10 Occlusion and Temporomandibular Joint Disorders

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10.1 Introduction

The term Occlusion belongs to the Latin verb *occludere,* meaning "to close up", "Occludere" in turn comes from the prefix *ob-,* denoting "in the way", and the verb *claudere,* denoting "to close or shut". In dentistry, the term occlusion is used for four separate entities (Table 10.1) [1–3].

As stated by ***Glossary of Prosthodontic Terms*** (GPT) 9, occlusion can be defined as

1. The act or process of closure or of being closed or shut off.
2. The static relationship between the incising or masticating surfaces of the maxillary or mandibular teeth or tooth analogues [4].

The success of any restorative procedure depends solely on the stable occlusal contacts and various components of stomatognathic system. Any discrepancies in the occlusion are identified as a major aetiological factor for the development of temporomandibular joint disorders (TMDs) [1, 3].

Table 10.1 Entities for occlusion in dentistry

1	Angle's classification—For anatomic or orthodontic jaw relation
2	Static contact of the maxillary and mandibular teeth
3	Dynamic contact of maxillary and mandibular teeth in form of canine guided occlusion or group function occlusion
4	Classifications in prosthodontics for the complete dentition or incomplete dentition with fixed or removable prosthetics

10.2 Origin of Occlusion

An initiative to the study of occlusion dates back to the nineteenth century to Orthodontists, who endeavour to decode the concept for arrangement of dentition. Karolyi (1901) discussed the role of occlusion in bruxism, without any evidence and suggested that occlusal interferences are responsible for the atypical temporomandibular joint (TMJ)/masticatory muscle function, periodontal disease and bruxism. In the 1920s Goodfriend dissected cadaver heads with an attempt to correlate the dental occlusion with joint anatomy. He concluded that many factors play an important role in the predisposition and escalation of

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cranio-mandibular disorders like muscle spasms, external injuries, deleterious habits, stressful life style, etc. [5, 6].

Costen reported increase in vertical dimension is responsible for altered pressures on the joint. He assumed that this altered pressure in the joint is responsible for glossopharyngeal neuralgia and disturbed Eustachian tube function. This gave rise to the concept of occlusal pain and dysfunction co-relation. *Travell and Ramjford* reported that occlusal adjustments are beneficial in patients with both intra-capsular and extra-capsular disorders. Contrary to Costen's work, they suggested that the discrepancy between centric relation and centric occlusion is more significant interference rather than changes in vertical dimension [5, 6, 7].

10.3 Various Concepts of Occlusion

10.3.1 Gnathological Concept

The term *gnathology* was coined by Stallard in 1924. In 1926, McCollum formed the Gnathological Society together with Harlan, is credited with the ascertainment of the first conclusive method of locating the transverse horizontal axis. These recordings are transferred to an articulator using a Snow Facebow.

The principles of gnathology include the concept of centric relation, anterior guidance, vertical dimension of occlusion, the inter-cuspal design and the correlation of the anterior and posterior determinants of mandibular movements. According to this theory, condylar guidance is established first then anterior guidance will be designed to deocclude posterior teeth when the anterior teeth come into contact [6, 7].

10.3.2 Schuyler's Concept

The concept of "freedom in centric" was first advocated by Schuyler. This concept states that, "the central fossa exhibits a flat area upon which opposing cusps contact and permits a degree of freedom (0.5–1 mm) in all eccentric movements" [6, 8].

10.3.3 Wiskott and Belser's Concept

According to this concept, rather than three-point contact only one-point occlusal contact is sufficient. Anterior guidance should be followed in order to avoid posterior occlusal interferences during lateral excursive movement. Grossly number of occlusal contacts are diminished. It follows the concept of freedom in centric [6, 7].

