2 Periodontal Anatomy and Its Role on the Treatment Planning of Aesthetic Areas

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2.1 The Periodontium: The Balance Between Function and Aesthetics

The periodontium can be defined as "the tissues that invest and support the teeth including the gingiva, alveolar mucosa, cementum, periodontal ligament, and alveolar and supporting bone" [1] (Fig. 2.1).

Shaped during teeth's formation and development, these structures may be modified during a subject's life, leaving their "pristine" characteristics, as result of several inherent local, environmental, and systemic conditions. For instance, parafunctional habits/heavy occlusal forces may promote a reinforcement of the bone trabeculae and the deposition of cellular cementum at the root apex (Fig. 2.2a) [2, 3], periodontitis promotes a resorption of alveolar bone and loss of periodontal ligament (Fig. 2.2b–e) [4, 5], and tobacco smoking may decrease peripheral vascularization and increase keratinization of oral gingival epithelium [6]. Also, even in well-maintained subjects who practiced oral hygiene and returned periodically for maintenance care appointments, slight to moderate incidence of periodontal destruction (0.02–0.1 mm/year) may increase with age, especially between 50 and 60 years of age [7]. Apart of any "positive" or "negative" impact on the periodontium, it is of paramount importance to consider that the conditions of periodontal structures surrounding a natural tooth are directly associated to the patient's quality of life by maintaining the ability to chew, digest food, and smile. Conversely, the clinical response of an individual tooth to periodontal treatment over time may not be easy to be predicted precisely, particularly if the tooth has been exposed to periodontal disease and anatomic and/or traumatic conditions [5, 8–11].

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L. Chambrone (ed.), *Evidence-Based Periodontal and Peri-Implant Plastic Surgery: A Clinical Roadmap from Function to Aesthetics*, DOI 10.1007/978-3-319-13975-3_2, © Springer International Publishing Switzerland 2015

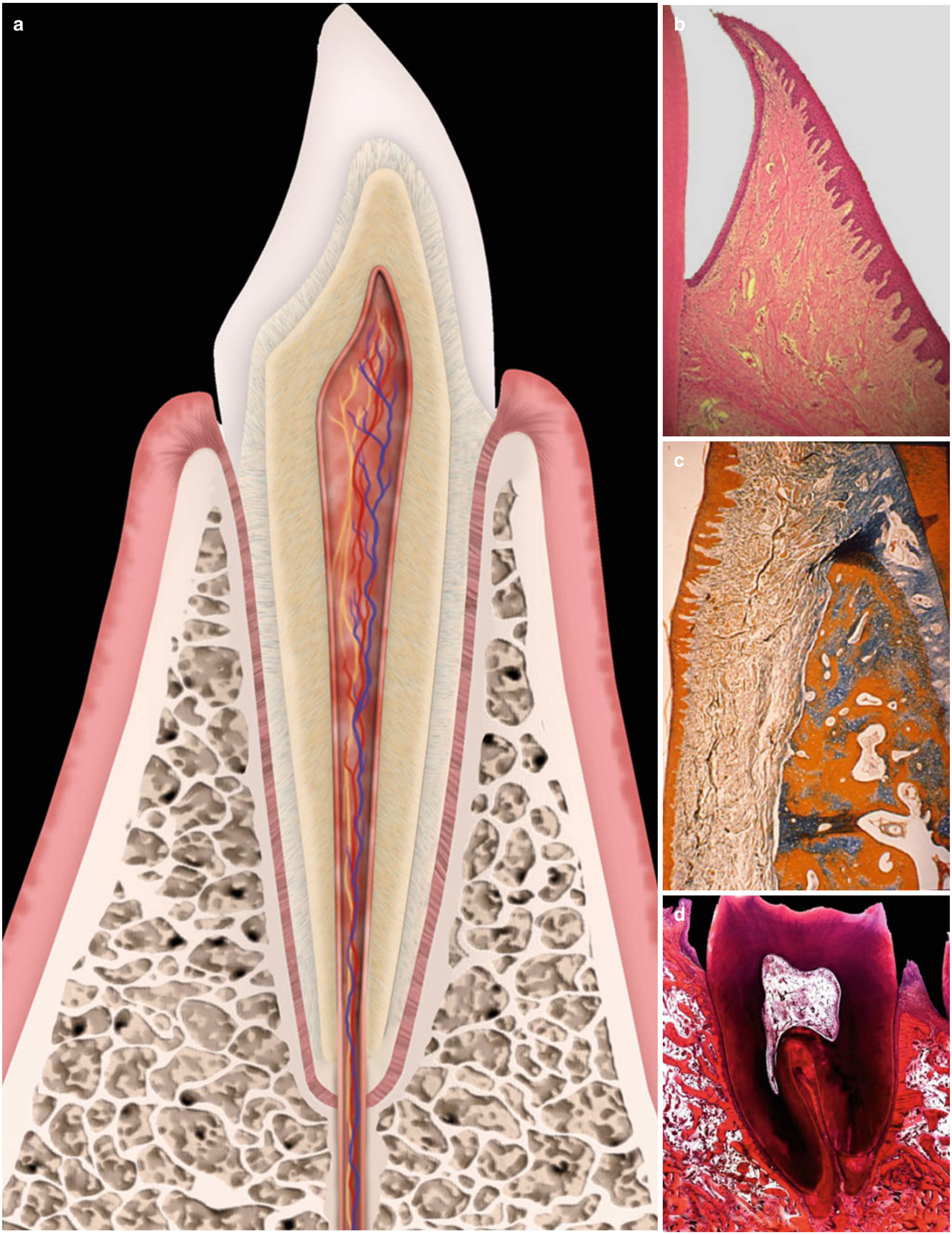

Fig. 2.1 Periodontal tissues: the cementum, alveolar bone, periodontal ligament, and gingiva

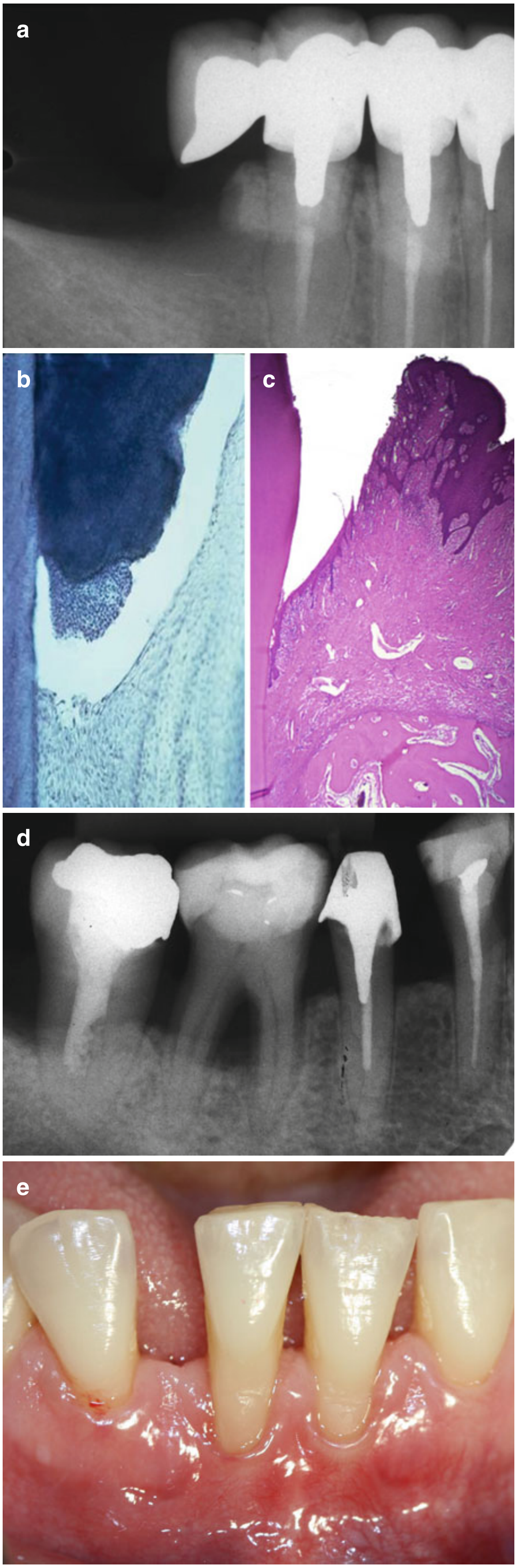

Fig. 2.2 Increase of the cementum and trabecular bone in response to occlusal forces (bony exostosis) (**a**); periodontitis (**b**–**e**)

In the field of periodontics/periodontology, when a patient presents discrepancies in soft tissue morphology, osseous architecture, tooth morphology (e.g., color alteration and shape), and positioning, aesthetical and/or functional treatment approaches may optimize the "pink" and "white" aesthetics concomitantly. Especially within aesthetic areas, the treatment of soft/hard tissue deformities represents an important challenge for the dental clinician, since it may involve a complex, multidisciplinary decision-making process for the concomitant accomplishment of health and harmony between dental and periodontal tissues. For such cases, the balance between function and aesthetics will be dependent on the clinician's skills and knowledge on tissue anatomy and morphology. Thus, the actual treatment paradigm must be associated with composed functional (e.g., reestablishment of health and proper occlusion) and aesthetical/cosmetic approaches, or in other words, the treatment planning of aesthetic areas must lead to satisfactory clinical and aesthetic long-term results, by achieving a pleasant and harmonious smile [8–11].

2.2 The Anatomy of Soft Tissues Surrounding Human Teeth: The Mucogingival Complex

"The mucogingival complex" is formed by the portion of the oral mucosa that covers the alveolar process including the gingiva (keratinized tissue) and the adjacent alveolar mucosa [1]. Clinically, the gingiva ("the fibrous investing tissue, covered by keratinised epithelium, that immediately surrounds a tooth and is contiguous with its periodontal ligament and with the mucosal tissues of the mouth") [1] can be found around the cervical portion of the teeth and is characterized by (a) a pink and opaque color, (b) scalloped appearance/contour, (c) a stippling texture that reminds an "orange peel," and (d) firm consistence, (e) may present melanic pigmentation, and (f) may vary in width, and (g) it usually assumes its definitive shape and texture following the eruption of permanent teeth (Fig. 2.3) [12, 13].

In terms of clinical anatomic limits, the gingiva is delimited by the free/marginal gingiva ("that part of the gingiva that surrounds the tooth and is not directly attached to the tooth surface/the most coronal portion of the gingiva that forms the wall of the gingival crevice in health") [1] and the attached gingiva ("the portion of the gingiva that is firm, dense, stippled, and tightly bound to the underlying periosteum, tooth, and bone"). The free/marginal gingiva includes the interdental papilla ("that portion of the gingiva that

