY TO CARE FOR ONE'S TEETH
PATIENT/FAMILY REQUEST EXTRACT.
LACK OF FINANCIAL RESOURCES

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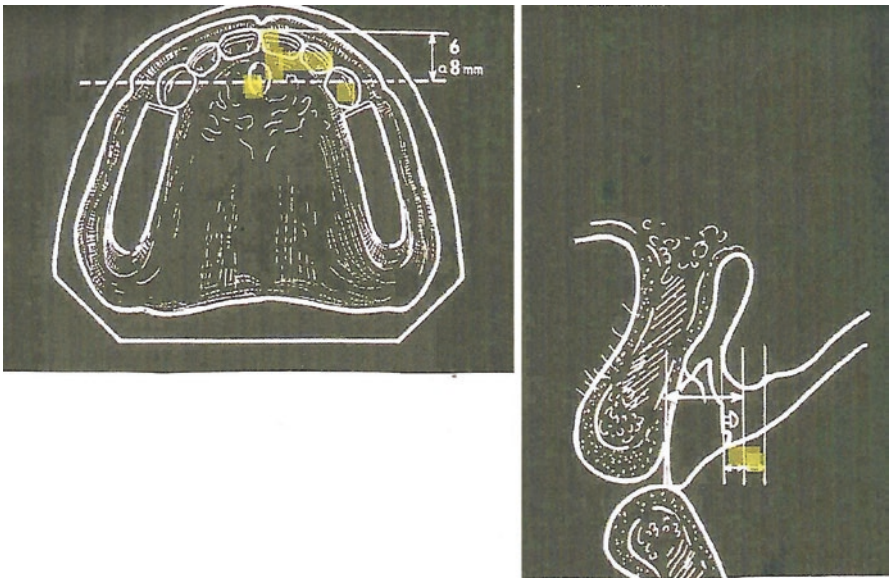

Fig. 10.26 Anterior set-up in relation to the incisive papilla

denture. In fact, it is very difficult for the elderly to adapt f to an intercuspation system after flat occlusion. In fact, a side of the intellectual satisfaction engineering a proper occlusion for the patient is a strange issue; often a return to the old dentures is requested.

10.10.3 Teeth Arrangement Dogmas

To obtain a perfectly balanced occlusion, the use of several complex instruments based on classical theories is taught to dental students.

1. The articulators:
   the most common articulators are the semi-adjustable articulators, which means that they are able to only partially reproduce the dynamic of the maxillary

and the mandibular teeth. Since Bonwill, Gysi, and Hanau, various types have been launched.

When examining the articulator, it can be noticed that:

– Only the upper maxilla is moving and not the lower mandible
– The two condyles are at the same high level.
– The condylar guidance glides in a flat trail

2. The face bow:

this device is aimed at isolating the hinge axis and reporting the relationship of the maxilla and condyle to the articulator. There are two main remarks:
– The hinge axis is not an anatomical landmark but a geometric figure
– The intra-auricular face-bow utilizes the external acoustic meatus, and had no value because the morphology of each individual changes (Figs. 10.26, 10.27 and 10.28).

Therefore, the utilization of this method could only be accepted for an attempt at a balanced occlusion approach. This also explains why after their studies general practitioners are not enthusiastic about performing an oral complete denture restoration with these devices [26].

10.10.3.1 The Updated Occlusal Concept

This approach is based on respect of the physiological situation of the patient, if the actual VD, the asymmetrical chewing cycle, and the anterior maxilla–mandible relationship are taken into consideration. An important step is also the appreciation of the neutral zone, defined as the potential space between the lips and cheeks one side and the tongue on the other side [27]. Then, the dentist should evaluate the limits of the possible corrections (Figs. 10.28 and 10.29).

The set-up of the teeth. At this stage, a first set-up is obtained, respecting the orientation plane defined by the mandibular landmarks. After the centric relation has been established by simple open–close hinge axis movements, the patient is asked to perform small eccentric movements. The premature contacts are eliminated in accordance with the occlusal concept that states:

1. Elimination of upper buccal contacts.
2. Elimination of the lower lingual contacts.
3. Elimination of anterior teeth contacts by grinding out premature contact on the lower incisors and the lower canines (Figs. 10.30 and 10.31).