Pankey, Mann and Schuylers concept was introduced by Pankey and follows the postulate of occlusion given by Schuyler. It follows the principle of spherical theory of occlusion. The anterior guidance is established according to aesthetics, function and comfort. The main objective is to establish and restore the lower posterior occlusal plane in harmony with the anterior guidance in such a way that it will not impede with condylar guidance. After completion of lower posteriors upper occlusal surfaces are established by following functionally generated path technique. It is based on the principle of long centric and group function in working excursion [9, 10].

10.3.4 Hobo's Twin Table Concept

According to this concept, molar disocclusion is determined by two important factors, namely cusp shape and an angle of hinge rotation. This technique utilizes two incisal tables to achieve molar disocclusion. The first incisal guide table is described as the incisal table without disocclusion. The aim of this table is to fabricate restoration for posterior teeth. The second incisal guide table is described as the incisal table with disocclusion. The aim of this table is to achieve incisal guidance with posterior disocclusion [11, 12].

10.3.5 Hobo's Twin Stage Concept

According to this concept cusp angle is the most reliable determinant of occlusion as it does not

deviate. A standard value of cusp angle was determined irrespective of condylar and incisal guidance such that it is possible to establish the standard amount of disocclusion [11, 12].

10.4 Types of Occlusion

10.4.1 Dawson's Classification

This classification system for occlusion links maximal inter-cuspation to the position and condition of the TMJ.

Type I: Maximal inter-cuspation is in harmony with centric relation.

Type IA: Maximal inter-cuspation is in harmony with adapted centric posture.

Type II: For maximum inter-cuspation to occur condyles must displace from a true centric relation.

Type IIA: For maximum inter-cuspation to occur condyles must displace from adapted centric posture.

Type III: Verifying centric relation is difficult.

Type IV: Presence of pathologically unstable TMJs dictates that occlusal relationship is in active stage of progressive disorder [13, 14].

10.4.2 Unilaterally Balanced Occlusion/Group Function

This theory states that, during lateral movement excursive contact occurs between all opposing posterior teeth on the laterotrusive (working) side only. This in turn leads to distribution of load amongst the periodontal support of all posterior teeth on the working side. Disocclusion of posterior teeth occurs during protrusion [13, 14].

10.4.3 Long Centric Occlusion

This theory suggests that there should be some degree of freedom in antero-posterior direction. It is based on presumption that the condyle can translate horizontally in the fossae over a commensurate trajectory before initiating to glide downward. To allow some degree of horizontal movement (0.5–1.5 mm) before posterior disocclusion it is necessary to have a greater horizontal space between maxillary and mandibular anterior teeth [13, 14].

10.4.4 Mutually Protected Occlusion

During the early 1960s, Stuart and Stallard advocated mutually protected occlusion. This theory emphasizes that centric relation coincides with maximum inter-cuspation.

- Uniform occlusal contact of all maxillary and mandibular teeth in centric relation position.
- Posterior tooth contacts should be stable along with vertically directed resultant forces.
- Centric relation must coincide with maximum inter-cuspation.
- During lateral or protrusive movements there should be no contact of posterior teeth.
- Anterior teeth contacts harmonizing with functional jaw movements [13, 14].

10.4.5 Optimum Occlusion

In an ideal occlusal arrangement, there should be optimum load distribution on the dentition. Avoid or minimize horizontal forces on teeth as forces should act predominantly parallel to the long axis of the teeth. The functional cusps tip should be located centrally over the roots. Loading of the teeth occur on the occlusal fossae rather than on the marginal ridges. The contacts of posterior teeth must be avoided during excursive movements [15].

There are various concepts and types of occlusion documented in the literature. Careful assessment of the patient paves way for achieving appropriate contact of the maxillary and mandibular teeth for harmonious function of the stomatognathic system without any adverse effects for the TMJ and other structures in the oro-facial region [15, 16].

10.5 Determinants of Occlusion

Mandibular movements and determinants of occlusion are mainly governed by 3 factors, namely anterior determinants, posterior determinants and others. Anterior determinants include teeth of maxillary and mandibular arches, posterior determinants include right and left TMJ and other determinants include overall neuromuscular system (Table 10.2) [17, 1, 2].