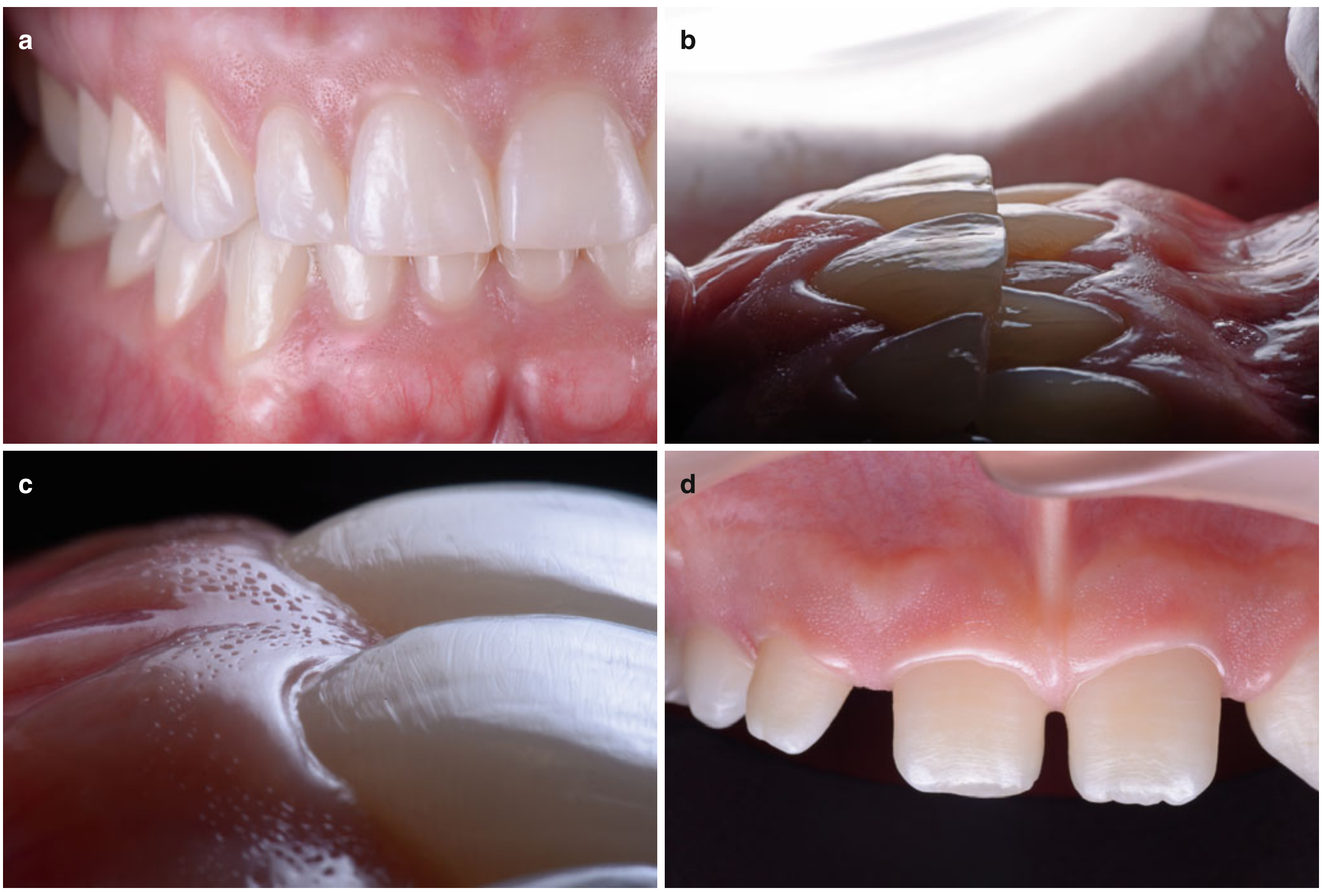

Fig. 2.3 Clinical characteristics of the gingiva

occupies the interproximal spaces [the interdental extension of the gingiva]") [1] and the col ("a valley-like depression of the interdental gingiva that connects facial and lingual papillae and conforms to the shape of the interproximal contact area") [1]. Within anterior interproximal sites, the interdental papilla assumes a triangular shape, whereas at the posterior teeth these are more "smooth-edged" given the impression that the posterior papilla is formed by two parts, one buccal and one lingual separated by the col area [13, 14]. Usually, the free/marginal gingiva extends to the gingival groove ("a shallow, V-shaped groove or indentation that is closely associated with the apical extent of free gingiva and runs parallel to the margin of the gingiva") [1] where it "connects" to the attached gingiva [13, 14]. Regarding the attached gingiva it extends from the apical limit of the free/marginal gingiva to the mucogingival junction, its width may vary between the anterior and posterior teeth, and it may increase with age (Fig. 2.4) [13, 14].

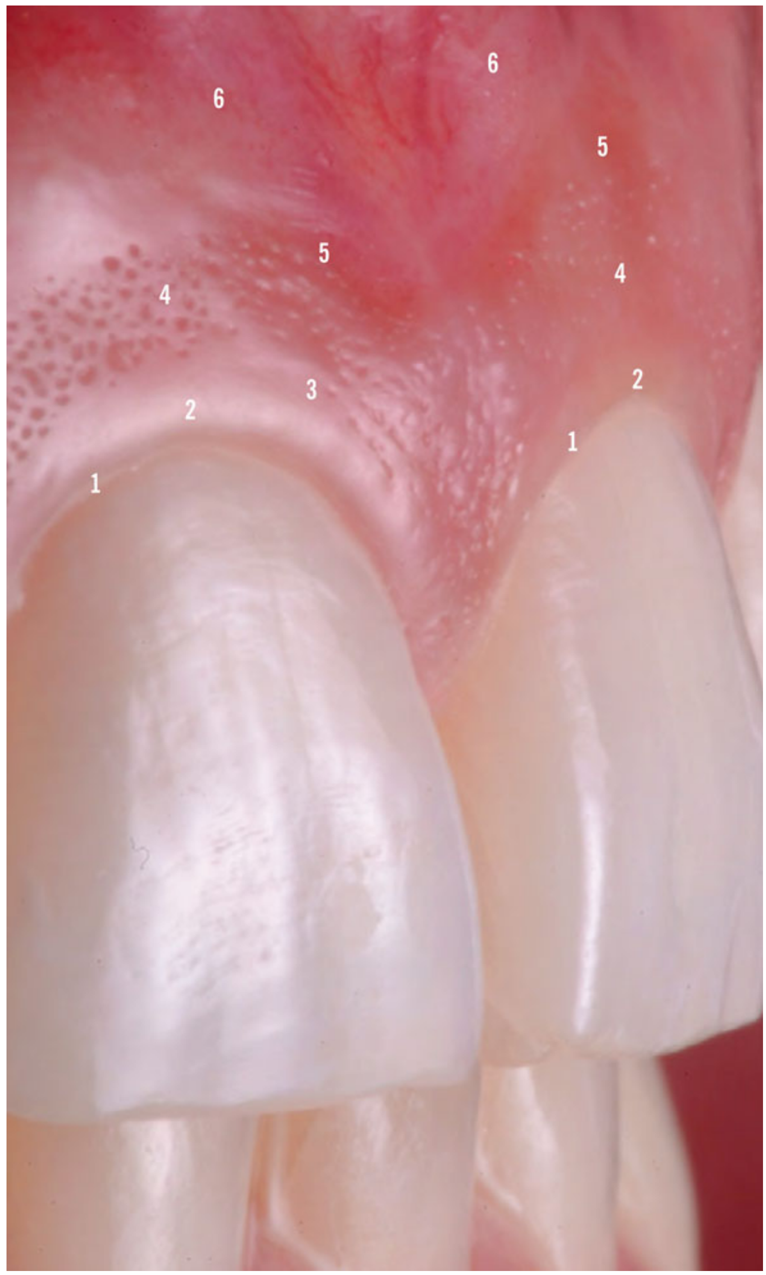

Fig. 2.4 Anatomic limits of the gingiva. *1* Gingival margin, *2* free gingival margin, *3* gingival groove, *4* attached gingiva, *5* mucogingival junction, *6* alveolar mucosa

Microscopically, the gingiva is formed by three epithelial (oral, oral sulcular/crevicular, and junctional) and one connective tissue layer (Fig. 2.5). With the assistance of biopsy samples of human teeth sectioned in a buccal–lingual plane, it can be seen that the buccal gingiva facing the oral cavity presents a layer of keratinized stratified squamous epithelium denominated “oral epithelium” that extends from the mucogingival junction to the gingival margin (Fig. 2.6). This epithelium is formed by four layers/stratums (Fig. 2.7):

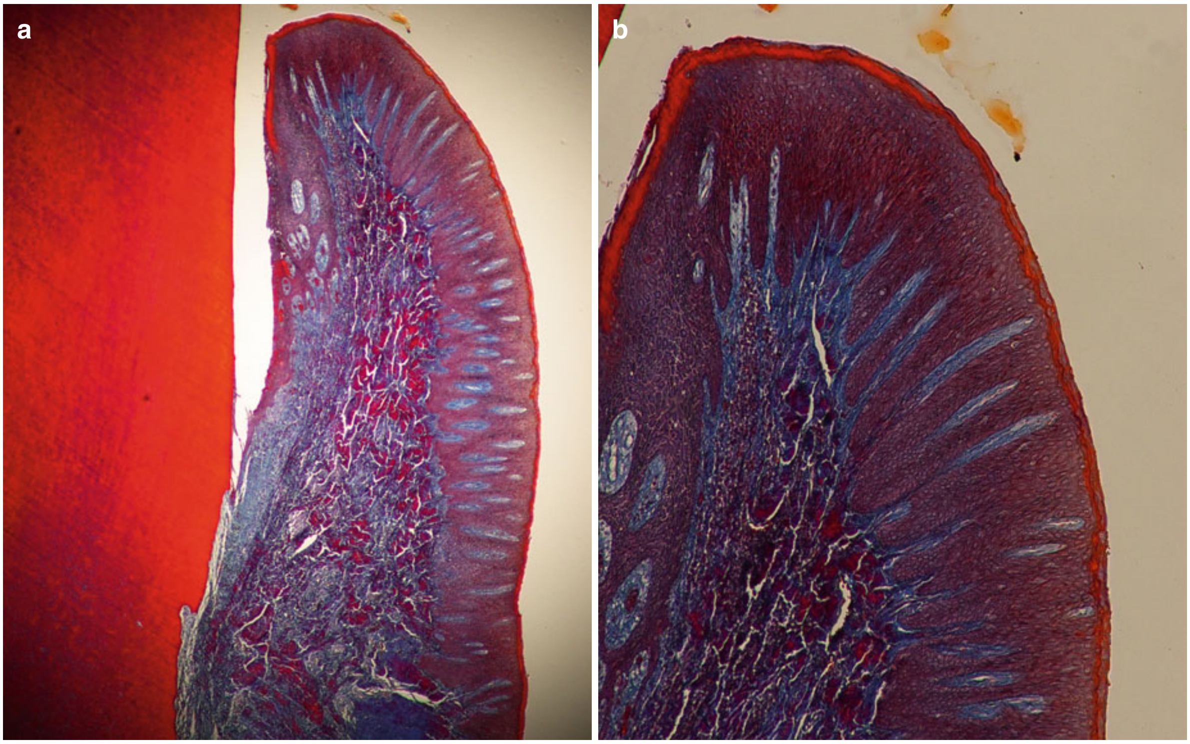

Fig. 2.5 The oral epitheliums (40×) (**a**) and (100×) (**b**)

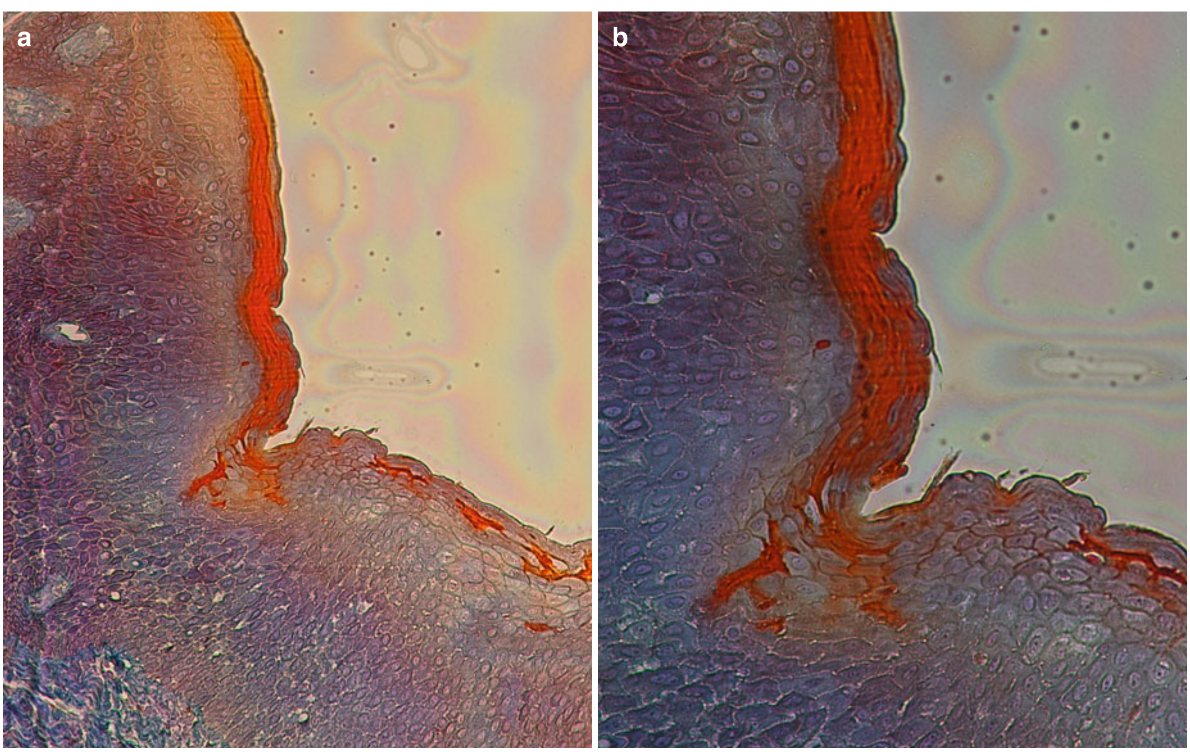

Fig. 2.6 Mucogingival junction (100×) (**a**) and (200×) (**b**)

- Basale: Formed by rounded and small proliferative cells, known as keratinocytes. These mother cells multiply constantly forming new cells (daughter cells) that will follow through the other three stratums until reaching the corneum one [13, 15]. Also, they are in contact with the basement membrane (the membrane that separates the connective tissue of the lamina propria from the gingival epithelium) [13, 15].
- Spinosum: Considered to be the thickest stratum of all, it is formed by large polyhedral spinous-appearing cells [13, 15].
- Granulosum: This layer received this name because of the presence of flattened-shaped cells that present within their cytoplasm the presence of dense cytoplasmic keratohyalin granules (this protein provides the "grainy aspect" of this stratum and leads to nuclei and organelle disintegration) [13, 15].
- Corneum: Formed by flattened keratin cells. They may provide the configuration of a keratinized epithelium when the nuclei and organelles are no longer present or of a parakeratinized epithelium when remaining components of the nuclei may be found [13, 15].

Within the oral epithelium, different types of cells may be found, such as melanocytes (cells that produce the dark, amorphous pigment of the skin, hair, and the choroid coat of the eye and that give the darkish color of the gingiva – Fig. 2.8) [1], Langerhans (defense cells originated of macrophages), and Merkel (sensorial/tactile) cells [13, 15].