10.10.3.2 Delivery, Insertion, and Follow-Up

The last step of our treatment is always complicated by personal emotional involvement from the anxious patient [28] and also from the dentist. Therefore, a severe protocol is recommended during this session (Fig. 10.32) [29].

10.10.3.3 Rationale

Looking at the behavioral attitude of the dentist toward the elderly patient, a number of studies have indicated a negative stereotype. In general, the aged patient was

Fig. 10.27 Traditional esthetics

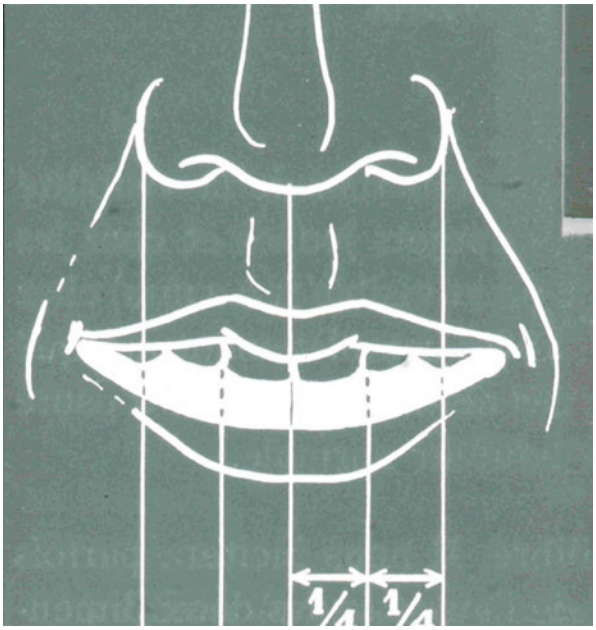

Fig. 10.28 Admitted esthetics

perceived as rigid, unable to adapt, and slow in responding. The professional believed it was safer to diagnose illness rather than health. On the other hand, the practitioner is tired and stressed about dealing with depressed or hysterical patients. A burn-out phenomenon appears to compromise the results of long and hard clinical work.

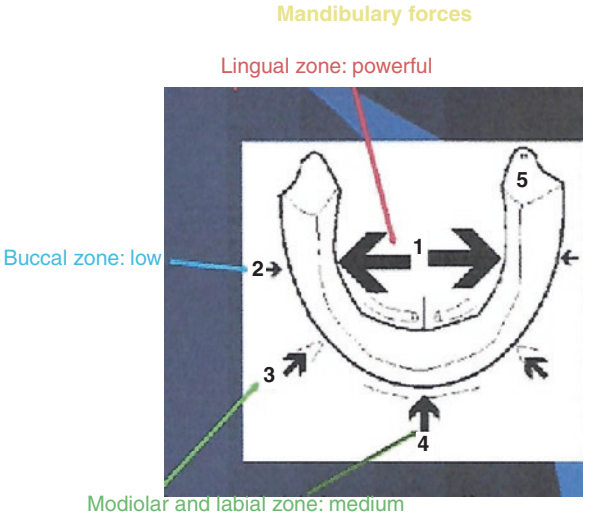

Fig. 10.29 An classic asymmetrical mandible

Fig. 10.30 Occlusion: premature contact in a lateral movement

10.10.3.4 Recommendations

1. Never reveal too much about yourself; elderly patients have generally little interest in younger people's stories.
2. Never show the new dentures before you try them in the mouth. Patients want to examine them and tend to be very critical.
3. Never give the patient the old dentures back, so that he cannot compare them with the new ones.
4. Never deliver new dentures before a week-end, official holidays, or special social events.

Fig. 10.31 Occlusal balance in lateral movements

Fig. 10.32 Major premature contact by the distobuccal cusp

5. Never let the patient come back at his will. Organize a strict follow-up schedule: 24 h post-delivery, then every 2 days, and once a week when reasonable satisfaction is noted.
6. Never speak about implants before examination of the complete situation.
7. Learn to listen to your patients' stories with great attention; thus, open a guided dialogue with them or perhaps their family [30].