Table 10.2 Determinants of occlusion

Determinants	Conditions	Effect on cusp height and angulation
Posterior determinants		
During protrusion		
Inclination of articular eminence (Figs. 10.1 and 10.2)	Steep Shallow	More cusp height Less cusp height
During lateral translation		
Morphology of medial wall of glenoid fossa which allows immediate lateral shift	More Less	Less cusp height More cusp height
Inter-condylar distance	More Less	Small angle between working and non-working condylar movement Greater angle between working and non-working condylar movement
Anterior determinants		
Over-jet (Fig. 10.3a, b)	Increased Decreased	Short cusp height More cusp height
Overbite (Fig. 10.4a, b)	Increased Decreased	More cusp height Less cusp height
Others		
Plane of occlusion	More parallel to condylar guidance Less parallel to condylar guidance	Less cusp height More cusp height
Curve of Spee	Radius of curve short Radius of curve large	Less cusp height More cusp height

10.6 Aetiology of TMDs

The aetiology for the development of TMDs is multifactorial. It may be biopsychosocial, biomechanical, neurobiological and neuromuscular. The predisposing factors depend on structural, metabolic and/or psychological states. The initiating factors can originate due to recurrent unfavourable loading of the masticatory system or trauma. In addition aggravating factors may include para-functional habits, hormonal changes or psycho social factors [18].

Change in occlusion may be evident in patients undergoing orthodontic, periodontic, prosthodontic or oral surgery procedure(s). Dental procedures like tooth extraction, prosthesis use for missing teeth, correction of malocclusion may change the occlusion in patients. Occasionally the occlusal changes may lead to discomfort in muscles of mastication, with acute pain which later leads to the development of a TMD. The clinical aim of the treating prosthodontist should be to diagnose and manage the occlusal problem initially before the disorder progresses [19].

Several controversies exist regarding the role of occlusion as main aetiological factor for TMDs. Few studies have demonstrated that the occlusion has no role in TMD, unlike others studies where they observed occlusion plays an important role in TMD with the presence of certain features like skeletal anterior open bite, significant over-jet, loss of molar support, extent of lateral deviation of the slide between the retruded contact position and maximal inter-cuspal contact position (RCP-ICP). Severe malocclusion may also be considered as a predisposing factor for degenerative TMJ changes [18, 19].

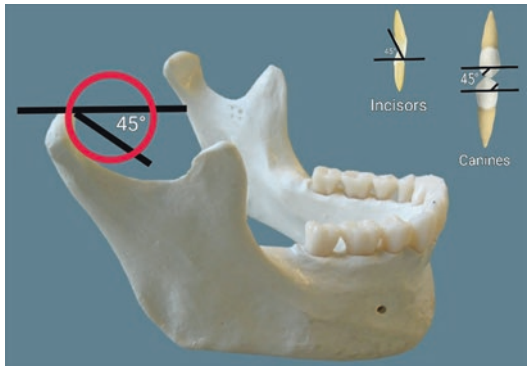

Fig. 10.1 Lesser the angle of articular eminence, lesser the steepness of the cuspal angle and minimum overbite

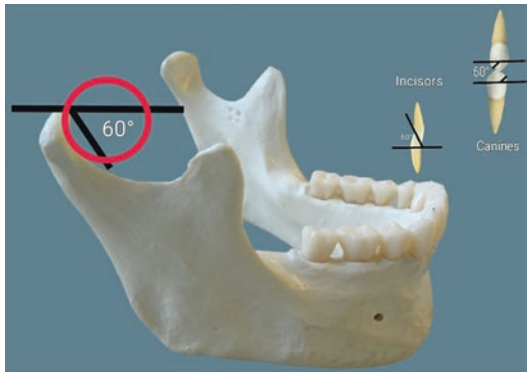

Fig. 10.2 Greater the angle of articular eminence, greater the steepness of cuspal angle and more overbite

Jussila et al. through their research emphasized that occlusal factors exhibited a statistically significant association with development of TMD. The TMD signs were related with unstable occlusion, mainly with the extent of lateral deviation in retruded contact position and inter-cuspal contact position (RCP-ICP) slide, as well as negative over-jet [20].