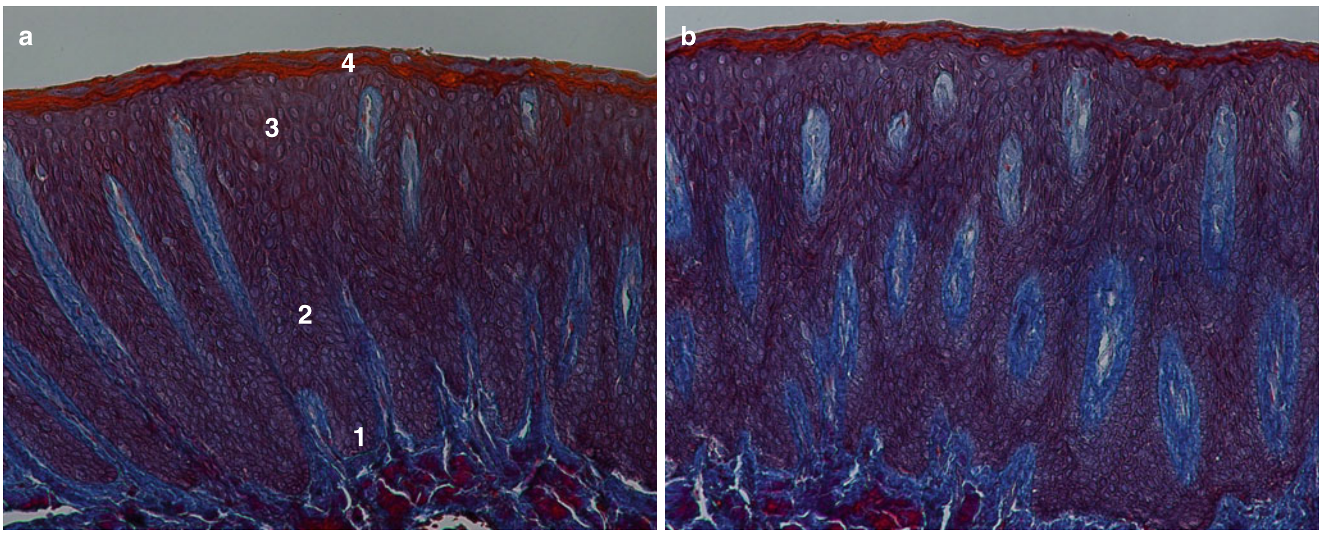

Fig. 2.7 Epithelial layers (*1* basale, *2* spinosum, *3* granulosum, *4* 0 corneum (200×))

Fig. 2.8 Pigmented gingiva (melanocytes of the oral epithelium)

At the gingival margin, the oral epithelium "continues" through the interior of the gingival sulcus/crevice (i.e., the shallow fissure between the marginal gingiva and the enamel or cementum) [1], and there it becomes the oral sulcular/crevicular epithelium, a nonkeratinized stratified squamous epithelium formed by three layers (basale, spinosum, and granulosum) [13–15]. Despite being described as "nonkeratinized," there has been evidence of areas/portions of keratinization mainly close to the entrance of the crevice (Fig. 2.9). Additionally, in the presence of gingival health, it will allow the formation of a gingival sulcus/crevice of 0.69 mm that extends from the gingival margin to the bottom of the crevice all around the tooth [16].

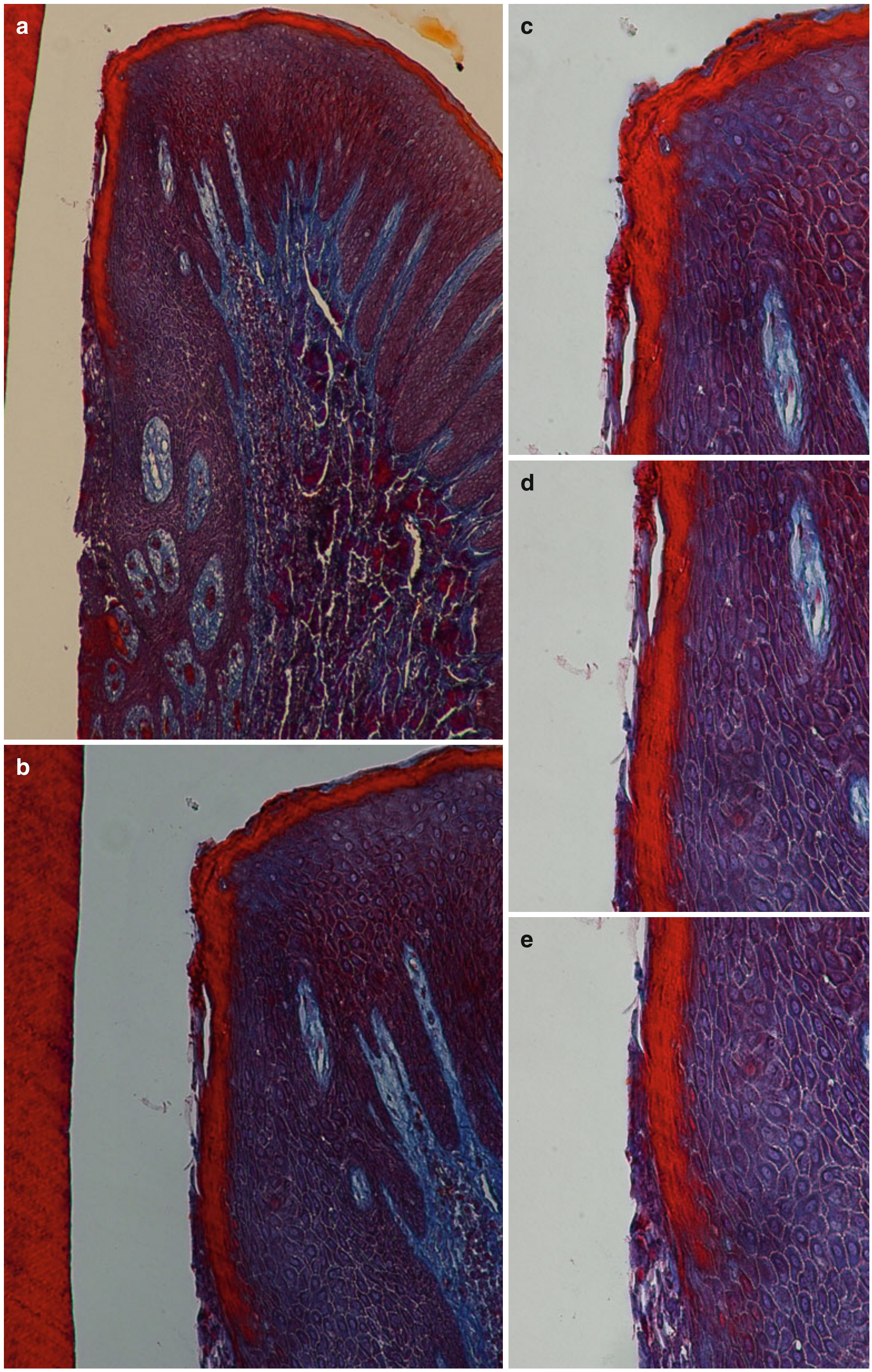

Fig. 2.9 Sulcular/crevicular epithelium (100×) (**a**, **b**) and (200×) (**c**–**e**)

The bottom of the gingival crevice separates the sulcular of the junctional epithelium, which is defined as "a single or multiple layer of nonkeratinizing cells adhering to the tooth surface at the base of the gingival crevice" [1]. It is formed by 15–30 parallel layer cells at its most coronal portion adjacent to the oral sulcular/crevicular epithelium to just a few cells at its most apical position [15]. Despite presenting just two strata (basale and suprabasale), the junctional epithelium is characterized by its capacity of sealing the internal or the external environment and by its high capacity of cellular turnover (as provided by its basal layer) and bigger intercellular spaces than the other two epitheliums (Fig. 2.10) [13, 15]. These features provide the ability not only of attachment, but of protection because of cell desquamation at its most coronal portion (i.e., close to the base of the gingival sulcus/crevice) and permeability to polymorphonuclear neutrophils (which are quite evident) [13, 15].

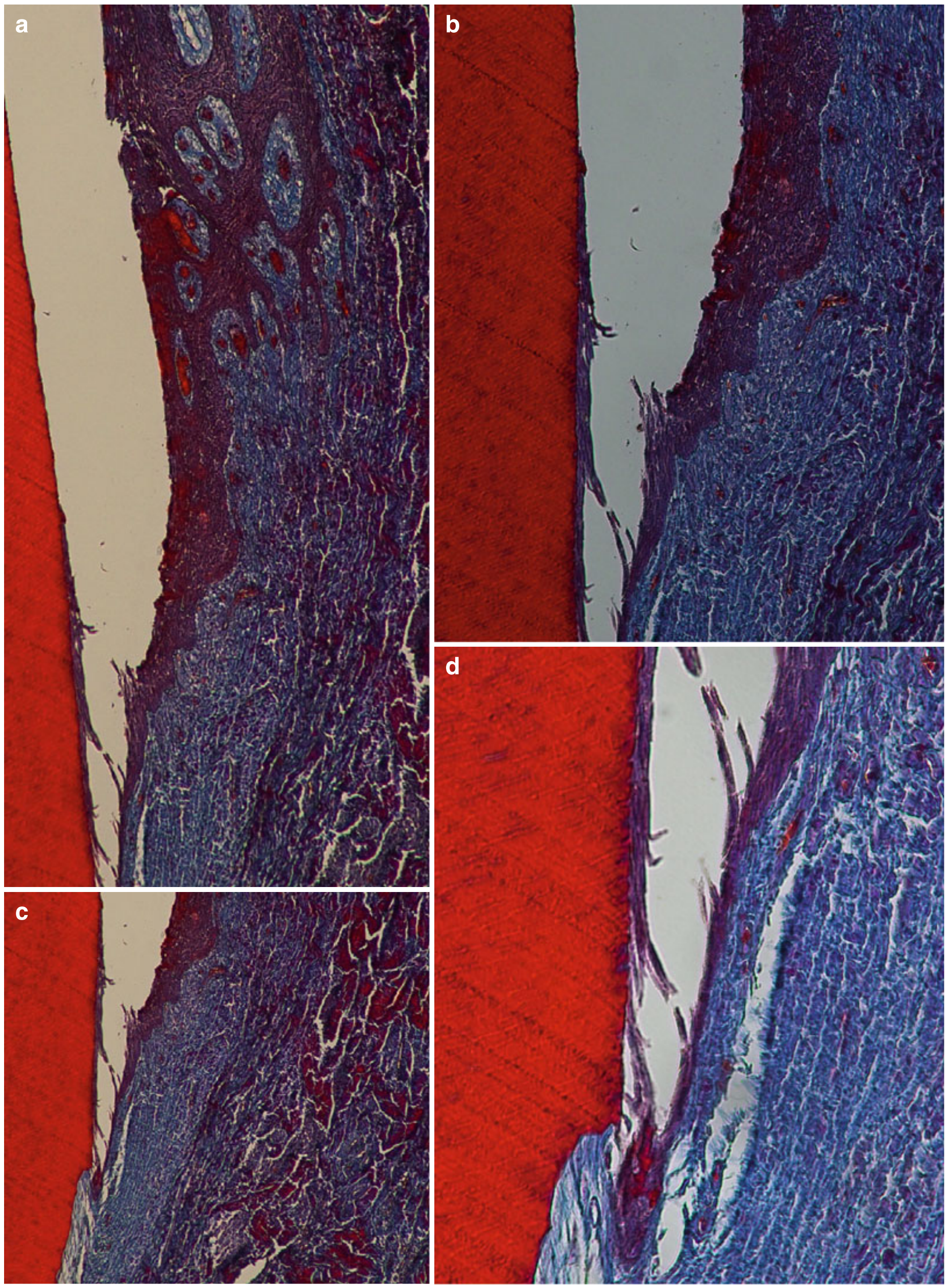

Fig. 2.10 The junctional epithelium (transition between the sulcular epithelium and the junctional epithelium). Note to the readers: the specimens presented in this chapter are derived from a clinical study on soft tissue root coverage. They were only used with the purpose of providing a histologic description of gingival epithelium and connective tissue. Probing depth was performed immediately before tooth extractions; thus, portions of the junctional epithelium are not completely attached to the root surface (technical artifact) (100×) (**a**, **b**) and (200×) (**c**, **d**)

All epitheliums are underlined by a connective tissue layer of the lamina propria ("the connective tissue coat just beneath the epithelium and the basement membrane") [1]. For the oral epithelium, the interface formed with the connective tissue is irregular and comprises "fingerlike projections" of connective tissue from the papillary layer ("connective papilla") that extends into depressions on the undersurface of the epithelium ("epithelial crests") [16]. These ridge-like projections of epithelium into the underlying stroma of connective tissue [1] (or rete pegs when seen in histological sections– Fig. 2.11) improve its attachment to the lamina propria [16]. The sulcular/crevicular epithelium also presents such "rete ridges" but in a diminished number, while at the junctional epithelium these are not present [17].