Conclusion

Special knowledge and training are necessary before starting treatment in the elderly. Denture rehabilitation was a common form of treatment; however, with the constant increase in the lifespan, edentulous patients present increasingly complicated clinical situations. Obviously, implant-supported dentures are very attractive, but often, because of morphological and psychological factors, this solution cannot be suggested. Recently, some research has tended to present appropriate clinical solutions to prosthodontic challenges. An adapted prosthetic solution and clear psychological management are the keys to success and guarantee a happy ending.

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Implant-Supported Overdentures: Benefits and Risks

11

Joseph Nissan

Abstract

The restoration of edentulous patients using implant-supported dentures became a very popular treatment modality with world-wide acceptance; however, some principles remain controversial. This chapter emphasizes the uniqueness of implant overdentures and some important considerations when such treatment is planned.

It was concluded that the attachment incorporation techniques are detrimental to the long-term prosthetic aftercare and to the benefit or success of implant-supported overdentures, indicating the implant number to be used, attachment type related to splinting or nonsplinting, the importance of timing in restorations.

11.1 Introduction

The statistically increasing life expectancy in the world population has an effect on dental practitioners, who, like specialists from other medical fields, in that they will encounter an increasing proportion of people in the older age group, who most likely will need dentures [1]. Although, the absolute number of people who need complete dentures in the developed world (most western countries) will decrease over the next few decades [2], it will still leave a substantial number of edentulous patients requiring treatment. These patients, with a longer active life and higher standards of life quality, have different expectations of their complete dentures, higher than the standard treatment that conventional complete dentures can offer [3–5].

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The concept of overdentures as a realistic alternative to the extraction of teeth is well documented, presenting the use of remaining tooth roots to gain alveolar bone preservation, improve proprioception, stability, and retention of the prosthesis, resulting in increased properties of function and comfort for the patients. However, several longitudinal studies have shown that patients with overdenture abutments are at a higher risk of developing caries, root fractures, and periodontal disease [6–8]. Ettinger and Qian found a tooth loss rate of 20% (22% for maxillary overdenture abutment teeth and 18.7% for the mandible) after long-term (22 years) overdenture therapy [9].

Progressively, in the current practice of dentistry, implant treatment is increasingly carried out because of functional, anatomical, economic or esthetic advantages. Overdenture on implants has multiple benefits (compared with teeth overdenture or conventional dentures) in achieving better conditions of prosthesis: improved support, retention, and stability together with the proprioception-enhancing balance and effectiveness and provision of an acceptable level of comfort. Moreover, implants reduce further bone resorption and minimize clinical complications [10–15]. The most important topic that causes the shift toward implant-supported prosthesis is the long-term success rate (95.5% after 20 years for implants compared with 80% for teeth overdenture), especially in the mandible [9, 16].

In this respect, the McGill Consensus Statement in 2002 [3] established a new accepted standard of care procedure for patients with complete mandibular edentulism that offers two implant overdentures placed interforaminally, with the possibility of immediate loading, as the primary treatment of care. It became very popular because of the many advantages it brings to patients, significantly improving their quality of life. Furthermore, to emphasize this concept and to support and follow up the McGill Consensus Statement, the York Consensus Statement was released in 2009 [5]. It noted that the two-implant overdenture is not the gold standard of implant therapy, but it is the minimum standard offered to edentulous patients as a first choice of treatment, taking into account masticatory performance, patient satisfaction, cost, clinical time, and patient choice (Fig. 11.1).