A typical shift regarding TMDs has occurred recently from the bio-medical model of occlusion to a biopsychosocial model of the disease. In 1977, Engel introduced biopsychosocial model based on a common structure to provide an entire sub-structure in which all the extent of organization relevant to disease and health could be considered. One of the sub-structures of organization in the TMD related to musculoskeletal pain condition is occlusion. The role of occlusion in TMD is not completely assessed and also the effects of the occlusal interferences on TMJ are a subject for exhaustive research [21].

Xie et al. reviewed the association between occlusal interferences and TMDs from insights collected from animal and human experimental analysis and concluded that experimental occlusal alteration can be considered as an interesting topic for occlusion engrossed scientific research. They observed that changes in occlusion leads to

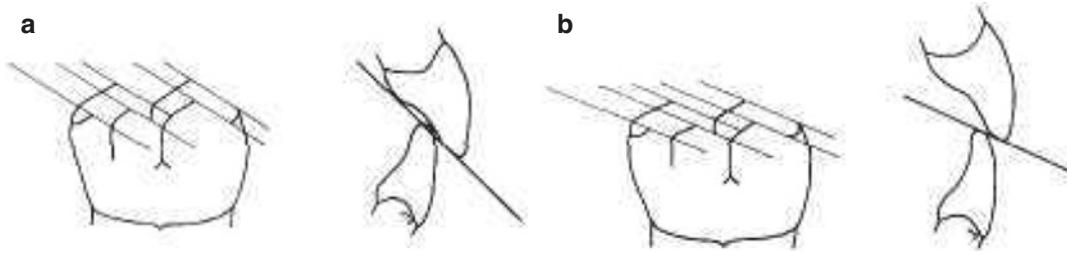

Fig. 10.3 (**a**) Pronounced overbite permits longer posterior cusp. (**b**) Minimum overbite permits short posterior cusp

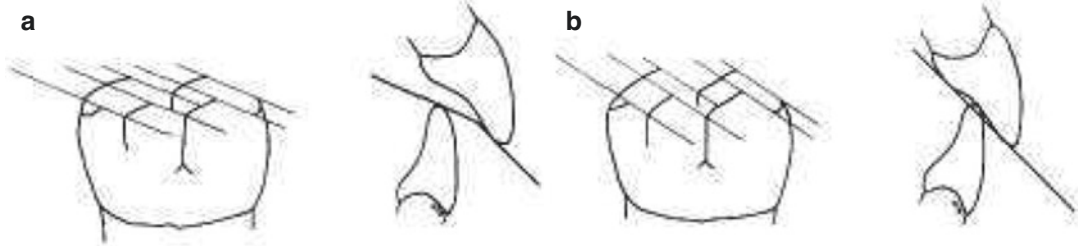

Fig. 10.4 (**a**) Pronounced overjet permits short cusp. (**b**) Minimum overjet permits long cusp

alterations in the masticatory muscles, TMJ and the nervous system in animal models. In human experimental studies, it has been noted that subjects without symptoms of TMD may adapt well to experimental interferences. But patients with a pre-existing symptoms of TMD seem to nominally adapt to the introduced experimental interferences [22].

Many researchers consider occlusal discrepancies as main aetiological factor in the progression of TMJ dysfunction [23, 24]. Zarb and Thompson in their study stated that 61% of the patients had occlusal discrepancy who needed treatment for TMJ dysfunction. The occlusal discrepancies may be in the form of an anterior and/or lateral slide from centric relation (CR) to centric occlusion (CO) or the presence of non-working side contacts and disocclusive contacts distal to the canine on the working side during purposeful lateral side shift of the mandible [23, 25].