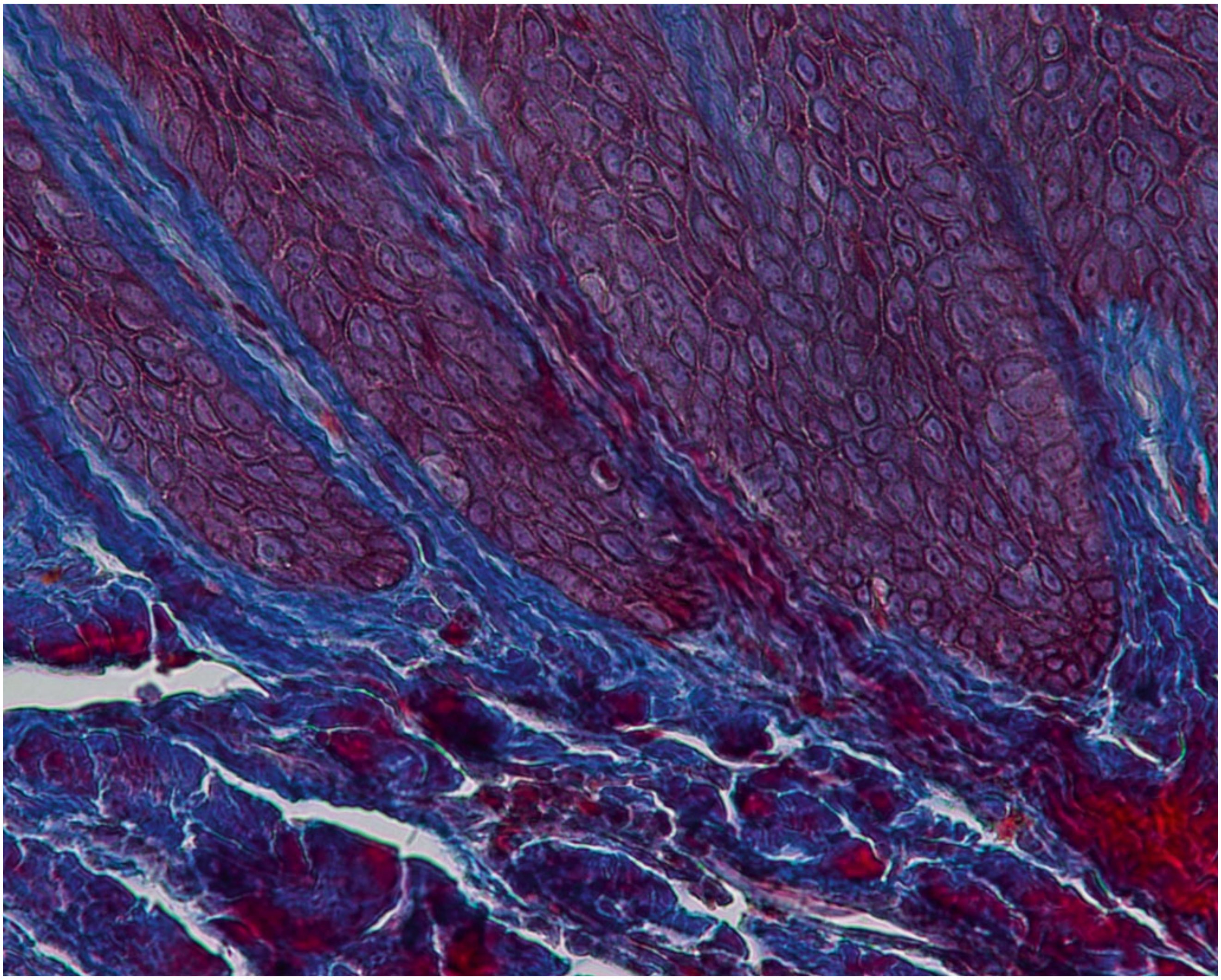

Fig. 2.11 Rete pegs (200×)

Regarding the components of the gingival connective tissue, it is formed by fibroblasts (65 % of all tissues) and other cells (i.e., mast cells, macrophages, undifferentiated mesenchymal cells, neutrophils, and plasma cells), fibers, blood vessels, and nerve fibers that are intended to act for cell nutrition, tissue healing, as well as mechanical (by the group of collagen fibers and the viscosity of the amorphous intercellular substance of the extracellular matrix) and phagocytic (via macrophages, neutrophils, antigen–antibody reactions, and activation of the complement system) mechanisms of defense [13, 15] Figs. 2.12 and 2.13.

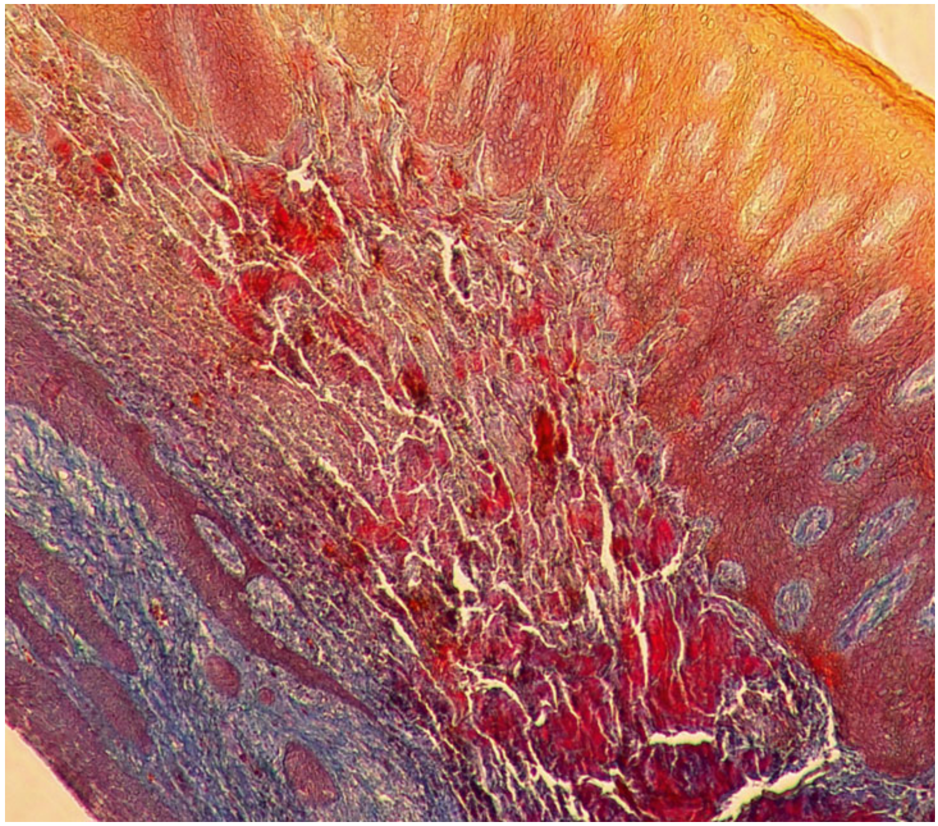

Fig. 2.12 Gingival connective tissue (100×)

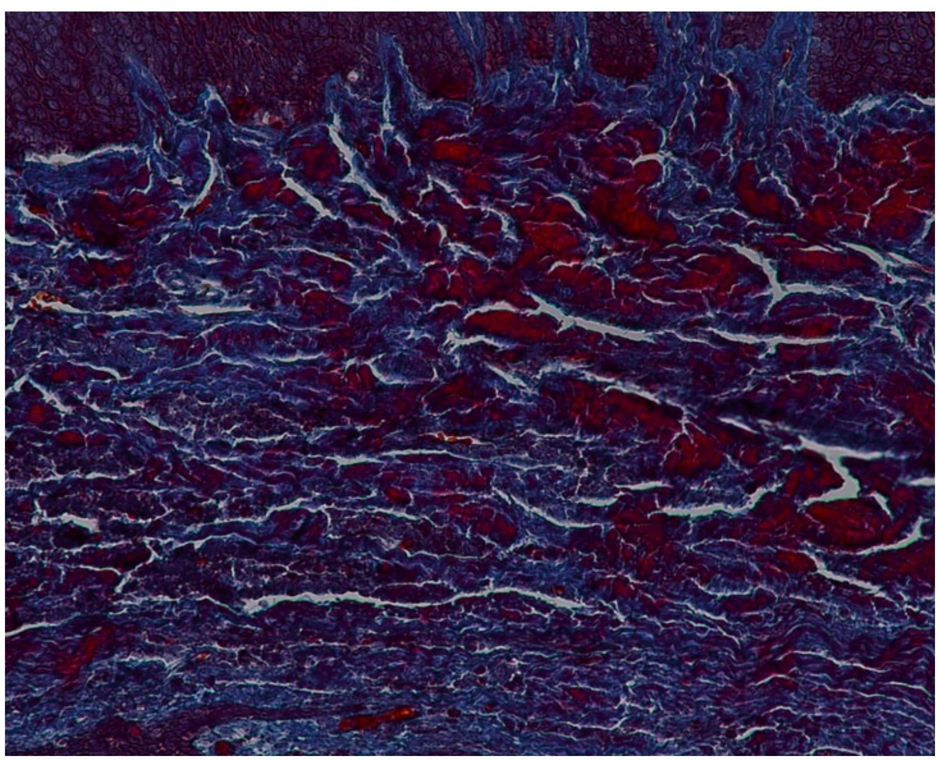

Fig. 2.13 The gingival connective tissue (note the presence of the inflammatory cell within the tissue) (200×)

Although parts of the fibers are irregularly distributed through the connective tissue layer, most of them consisting of a dense network of collagen fiber bundles form an organized supra-alveolar fiber apparatus. Their function and location are illustrated in Figs. 2.14 and 2.15 (notes 1–9) and depicted as follows [1, 13, 15]:

- Dentogingival fibers: Group of collagenous fibers that extend from the cervical cementum to the lamina propria of the free and attached gingiva (1).
- Dentoperiosteal fibers: Group of fibers running from the cementum over the periosteum of the outer cortical plates of the alveolar process where they insert into the alveolar process or muscle in the vestibule of the floor of the mouth (2).
- Alveolo-gingival fibers: Group of collagenous fibers that radiate from the bone of the alveolar crest into the lamina propria of the free and attached gingiva (3).
- Circular/semicircular fibers: Group of collagenous fiber bundles within the gingiva that encircle the tooth in a ring-like fashion (4).
- Intergingival and transgingival fibers: These groups of fibers are narrowly associated to the semicircular fibers.

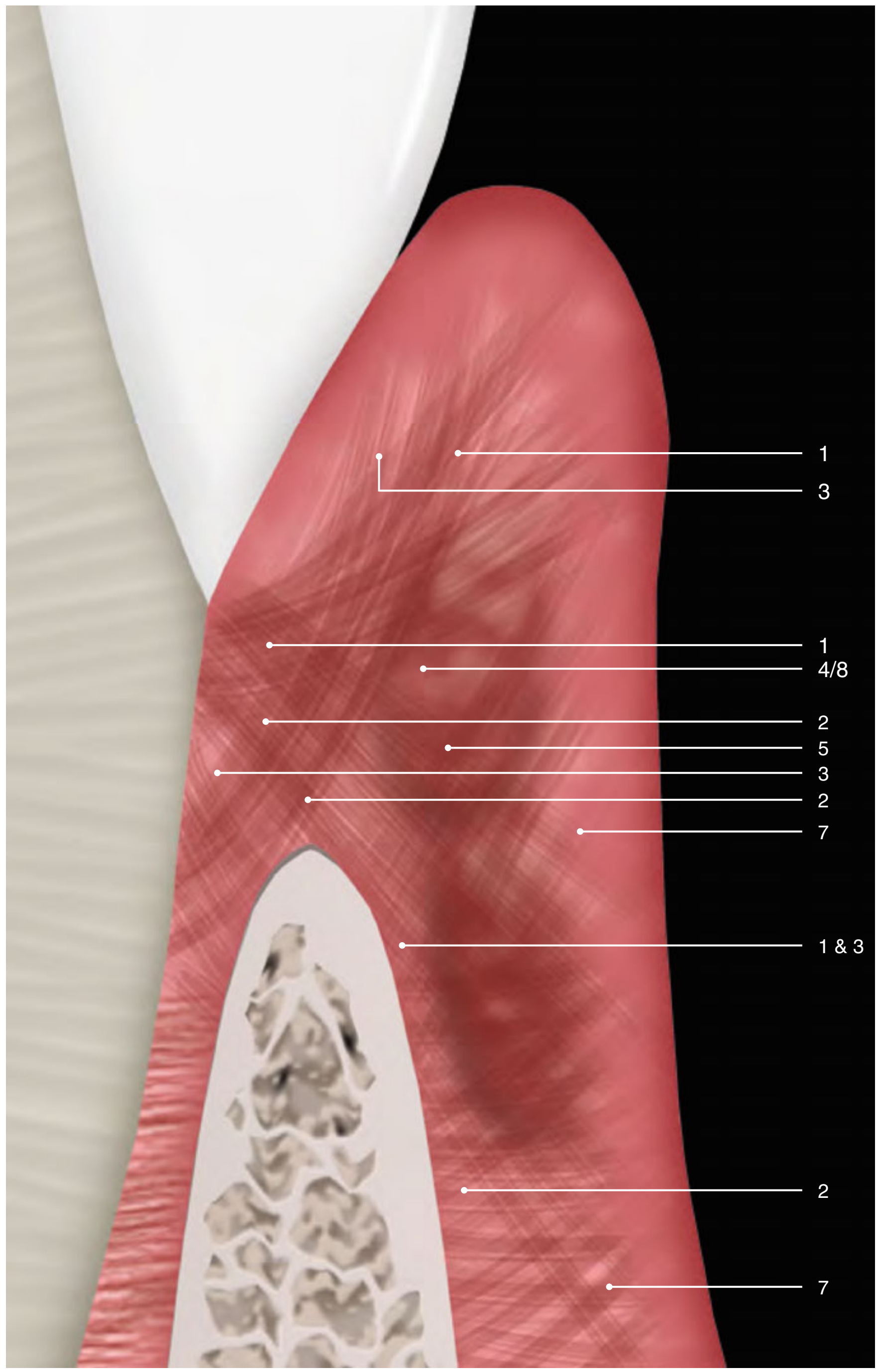

Fig. 2.14 Supragingival fibers: view 01 (as described by Schroeder and Listgarten [13])

They ascend in the cementum and outspread through the intergingival fibers and interdental septum and eventually merge with the semicircular fibers of the adjacent tooth (5).