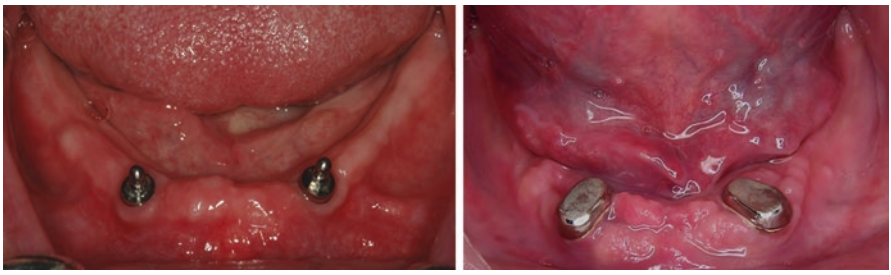

Fig. 11.1 Teeth overdenture and implant overdenture

11.2 Implant-Supported Overdenture: Indications, Advantages, Disadvantages

When considering prosthetic rehabilitation of the edentulous mandible with implant-supported or retained overdenture, various parameters may affect the chosen treatment plan. Subjective and objective patient data, such as residual ridge resorption, the patient's expectations, medical condition, motoric skills, and financial capabilities have to be considered [17].

The major indications for implant-supported overdenture (ISOD) can be divided into patient level and arch level. At the patient level, demand for greater retention for an existing mandibular denture, exhibiting advanced resorption of alveolar ridges, and experiencing parafunction; patients with decreased oral motor control (facial paralysis, Bell's palsy, elderly patients, Parkinson's disease) and decreased manual control, which may compromise oral hygiene; edentulous patients demanding a more stable mandibular complete denture or overdenture prosthesis, but who have a limited financial budget; medically compromised edentulous patients who cannot cope with complicated, long implant-supported fixed prosthesis treatment; maxillofacial patients, other important indications may be considered at the interarch and arch level when treating edentulous patients with ISOD instead of fixed implant supported restorations, such as: increased inter-arch clearance/discrepancy, vertical clearance (crown height space, CHS) of more than 12 mm, horizontal discrepancy between upper and lower jaws. At the arch level considerations such as advanced resorption of alveolar ridges owing to the deficiency of the primary bearing area (buccal shelf), sharp mylohyoid ridge and deficiencies due to congenital conditions, post-trauma, maxillo-facial surgery or failure of previous fixed implant prosthesis should be taken into account.

The advantages of using ISOD are: Improved denture retention, denture stability and stable occlusion, simplicity, irretrievability, easy implant follow-up, avoidance of pre-prosthetic surgery (vestibuloplasty) and bone augmentation, reduced alveolar bone resorption (anterior mandible alveolar ridge height reduction 0.5 mm over 5 years and long-term resorption 0.1 mm annually compared with 0.4 mm annually) [18, 19]. A major advantage of using ISOD is in cases of advanced bone loss with alteration of peri-oral tissue support and potential changes in facial appearance in which ISOD maintains facial esthetics by supporting peri-oral soft tissues (lips, etc.) compared with fixed implant-supported restoration.

On the other hand, ISOD also presented some disadvantages such as it may not psychologically satisfy patients whose expectation is set on a fixed prosthesis; it will not solve the complaint of food penetration and accumulation for the patient with a conventional complete mandibular denture; the overall cost of an ISOD is more than 1.8 times that of a conventional complete denture [20, 21].

11.3 IOD: Implant Number and Position

A controversy exists in the literature as to the number of implants recommended for retaining or supporting a mandibular overdenture. It is important to be able to justify how many implants should be used to support or retain an overdenture in each individual case. Addressing the topic of the number of implants, on the one hand, installing more than two implants benefits from less denture rotation around the implant fulcrum than when using only two implants, and better survival of the prosthesis in the case of an implant failure. If shorter implants have to be used, there should be more than two implants [22–24].

It seems that for overdenture treatment of the mandible, the success rate of implants and prostheses or patient satisfaction is not very dependent on the number of implants or abutment type. If cost-effectiveness is the preliminary goal, a two-implant overdenture provides an excellent alternative to a conventional complete denture. This recommendation is supported by comparative prospective studies of patients with two or four implants in the edentulous mandible. These studies concluded that there were no significant differences in survival rates, clinical outcomes, and patient satisfaction for mandibular overdentures supported by two or four implants in the interforaminal region [25, 26]. Patient satisfaction or function of the prosthesis do not seem to be dependent on the number of implants or type of attachment used; there was no statistical difference when long-term maintenance was compared among mandibular implant overdentures retained by two implants compared with those retained by three or more implants [27, 28]. Even the masticatory performance is not influenced by the number of implants used to support the overdenture (two, four, and six implants) [28, 29].