10.7 Occlusal Indicators

The main purpose of occlusal indicators is to locate and determine the specific areas of occlusal contact. They may be classified as near contact areas and non-contact areas. Near contact areas are those wherein there is a gap of 0.5 mm between the occluding surfaces, whilst non-contacts are those areas where there is a 0.5–2 mm separation of the teeth.

Presently, a variety of occlusal indicators are available and proper selection of occlusal indicator provides the valuable information regarding refinement of occlusion. Broadly they can be divided as qualitative and quantitative occlusal indicators (Table 10.3). Qualitative indicators are routinely used because of its low cost and ease of use. However, presence of saliva may affect the marking abilities. On the other hand, quantitative indicators mainly identify the time and force of true occlusal contacts. However repeated use of sensor negatively affects the marking characteristics. Every material has its own limitations. The choice of material selection depends upon the clinical condition, clinician's proficiency and sensitivity, economics and comfort [24–28].

Table 10.3 Types of occlusal indicators

Qualitative indicators	Quantitative indicators
Articulating paper	T-scan occlusal analysis system
Articulating silk	Virtual dental patient
Pressure sensitive film	
Metallic shim stock film	
High spot indicator	
Occlusal sprays	
Mylar strips, silk strips	
Polyether rubber impression bites	

10.8 Methods of Occlusal Corrections

10.8.1 Position of the Mandible

McCollum and Stuart had given the centric relation approach and suggested that the condyle should be positioned in the terminal hinge arc of closure. Later, Schuyler, Mann and Pankey suggested that the long centric concept or freedom in centric concept where the terminal hinge position is used as a reference point, with the protrusive movement of mandible in horizontal plane without any change in the vertical dimension. Still, the controversy exists about which position of the mandible is biologically more acceptable. The most common method used to position the mandible is by occlusal splints which will be elaborated in the chapter on occlusal splint therapy.

Enameloplasty/Spot grinding is another technique where only those teeth with heavy occlusal contact were adjusted so that the occlusal load can be re-distributed. Other fewer common methods documented to re-position the mandible are the use of dental, alveolar and skeletal landmarks and by applying external electrical pulses to the pre-auricular region [8, 9].

10.8.2 Canine Protected Occlusion (Group Function Occlusal Scheme)

Nagao, Shaw and D'Amico proposed the theory of canine protected occlusion. It is a type of mutually protected occlusion in which vertical and horizontal overlap of canines disocclude the posterior teeth during excursive movement of the mandible. The protected occlusion is also known as canine disocclusion/canine rise or canine guided occlusion [29]. The most appropriate teeth considered to guide mandibular excursion is canine as

1. It has good crown root ratio.
2. It can tolerate high occlusal forces.
3. It has high proprioceptive response.

The concave nature of the palatal surface of canine makes it suitable for guiding lateral movements. In anterior open bite cases, extreme Angle class II division 1 or class III malocclusion and cross-bite, mandible cannot be guided by anterior teeth and canine guidance cannot be achieved. In order to obtain canine guided occlusion the anterior teeth must be healthy. In cases where healthy canines are present and restoration can re-establish lateral guidance, canine guided occlusion can be given. Cuspid protected occlusion is considered beneficial when posterior teeth have significant bone loss, considerable occlusal wear and in cases of bruxism [30].

10.8.3 Group Function

GPT defines group function as multiple contact relations between maxillary and mandibular teeth in lateral movements on the working side whereby simultaneous contact of several teeth acts as a group to distribute occlusal forces. The group function occlusion was described by Beyron and is commonly known as unilateral balanced occlusion. The group function of the teeth distributes the occlusal load on working side [31].

Group function of working side is indicated in patients with Class I occlusion with extreme over-jet, Class III occlusion with all lower anterior teeth are anterior to the upper arch, end to end and anterior open bite, when the arch relationship is such that it does not allow the anterior guidance to disocclude the teeth on non-working side. Group function is most often seen in elderly population. This occlusal scheme allows achieving harmonious balance of all structures including TMJ and associated musculature.