- Interpapillary fibers: Group of collagenous fibers running between the gingival connective tissue of facial and lingual aspects of the posterior papilla (running in a buccolingual direction through the interdental tissue) (6).
- Periosteo-gingival fibers: Group of collagenous fibers that extend from the periosteum of the outer cortical plates to the lamina propria of the gingiva (7).
- Intercircular fibers: Group of fibers located both buccally and lingually and run in a mesiodistal manner to join circular fibers of adjacent teeth (8).
- Transseptal fibers: Collagenous fibers that run interdentally from the cementum just apical to the base of

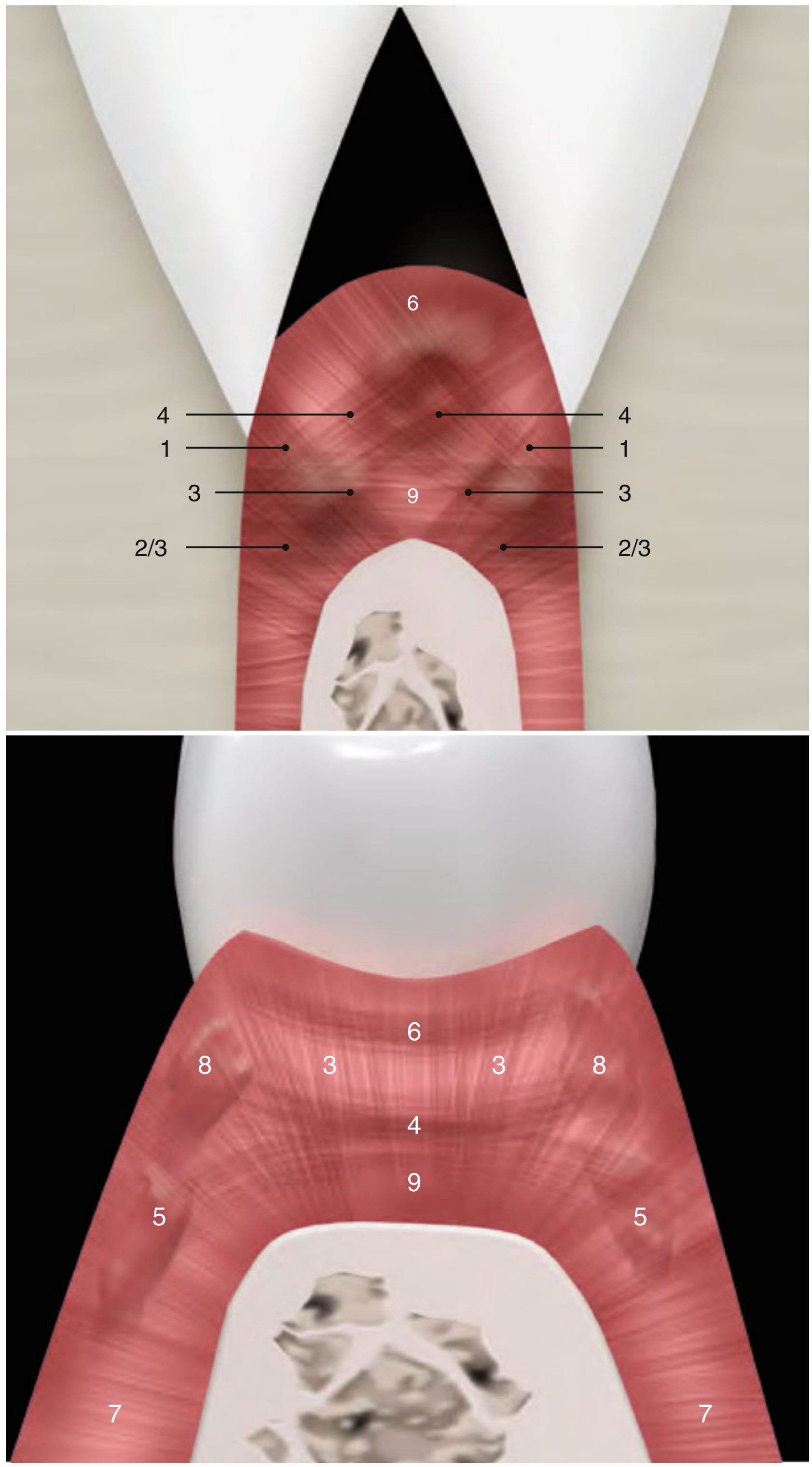

Fig. 2.15 Supragingival fibers: views 02 and 03 (as described by Schroeder and Listgarten [13])

the junctional epithelium of one tooth over the alveolar crest to insert into a comparable region of an adjacent tooth (9).

Additionally, other types of fiber bundles such as oxytalan ("fibers found in all connective tissue structures of the periodontium that appear to consist of thin, acid-resistant fibrils – their function is unknown") [1], reticular (type III collagen fibers secreted by reticular/fibroblast cells that give support to the lamina propria of the gingiva), and elastic (around blood vessels) are present at the gingival connective tissue.

With respect to the neurovascular composition of the gingival connective tissue, the vascularization of the gingiva is primarily supplied by blood vessels located at the periodontal ligament and at the supraperiosteal portion of the lamina propria (i.e., supraperiosteal vessels) and by the intraseptal artery [13, 15]. These vessels/artery and capillary loops will originate from two vascular networks of arteriovenous anastomoses, the subepithelial and the dentogingival plexus (Fig. 2.16) [15]. Regarding the neural elements, these are its great majority surrounding/close to blood vessels and composed by myelinated fibers that play a sensory part [15].

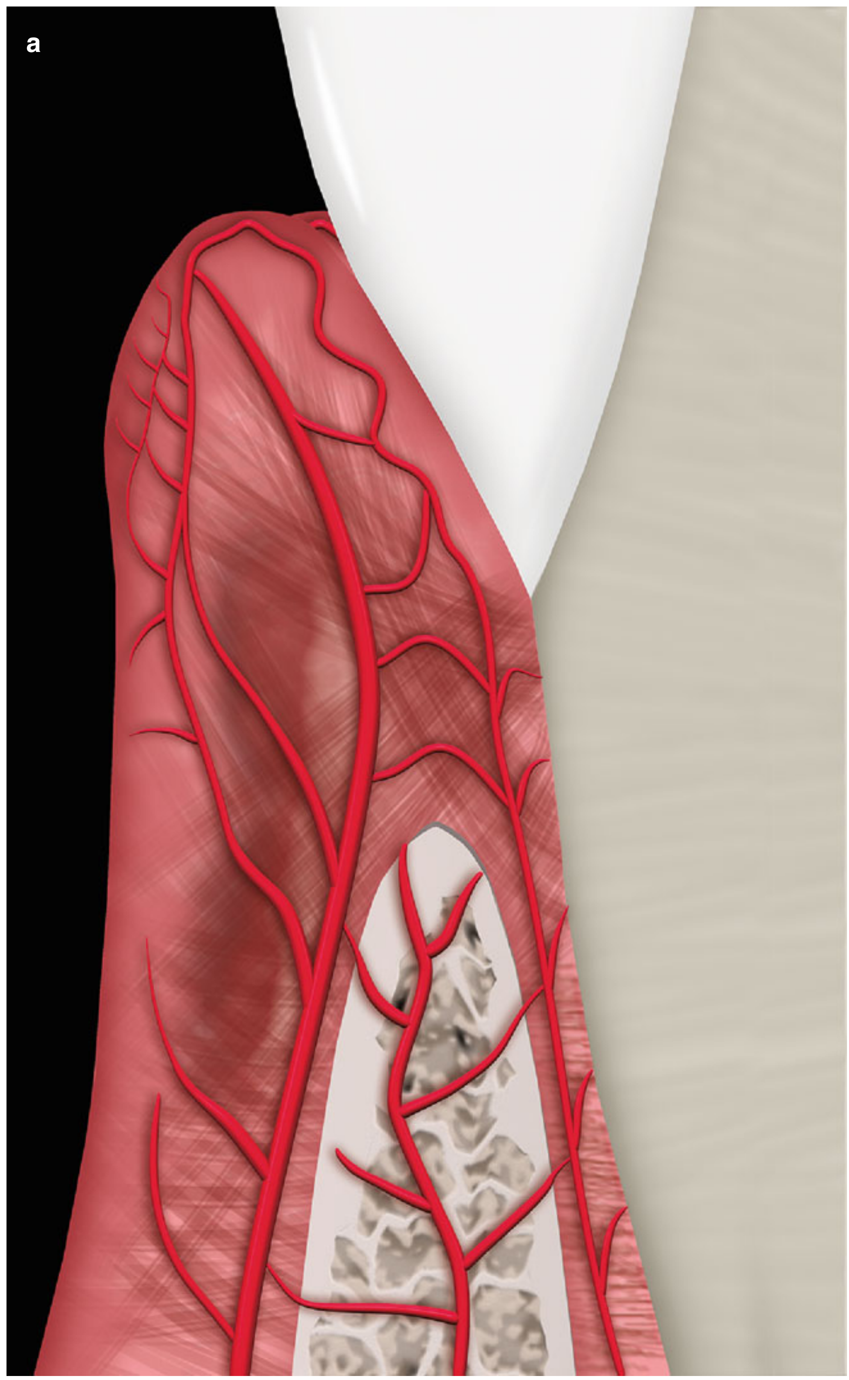

Fig. 2.16 Gingival vascularization

Fig. 2.16 (continued)

2.3 Anatomy of Supporting Periodontal Tissues: The Clinical Role of Cementum, Alveolar Bone, and Periodontal Ligament Conditions

The clinical role of the cementum, the alveolar bone, and the periodontal ligament conditions is briefly depicted below [1, 18]:

- It is described as "the thin, calcified tissue of ectomesenchymal origin, similar to the alveolar, covering the roots of teeth which embedded collagen fibers attach the teeth to the alveolus" [1]. Its function is related to repair and attachment, as well as it is continuously deposited over a tooth's life. It can be of acellular/primary (i.e., "that portion of the cementum that does not incorporate cells – it is formed during the root's formation") or cellular/secondary (i.e., "that portion of the cementum that contains cementocytes – it is formed during a tooth's life in the apical third of the root as a response to occlusal forces") origin (Fig. 2.17) [1, 18].
- Alveolar bone: "The hard form of connective tissue that constitutes the majority of the skeleton of most vertebrates. It consists of an organic component and an inorganic, or mineral, component. The organic matrix contains a framework of collagenous fibers and is impregnated with the mineral component, chiefly calcium phosphate and hydroxyapatite, that impart rigidity to bone. The alveolar process supports to alveoli, and consists of cortical bone, cancellous trabeculae, and the alveolar bone proper." [1] It can be divided into alveolar bone proper ("compact bone that composes the alveolus (tooth socket), also known as the lamina dura or cribriform plate – the fibers of the periodontal ligament insert into it") and basal bone ("the bone of the mandible and maxilla exclusive of the alveolar process"). Also, the alveolar bone may also be characterized

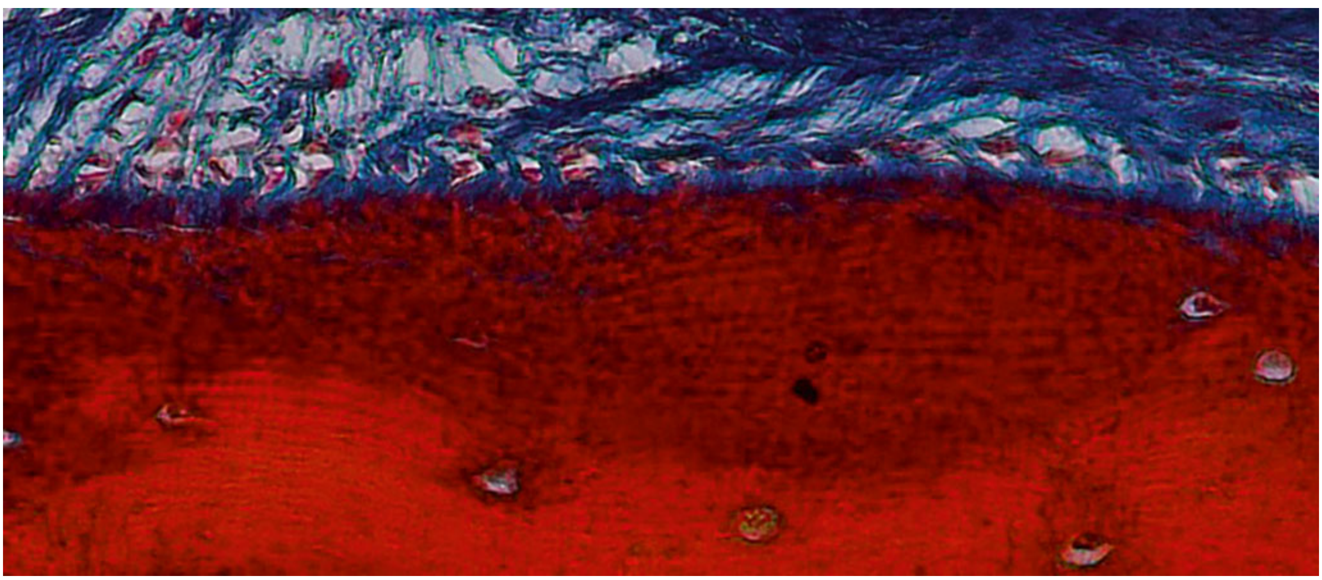

Fig. 2.17 Cementum and Sharpey's fibers (200×)

by its structure as bundle ("a type of alveolar bone, so-called because of the "bundle" pattern caused by the continuation of the principal [Sharpey's] fibers into it"), cancellous ("bone having a reticular, spongy, or lattice-like structure"), compact ("bone substance that is dense and hard"), or cortical bone ("the compact bone at the surface of any given bone") [1]. The osseous morphology is dependent of the structures attached to the tooth, as well as to the structure and position of a tooth (Fig. 2.18) [18].