In cases of opposing natural dentition or fixed prosthesis, more than two implants are recommended to provide better stability [27].

When two implant placements are used for retention, the preferred positions are 42 and 32. The lateral incisor position offers mechanical advantages, providing the maximum soft-tissue surface for load distribution and reduction of potential tipping forces (Fig. 11.2) [30, 31].

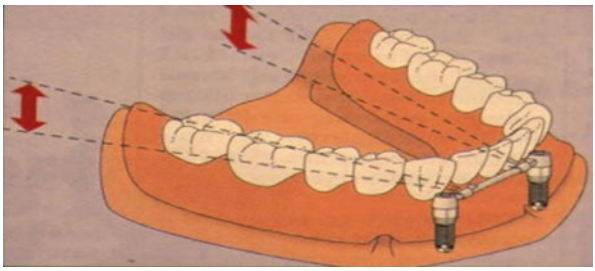

Fig. 11.2 Preferable implant position for implant-supported overdenture (ISOD)

11.4 Attachment Type: Splinting Vs. Nonsplinting, Immediate Loading/Loading Time

In general, ISOD attachments can be classified as studs, magnets, and bars [32]. They can be used as an isolated attachment mounted directly to the implant or attached to a bar system. Ball attachments are considered to be the simplest type of attachments for clinical application with tooth or ISODs and have proved to be reliable among the retention systems available. It appears that the attachment system does not influence the success rate of implants. Other factors, such as bone quality and quantity and arch morphology, seem to play far more important roles in implant survival rates. Implant survival does not appear to vary by splinting, rotational characteristics, or the number of implants, and ranged from 93 to 100% at 10 years [33, 34].

Controversy was mentioned concerning whether to use splinted (ball, locator) or nonsplinted (bar) attachments; no significant differences were shown in implant survival rates, patient's satisfaction, patient's preference, prosthesis retention, and the peri-implant outcome between the two different designs of ISOD [35].

Another controversy deals with the loading protocol of conventional vs early loading and immediate loading of implants supporting mandibular overdentures. The meta-analysis by Alsabeeha et al. [36] revealed no significant difference in the outcome between conventional and either early (p = 0.72) or immediate (p = 0.08) loading of implant-supporting mandibular overdentures (Fig. 11.3).

Fig. 11.3 Different types of stud and nonsplinted attachments for ISOD

11.5 Prosthetic Aftercare and Incidence of Technical Complications

Post-insertion prosthetic complications, which require aftercare over the years, are costly and cause discomfort to the patients. There are two categories of complications that can occur in implant therapy: biological and technical (mechanical). Biological complications include implant loss, bone loss around implants, sore spots, and ridge resorption.

"Technical complications" serves as a collective term for mechanical damage to the implant and implant components and superstructures. Such complications include implant fracture, wear or corrosion of the retention elements, fracture of the retentive elements or superstructure, abutment fracture, abutment screw loosening or fracture, attachment screw loosening or fracture, activation or changing of the clip, matrix activation (change of the rubber ring) or replacement (change of the ring housing), rebasing or relining of the overdenture, and overdenture fracture [37].

As was reported, technical complications concerning the attachments used are the most frequent [38].The attachment part can be incorporated into the mandibular complete denture, either by a direct (intraoral chair-side) or by an indirect (laboratory) technique [39]. In the indirect technique, impression-taking discrepancies and denture laboratory processing may result in inaccurate attachment incorporation, which increases the need for aftercare treatment. On the other hand, the direct technique using intraoral attachment incorporation, overcomes such inaccuracies and minimizes the need for aftercare treatment. It was concluded that the direct technique for attachment incorporation in mandibular ISODs is superior to the indirect technique, in both immediate (pressure sores) and long-term (liner and attachment replacement) aftercare treatment (Fig. 11.4) [39].