Furthermore, in a patient with history of bruxism there may be freedom of lateral excursions in group function. Factors such as patient's masticating pattern, craniofacial morphology, type of occlusion, oral hygiene status; para-functional habits might provide the important clue and relevant information about the suitable occlusal scheme for each patient [32].

10.8.4 Tripodal Cusp Contacts

Stuart and Stallard had given tripodal cusp contact theory. It is a posterior tooth-to-tooth contact pattern. Though it is stable in providing occlusion, it is difficult to clinically attain the goals. In this occlusal scheme patient has to function comfortably from a single point centric starting position. Researchers have recommended that "freedom in centric" concept allows cusp tip to fossa or marginal ridge occlusal contact patterns when compared to tripodal concept [33–35].

10.8.5 Occlusal Adjustments to Remove Traumatic Occlusion

Traumatic occlusion should be removed to reduce/eliminate any detrimental effects on the dentition and the TMJ. Traumatic occlusion can produce

1. Cracked/fractured tooth.
2. Initiate pulpitis/pulpal degenerative changes.
3. Leads to tooth mobility.

It is well documented that traumatic occlusion affect the periodontium and can lead to bone loss due to excessive load. It is the responsibility of the clinician to diagnose such discrepancies and deliberately plan the occlusal correction to correct the traumatic occlusion as an early intervention in the course of the treatment [35, 36].

10.8.6 Avoidance/Correction of Occlusal Interferences

An occlusal interference can be defined as any tooth contact that interferes with the remaining occluding surfaces from achieving a balanced and stable occlusal contacts (Table 10.4) [36].

10.8.7 Centric Interference

Centric interference denotes the first tooth contact (FTC) on the arc of rotation enfolding the mandibular movement when maximum intercuspation position does not coincide with the centric relation. In this situation the mandible generally avoids this contact and directly closes in to maximum inter-cuspation. During evaluation, the patient is asked to relax and mandible is guided to centric relation. It is the role of the treating prosthodontist to diagnose the problem and adjust occlusal interference by preparation of the involved tooth.

10.8.8 Working Side Interference

Working side interference refers to the side towards which the mandible is moving. The presence of working interference hampers the smooth movement of mandible leading to separation of teeth on working side.

Table 10.4 Types of occlusal interferences

1	Centric interference
2	Working side interference
3	Non-working side interference
4	Protrusive interference

10.8.9 Non-working Side Interference

Non-working side interference occurs between the inner incline of the supporting cusps of antagonist teeth and disocclude other teeth. The tooth involved will act as a pivot shifting the fulcrum from the TMJ and elevates teeth on working side out of contact. This type of occlusal interference may damage the dental structures and TMJ.

10.8.10 Protrusive Interference

Protrusive interference is observed during mandibular protrusion. It is present between the mesial inclines of mandibular posterior teeth and the distal inclines of maxillary posterior teeth. This type of interferences result in disocclusion of the anterior teeth during movement and may predispose to locking of the mandible. During protrusive movements, anterior teeth and TMJ bear majority of the forces of the elevator muscles. In such cases clinician should diagnose the problem and adjust the occlusal interference.

10.9 Occlusal Consideration for Dental Implants

Implant protected occlusion is an elaborate subject and is not covered in the present chapter in total. In brief, few important points to be considered are highlighted. This concept was first put forward by Carl Misch with an aim to reduce the occlusal forces on implant prosthesis. Few important factors should be considered during designing of occlusal pattern. Incisal guidance should be shallow with maximum inter-cuspation and bilateral stability.

The forces on teeth should be evenly distributed with freedom in centric. There should not be either working or non-working side interferences in lateral and protrusive movements. Any occlusal interference between centric relation and maximum inter-cuspal position should be eliminated by giving flat fossae and grooves. There

should be reduction of occlusal table by one-third in molar region to eliminate any cantilever effects. A shallow incisal guidance concept permits less loading on the anterior implants by disocclusion of the posterior teeth during lateral and protrusive mandibular movements [14].