- Periodontal ligament: fibers that allow tooth attachment, and occlusal forces transmission to the alveolar bone (Sharpey's fibers), protection to the neurovascular components, bone and cementum remodeling, and nutrition and proprioceptive sensitivity [18]. Among the fibers of the periodontal ligament, several types of cells may be found, such as fibroblasts, osteoblasts, osteoclasts, cementoblasts, cementoclasts, mesenchymal cells, epithelial cells, macrophages, and mast cells (Fig. 2.19) [18].

Fig. 2.18 Alveolar bone

Fig. 2.19 Alveolar bone (closer view)

Together with the knowledge of the soft tissue anatomy, the characteristics of these tissues, mainly of the alveolar bone, play an important role on the development of soft tissue deformities even without the presence of dental biofilm. Anatomical features of the alveolar bone, such as bone fenestrations (i.e., window-like apertures or openings in the alveolar bone over the root of a tooth without comprising the marginal crestal bone) [1, 19–22] and dehiscence (i.e., areas in which the root is denuded of bone and portions of the root surface are covered only by soft tissue, and this area extends to through the marginal alveolar bone) [19–22], may be important for the development of periodontal disease and non-plaque-induced gingival lesions, as well as for the prognosis of a periodontal plastic surgery procedure (Fig. 2.20). For instance, approximately 10 % of the teeth may present fenestrations or dehiscence of the bone, but when accounting the presence of such defects "per subject," this value increase up to 60 % [19]. Also, 12 % of maxillary central incisors may present lack of bone covering the root surface beneath the gingival tissues [20], and in the presence of malocclusions, the frequency of fenestrations and dehiscence may significantly increase to approximately 35 and 50 %, respectively, especially in the anterior region of the mandible (Figs. 2.21 and 2.22) [21, 22]. In addition, it should be noted that histological information indicates that the buccal bone wall is thinner than the lingual wall and both crests are located at a similar distance from the cementoenamel junction [23].

Fig. 2.20 Osseous dehiscence (premolars) and fenestrations (canine and lateral incisor) at the mandibular arch

Fig. 2.21 Osseous fenestrations (canines and incisors)

Fig. 2.22 (**a**–**c**) Anatomic conditions of the alveolar bone around crowded teeth

2.4 Additional Anatomic Conditions to Be Considered During the Decision-Making Process for Gingival Surgery: The Palatal Vault, the Periodontal Biotype, the Keratinized Tissue Band Around Natural Teeth, and the Biological Width

The palatal vault may play an important role during the decision-making process due to its inherent anatomical characteristics, in terms of potential damages and complications (e.g., small bleeding up to hemorrhage) that may occur to the greater palatine artery and their major branches [24, 25]. Known as the main artery supplying blood to the masticatory mucosa of the palatal vault, the greater palatine artery emerges on to the inferior surface of the hard palate through the greater palatine foramen and follows anteriorly close to the alveolar ridge up to the incisive foramen, where it leaves the palate (Fig. 2.23) [24–27]. Also, the greater palatine nerve accompanies this artery, and it is related to anesthetic procedures of the anterior teeth and palatal mucosa [24–28].

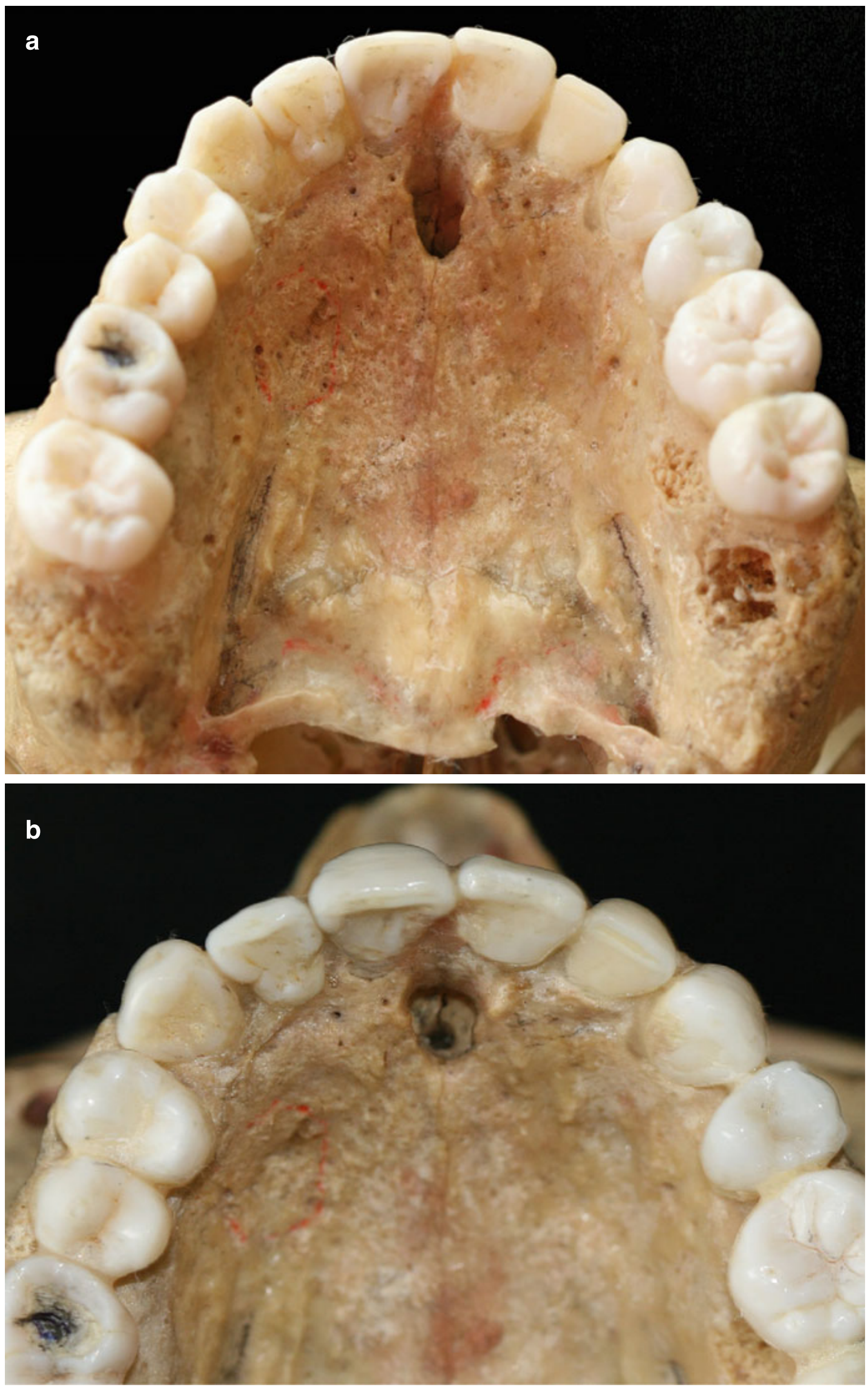

Fig. 2.23 Palatal vault – incisive foramen (**a**, **b**), greater palatine foramen (**c**, **d**), and schematics of the greater palatine artery (**e**)

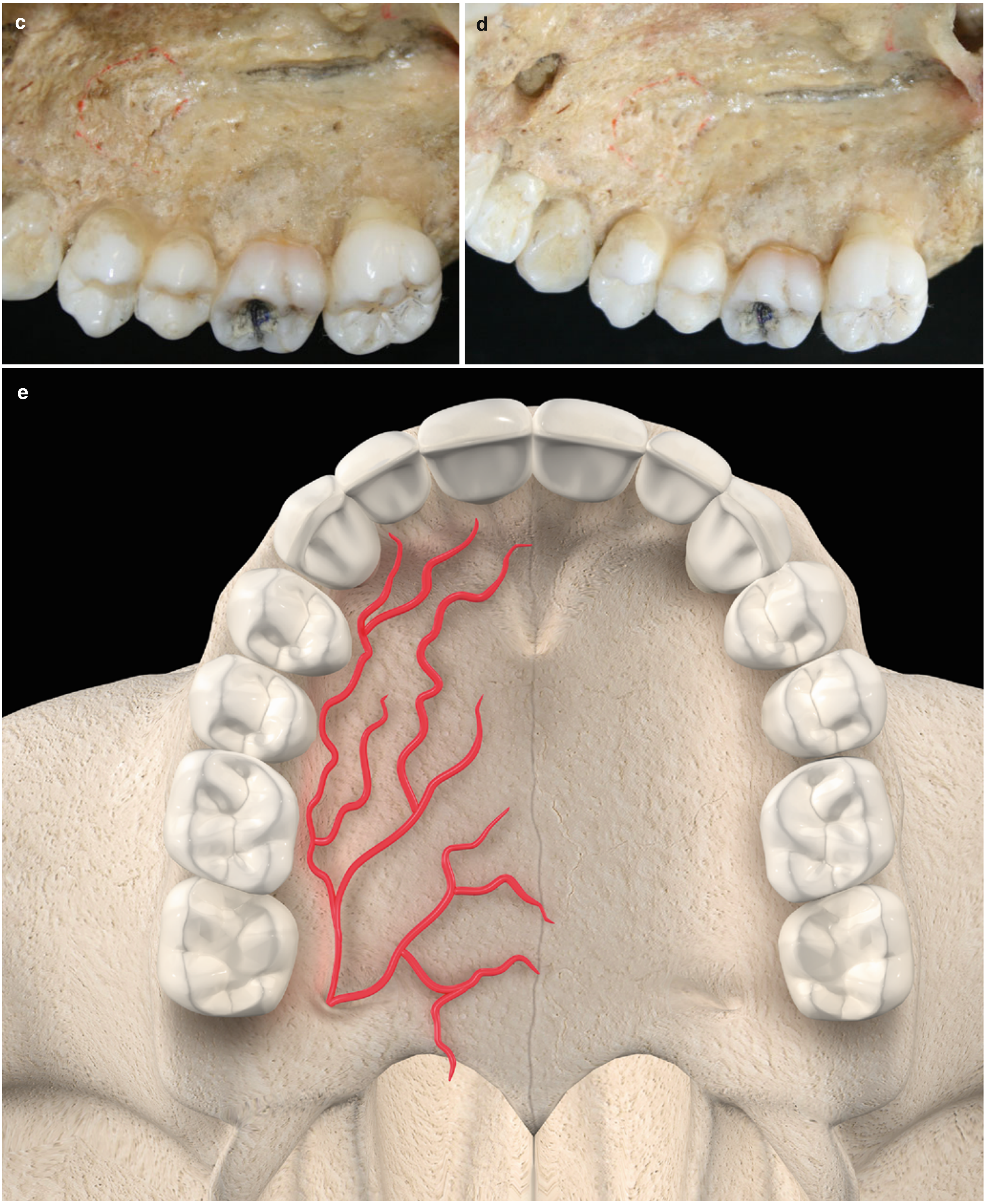

Fig. 2.23 (continued)

The knowledge of these topographic aspects is of great importance during flap procedures performed at the lingual posterior region of the maxilla, as well as to the achievement of free gingival grafts or subepithelial grafts harvested between the distal aspect of the canine and the midpalatal region of the second molar (i.e., the usual area used to obtain these grafts) [24, 25]. The selection of a palatal donor bed and the surgical harvesting procedures may vary but mainly from areas with less fat composition. Additional important information on this area is described in Chap. 3 (Treatment of Recession-Type Defects).