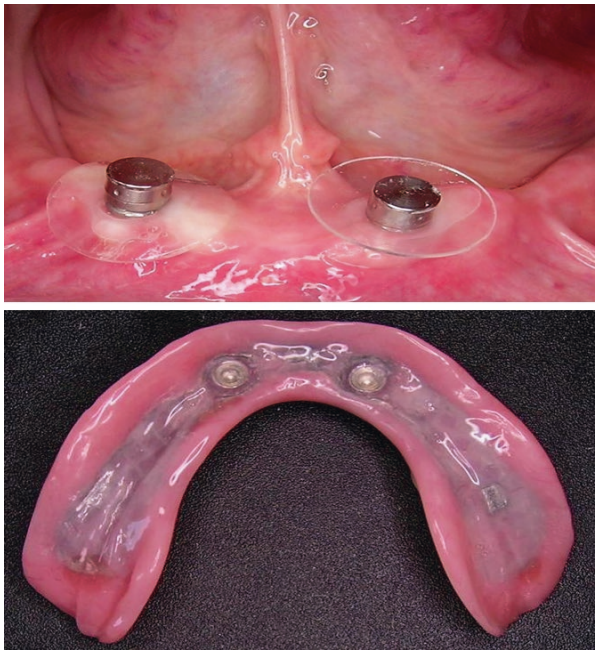

Fig. 11.4 Direct technique for attachment incorporation at ISOD

11.6 Conclusion and Clinical Recommendations

To achieve high levels of clinical success when using ISOD, these principles should be followed:

- ISOD is the preferred restoration for the edentulous mandible.
- In most cases two implants are sufficient to support the ISOD in edentulous patients.
- Ball attachments are considered to be the simplest type of attachment for clinical application with ISOD.
- There was no significant difference in the outcome between conventional and early or immediate loading of ISOD.
- The preferred positions for implants is 42 and 32 for ISOD.
- The direct technique for attachment incorporation in mandibular ISOD is superior to the indirect technique in both immediate (pressure sores) and long-term (liner and attachment replacement) aftercare treatment.

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Correction to: Minimalistic Approach for Conservative Restorations

Michel Goldberg

Correction to: A. Mersel (ed.), *Oral Rehabilitation for Compromised and Elderly Patients*, https://doi.org/10.1007/978-3-319-76129-9_8

The original version of Chapter 8 was inadvertently published with the incorrect figures and captions.

The chapter has been updated with the correct figures and captions listed below:

Figure 8.1; Page 122

Figure Caption: Initial enamel carious lesion including the different zones

Figure 8.2; Page 123

Figure Caption: Section of a white spot lesion: initial enamel carious lesion including the different zones

Figure 8.3; Page 124

Figure Caption: Initial carious lesion in dentin: schematic representation of the different carious layers (necrotic debris, soft carious dentin, intermediary zone: a mixture of soft carious dentin and empty tubules, above the sclerotic zone.

Figure 8.4; Page 126

Figure Caption: *rd*: reactionary dentin, and rep: reparative dentin after pulp capping with Dycal after 4 weeks. CTI is the calciotraumatic line at the junction between secondary and tertiary dentin.

Figure 8.5; Page 133

Figure Caption: Multipotent cell line may differentiate into bone (osteogenesis), cartilage (chondrogenesis), fatty tissue (adipogenesis) and odontogenesis. H8 and C5 are monopotent cell lines that do not display any change in their phenotype.

The updated original version for this chapter can be found at https://doi.org/10.1007/978-3-319-76129-9_8

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Figure 8.6; Page 134

Figure Caption: The cell line A4 express DSP and DMP1, in contrast with the H8 and C5 cell lines which are not reactive. B: Bone differentiation C: Immunovisualization of proteoglycans D: Lipids are expressed as LPL and PPAR gamma 2.

Figure 8.7; Page 135

Figure Caption: a & c: Anti-dentin sialophosphoprotein (DSP) immunolabelling. c & d Immunolabelling was carried out with an anti-osteopontin (OPN) antibody The anti-BSP shows extensive labelling nera the pulp perforation, but no around the agarose bead (b). Anti-OPN labeling is strong around the agarose beads, acting as a carrier for the protein.

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