10.10 Role of Tekscan (T-Scan) in Occlusion and TMJ Disorders

Tekscan is a computerized system developed in 1984 by Maness et al. which records the intraoral occlusal forces with the help of a pressure mapping sensor. The T-Scan makes it possible to quantify occlusal contact data by registering certain parameters such as the bite length as well as the timing and force of tooth contact and stores the data on a hard drive which can be played incrementally in a time-based video for analysis of data.

T-scan is used to record various functional movements of the mandible. It also records any premature contact in centric relation. Multiple bites can be obtained which helps in identifying the habitual inter-cuspation by the patients. The posterior disocclusion time that occurs during lateral and protrusive-excursive mandibular movements can also be recorded. Any mild painful occlusal contacts which occur during chewing can be easily diagnosed which may not be easily identified utilizing the direct observation or ink ribbon markings.

10.11 Applications of T-Scan in Dentistry

T-Scan finds its clinical applications in various fields of dentistry such as in prosthodontics, implant dentistry, orthodontics, restorative dentistry, oral and maxillofacial surgery and in identifying TMDs related to occlusion. Several studies have highlighted the use of T-scan in identifying occlusal discrepancies causing TMDs in human subjects [37, 38, 39, 40].

10.12 Terminologies [4]

Anterior Guidance: (1). The influence of the contacting surfaces of anterior teeth, limiting mandibular movements; (2). The influence of the contacting surfaces of the guide pin and anterior guide table on articulator movements.

Centric Occlusion/Maximal Inter-cuspal Position: The occlusion of opposing teeth when the mandible is in centric relation. This may or may not coincide with the maximal inter-cuspal position.

Centric Relation: A maxilla-mandibular relationship, independent of tooth contact, in which the condyles articulate in the anterior-superior position against the posterior slopes of the articular eminences; in this position, the mandible is restricted to a purely rotary movement; from this unstrained, physiologic, maxilla-mandibular relationship. The patient can make vertical, lateral or protrusive movements; it is a clinically useful, repeatable reference position**.**

Condylar Guidance: Mandibular guidance generated by the condyle and articular disc traversing the contour of the articular eminence.

Determinants of Mandibular Movements: Those anatomic structures that dictate or limit the movements of the mandible; the anterior determinant of mandibular movement is the dental articulation; the posterior determinants of mandibular movement are the temporomandibular articulations and their associated structures.

Interference: Any tooth contact that interferes with or hinders harmonious mandibular movement; an undesirable tooth contact.

Lateral Relation: The relation of the mandible to the maxillae when the lower jaw is in a position to either side of centric relation.

Laterodetrusion: Lateral and downward movement of the condyle on the working side.

Laterotrusion: Condylar movement on the working side in the horizontal plane; this term may be used in combination with terms describing condylar movement in other Planes.

Temporomandibular Joint: The articulation of the condylar process of the mandible and the intra-articular disc with the mandibular fossa of

the squamous portion of the temporal bone; a diarthrodial, sliding hinge (ginglymus) joint; movement in the upper joint compartment is mostly translational, whereas that in the lower joint compartment is mostly rotational; the joint connects the mandibular condyle to the articular fossa of the temporal bone with the temporomandibular joint articular disc interposed.

Temporomandibular Disorders: A collection of symptoms frequently observed in various combinations first described by Costen (1934, 1937), which he claimed to be reflexes because of irritation of the auriculotemporal and/or chorda tympanic nerves as they emerged from the tympanic plate caused by altered anatomic relations and derangements of the temporomandibular joint associated with loss of occlusal vertical dimension, loss of posterior tooth support and/or other malocclusions; the symptoms can include headache about the vertex and occiput, tinnitus, pain around the ear, impaired hearing and pain around the tongue/jaw.

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