Another important anatomic condition that may modify the soft tissue behavior around the individual tooth over time is the periodontal biotype. In the late 1980s, the "quality" of the periodontal tissues and its impact on the prognosis of periodontal plastic surgery has gained considerable importance [29–31]. For instance, periodontal biotypes categorized as "thin and scalloped" or "thick and flat" [29] (Fig. 2.24) present different characteristics that deserve special attention, as described by Cohen [32]: A "thin and scalloped" biotype may be found among subjects presenting delicate and tiny highly scalloped gingival and osseous architecture, bone dehiscence and/or fenestrations, a gingival margin located over the cementoenamel junction (CEJ), few or nonkeratinized tissue (KT), and some specific dental characteristics (small contact areas and long triangular-shaped teeth) [32], and this seems associated to an increased susceptibility to gingival recession when compared to teeth with a "thick and flat" periodontal biotype [30, 31]. On the other hand, subjects with "thick and flat" biotypes are described to present dense, flat gingival and osseous architecture, a gingival margin lying coronal to the CEJ, ample width of keratinized tissue, squared-shaped teeth with "contact areas instead of contact points," and a rounded convexity of the facial bone plate [32]. Moreover, subject may present a third type of biotype (thick and scalloped) represented by "a clear thick fibrotic gingiva, slender teeth, narrow zone of KT and a high gingival scallop" [33].

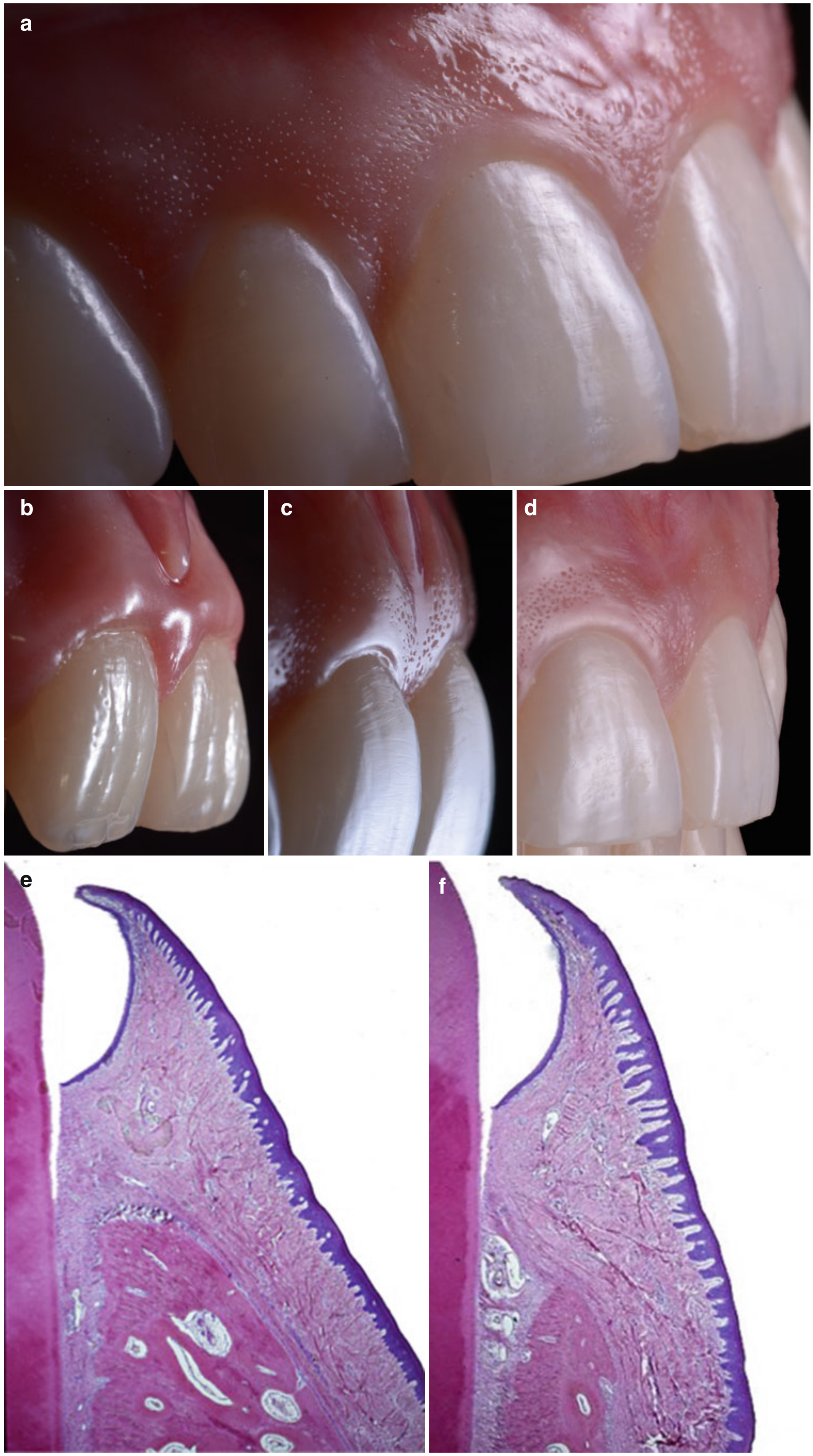

Fig. 2.24 (**a**–**f**) Periodontal biotypes (to note the histologic characteristics of a thick (**e**) and of a thin and scalloped biotype (**f**))

In gingival terms, the periodontal biotype seems to play an important role on the surgical prognosis most because of interdental papillary gingiva and the KT condition. For the interdental gingiva, teeth presenting long and narrow shape, with tiny incisally located contact points (e.g., subjects with a "thin and scalloped" biotype), are more inclined to present greater distances between the contact point and the interproximal crestal bone.

Regarding to KT and attached gingiva, it has long been suggested that their presence around a natural tooth and their augmentation when deemed necessary are the key elements of treatment planning involving periodontal plastic surgery. This assumption regards to early data on this topic, where a minimum band of 2 mm of keratinized tissue (with at least 1 mm of tissue attached) was considered necessary to maintain periodontal health [34]. On the other hand, Kim and Neiva [35] in its recent systematic review commissioned by the *American Academy of Periodontology* (AAP) observed that the definition of the precise extent of KT is still controversial, but in clinical terms, they reported important answers/conclusions to some different clinical scenarios/focused questions (these are reproduced below) [35]:

1. "***What are the alternatives to autogenous gingival grafting to increase the zone of keratinized attached gingiva***?" [35]

Answer(s)/**Conclusion**(s): "Alternative methods and materials have shown to provide enough attached keratinized tissue to correct areas lacking or with minimal KG (<2 mm) around teeth in short-term and in small-sample size studies. The advantages of these approaches are avoidance of donor areas and unlimited supply. However, long-term follow-up studies as well as randomized controlled trials should be conducted to strengthen this treatment approach." [35]

2. "***What is the patient reported outcome with minimal keratinized tissue compared to those that have received an enhanced zone of keratinized tissue***?" [35]

Answer(s)/**Conclusion**(s): "Alternative methods and materials appear to result in less patient discomfort after gingival augmentation procedures when compared to FGG. They have also shown to result in better color and texture match to surrounding tissue when compared to FGG. However, study investigators need to standardize how they collect the patient reported outcome so the obtained results can be compared to other studies." [35]

3. "***What is the ideal thickness of an autogenous gingival graft? Is a thick autogenous gingival graft more effective than a thin autogenous gingival graft***?" [39]

Answer(s)/**Conclusion**(s): "A palatal graft should be at least 0.75 mm thick. Thin grafts tend to result in more esthetic outcomes while thick grafts provide more functional resistance. Thick grafts tend to follow significant primary contraction while thin grafts are more prone to secondary contraction. The type of biotype may play an important role in maintaining optimal periodontal health, but disagreements exist among clinicians when describing the types of biotypes." [35]

4. "***Which restorative circumstance requires an increased zone of keratinized tissue or is keratinized tissue important***?" [35]

Answer(s)/**Conclusion**(s): "Authors have noted limitation of recent clinical studies as well as randomized control studies and systemic reviews to answer this question. However, clinical observations would suggest sites with minimal or no keratinized gingiva and associated with restorative margins are more prone to gingival recession and inflammation. Thus, gingival augmentation is indicated for sites with minimal or no KG and receiving intracrevicular restorative margins based on clinical observations." [35]

5. "***Does orthodontic intervention affect the soft tissue health and dimension***?" [35]

Answer(s)/**Conclusion**(s): "Authors have noted limitation of recent clinical studies as well as randomized control studies and systemic reviews to answer this question. However, historic clinical observations and recommendations can be referenced to answer this question. The direction of the tooth movement and the bucco-lingual thickness of the gingiva play important roles in soft tissue alteration during the orthodontic treatment. There is higher probability of recession during tooth movement in areas with <2 mm of KG. Gingival augmentation can be indicated prior to the initiation of orthodontic treatment in areas with <2 mm" [35].

One last (but important) complex involving the gingival tissues regards to the "width" of supracrestal components around each tooth. Known in the literature as the "biologic width," the supracrestal gingival complex involves the sulcular/crevicular and the junctional epitheliums, as well as the supracrestal connective attachment (Fig. 2.25) [36]. According to the classic study by Gargiulo et al. [36], the dimensions (extension) of this complex in means are as follows:

- Sulcular/crevicular epithelium: 0.69 mm
- Junctional epithelium: 0.97 mm
- Connective tissue attachment: 1.07 mm

Overall, it should be also noted that these outcomes are expressed as mean values, as well as the dimensions of the junctional epithelium may present greater variability [36]. Further studies have been conducted on this topic, and their general outcomes are depicted in this chapter at "Critical summary of the results of systematic reviews."

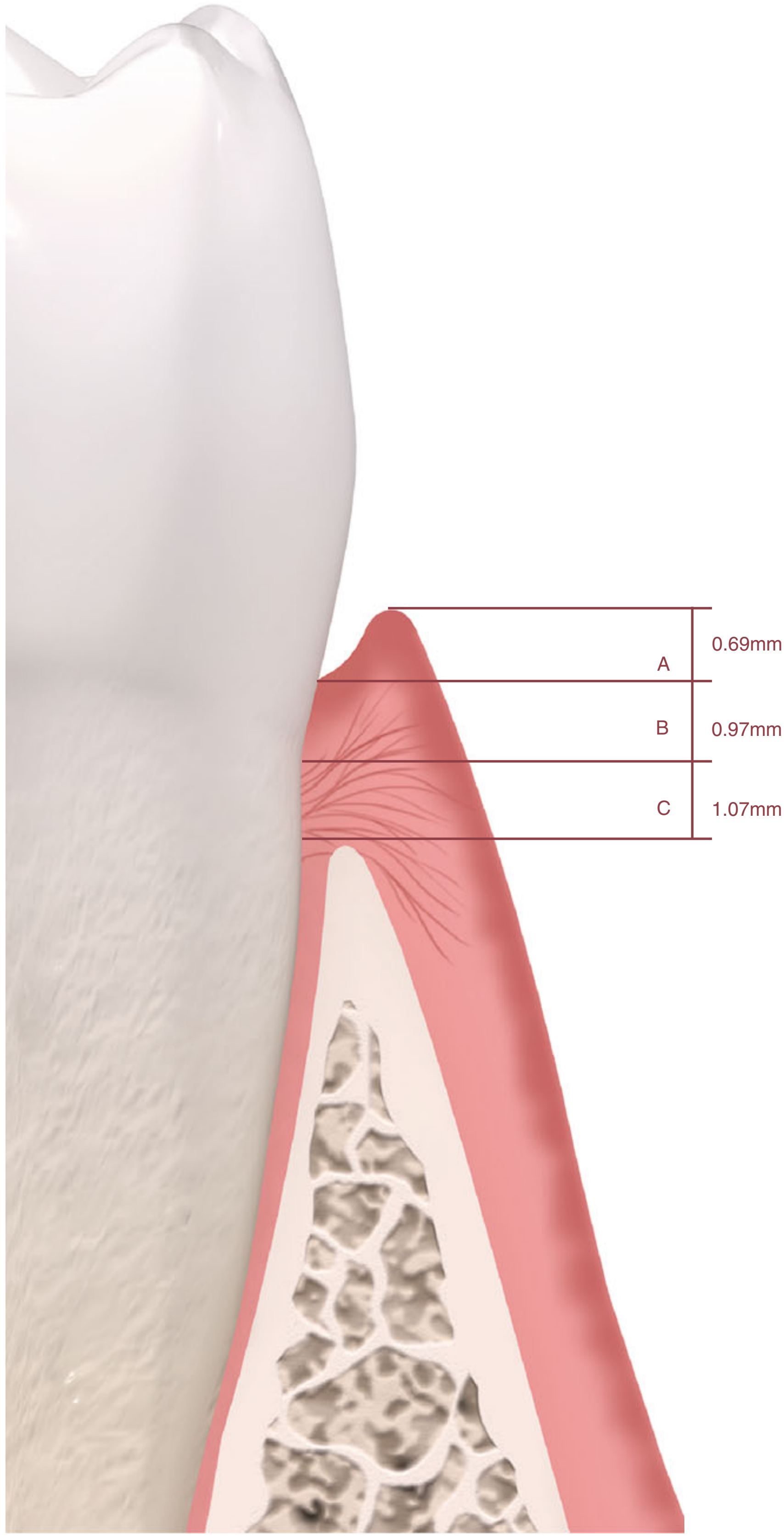

Fig. 2.25 Biologic width. *A* gingival sulcus, *B* junctional epithelium, and *C* connective tissue

2.5 The Importance of Interdental Papilla

The importance of the interdental papilla could have been depicted above, but this for periodontal plastic surgery deserves a separate topic. The interdental space has a pyramidal form and is delimited by the crestal bone, the contact point, and it is expected that it should be totally fulfilled by the interdental papilla in healthy conditions. This space filling may be lost because of periodontal disease. The form of interdental space is mainly established by the vertical dimension between the contact point and the alveolar crest (vertical) and the distance between adjacent teeth (horizontal). Those dimensions vary between teeth groups on the same patient and tooth shape from one patient to another.

Papilla loss causes unpleasant aesthetic problem such as black triangles [37]. In addition, it may jeopardize phonetics and lead to food impaction between teeth. Nordland and Tarnow proposed a classification to papilla loss [38] based on four classes of interdental papilla (Fig. 2.26):

- Normal: complete filling of interdental embrasure [38]
- Class I: papilla loss with the tip of interdental papilla between contact point and interproximal cementoenamel junction [38]
- Class II: papilla loss with the tip of interdental papilla lying apically to the interproximal CEJ, but coronally to the buccal CEJ [38]
- Class III: when the papilla loss extends at the level or apical to buccal CEJ [38]

A number of studies analyzed the anatomical factors that may influence the presence or absence of interdental papilla in healthy subjects [39–45]. Most of those studies consider interdental papilla presence when interdental space is totally fulfilled with gingiva. For instance, thick and wide interproximal dental papillae can positively influence the percentage of complete root coverage [46–48]; however, the papillae anatomy is directly associated with the distance from the contact point to the bone crest. When the measurement from the contact point to the bone crest is 5 mm or less, the papilla is present almost 100 % of the time, whereas when the distance is 6 mm, the papilla is present 56 % of the time [39]. When this distance is between 7 and 10 mm, the papilla is missing most of the time [39].

As mentioned above, the interdental space is not only delimited by vertical distance between contact point and bone crest. Root proximity is responsible for the interproximal alveolar crest shape [40–49] and is prone to interfere on papilla morphology. Cho et al. [40] performed a study analyzing horizontal (interradicular) and vertical distances. A total of 206 healthy interdental areas were measured (51 anterior, 69 premolar, and 86 molar) in 80 patients. The results demonstrated that a distance of 4 mm between the contact point and alveolar crest presented 89.7 % of papilla presence and that this percentage reduces when the distance increases. When both measures were considered together, an interradicular distance of 1–2 mm, associated with a vertical distance of 4 mm, presented 100 % of papilla presence; an interradicular distance of 1.5 and 5 mm of vertical distance was associated with 88.9 % of papilla filling the interdental space. This paper demonstrated that interradicular distance should be taken in consideration when papilla presence is required [40]. Other aspects can be considered too. Teeth with rectangular form were more likely to present interdental papilla [41], as well as increasing age might be associated papillary recession [50].

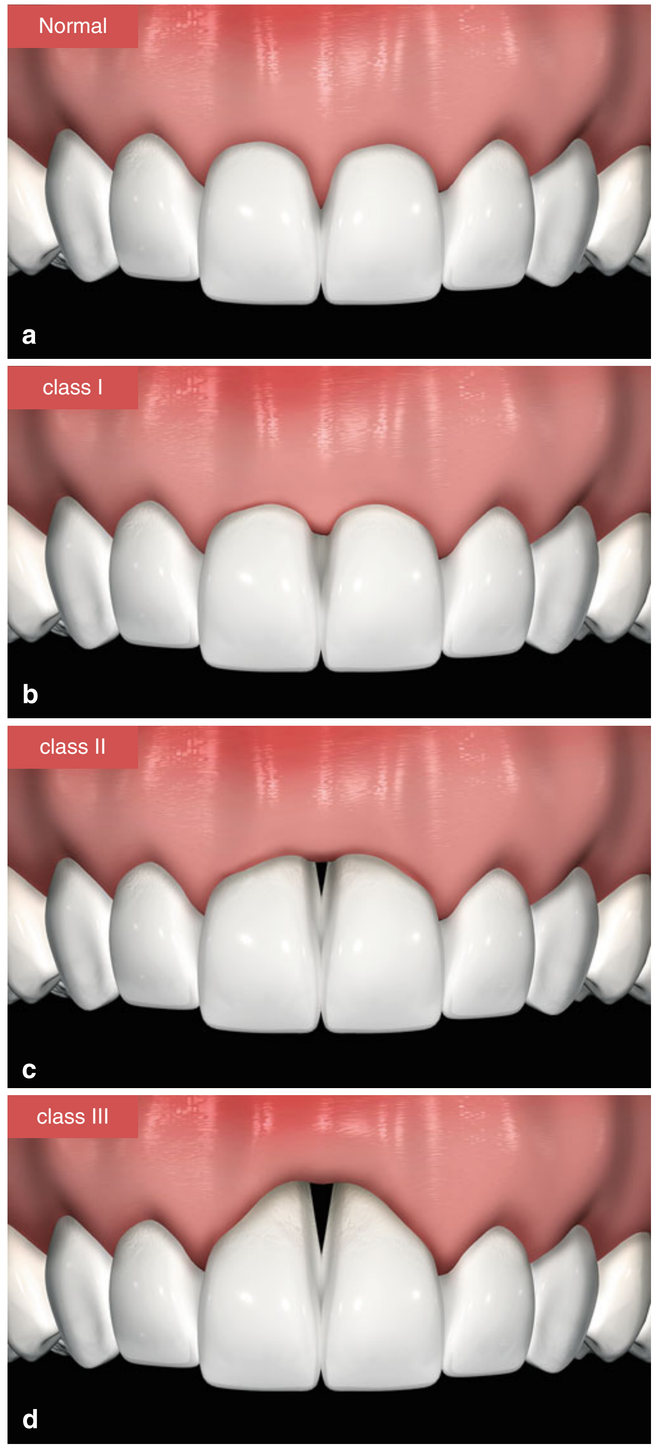

Fig. 2.26 (**a**–**d**) Schematic representation of the papilla loss classification by Nordland and Tarnow [38]

2.6 Rationale, Concepts, and Basic Surgical Principles of Periodontal Plastic Surgery

Although treatment planning involving periodontal plastic surgery procedures requires strong knowledge on anatomy of periodontal tissues and scientific background, the most common basic surgical principles of dental surgery should be followed to accomplish the foreseen outcomes. The proper diagnosis of the condition of interest as well as the selection of the best surgical approaches to each individual patient and sites can improve the odds of achieving the expected prognosis.

Periodontal plastic surgery involves the use of flap procedures (i.e., "a loosened section of tissue separated from the surrounding tissues except at its base" [1]) that may be classified by the AAP according to their thickness: the partial/split thickness (i.e., "a surgical flap of epithelium/mucosa and connective tissue that does not include the periosteum" [1]) or the mucoperiosteal/full thickness (i.e., a mucosal flap [usually the gingiva and alveolar mucosa] that includes the periosteum [1]) flaps (Fig. 2.27). Fundamentally, a flap may be categorized based on its location, shape, design, and proposal (Figs. 2.28, 2.29, 2.30, 2.31, 2.32, 2.33, 2.34, and 2.35) [1]:

- Double papilla pedicle flap: "The use of the papillae on the mesial and distal of a tooth as laterally positioned flaps sutured together over the tooth root" [1]
- Envelope flap: "A flap retracted from a horizontal linear incision, as along the free gingival margin, with no vertical incision" [1]
- Gingival flap: "A flap that does not extend apical to the mucogingival junction" [1]
- Modified Widman flap: "A scalloped, replaced, mucoperiosteal flap, accomplished with an internal bevel incision, that provides access to the root for root planing" [1]
- Mucogingival flap: "A flap that includes both gingiva and alveolar mucosa" [1]
- Papillary Pedicle flap: "A laterally rotated flap employing the gingival papilla" [1]
- Pedicle flap: "A surgical flap with lateral releasing incisions" [1]
- Positioned flap: "A surgical flap that is moved or advanced laterally, coronally, or apically to a new position" [1]
- Replaced/repositioned flap: "A flap replaced in its original position" [1]
- Sliding flap: "A pedicle flap moved to a new position" [1]

Additionally, other types of flaps were also described in the literature, such as the papilla preservation flap [51], modified papilla preservation flap [52], and the simplified papilla preservation flap [53] that may be used, for instance, for open flap debridement associated or not to regenerative approaches.

Altogether with flap procedures, grafts and biomaterials of different origins may be used for PPS, and these are defined by the AAP [1] as:

- Graft: "(a) Any tissue or organ used for implantation or transplantation; (b) A piece of living tissue placed in contact with injured tissue to repair a defect or supply a deficiency; (c) To induce union between normally separate tissues" [1]
- Allograft/allogeneic graft: "A graft between genetically dissimilar members of the same species" [1]
- Alloplast: "A synthetic graft or inert foreign body implanted into tissue" [1]
- Autograft/autogenous graft: "Tissue transferred from one position to another within the same individual" [1]
- Heterograft/xenogeneic graft: "A graft taken from a donor of another species" [1]

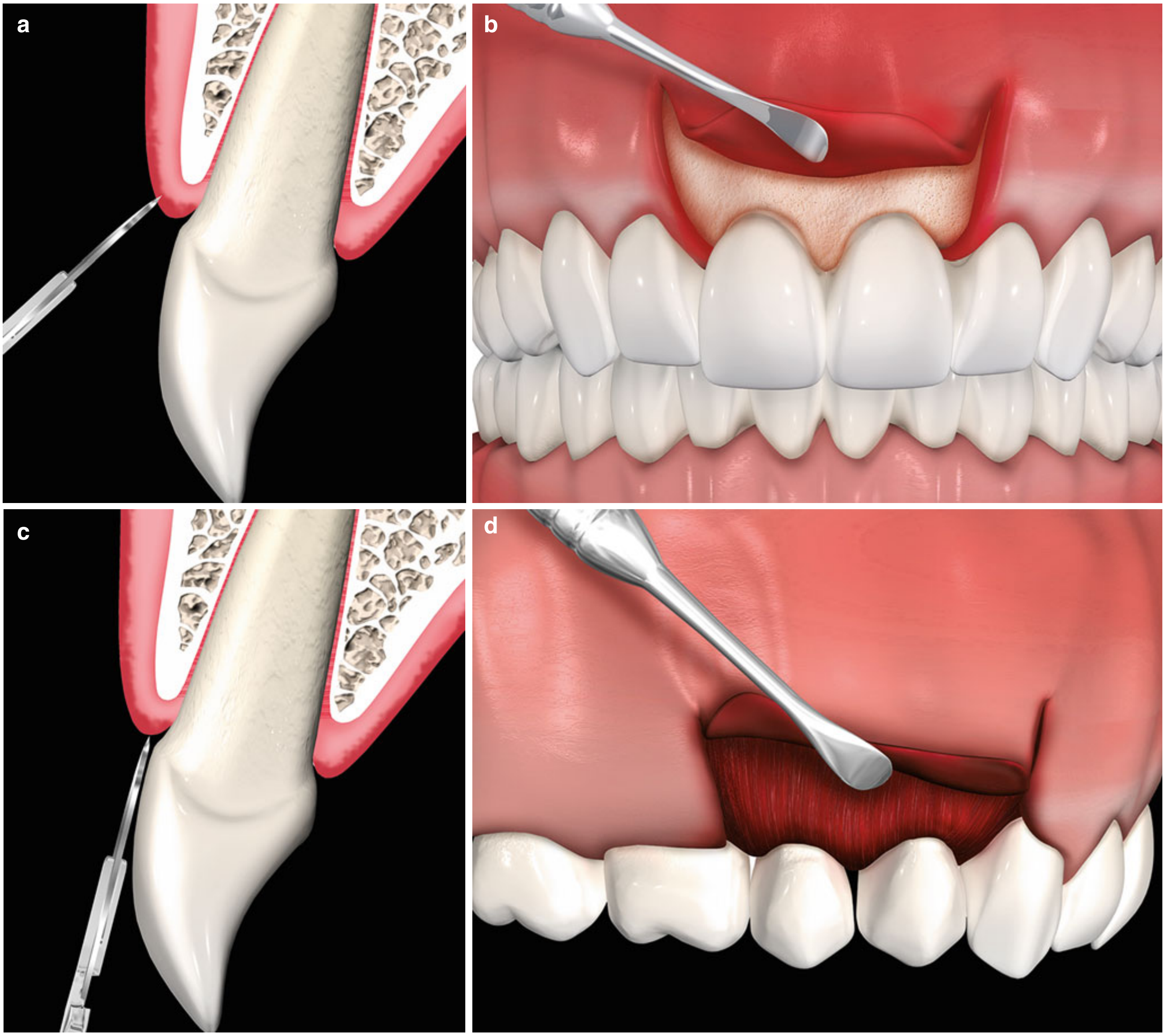

Fig. 2.27 Incision to bone crest (**a**), full-thickness flap (**b**), incision used for soft tissue separation (**c**), partial-thickness flap (**d**)

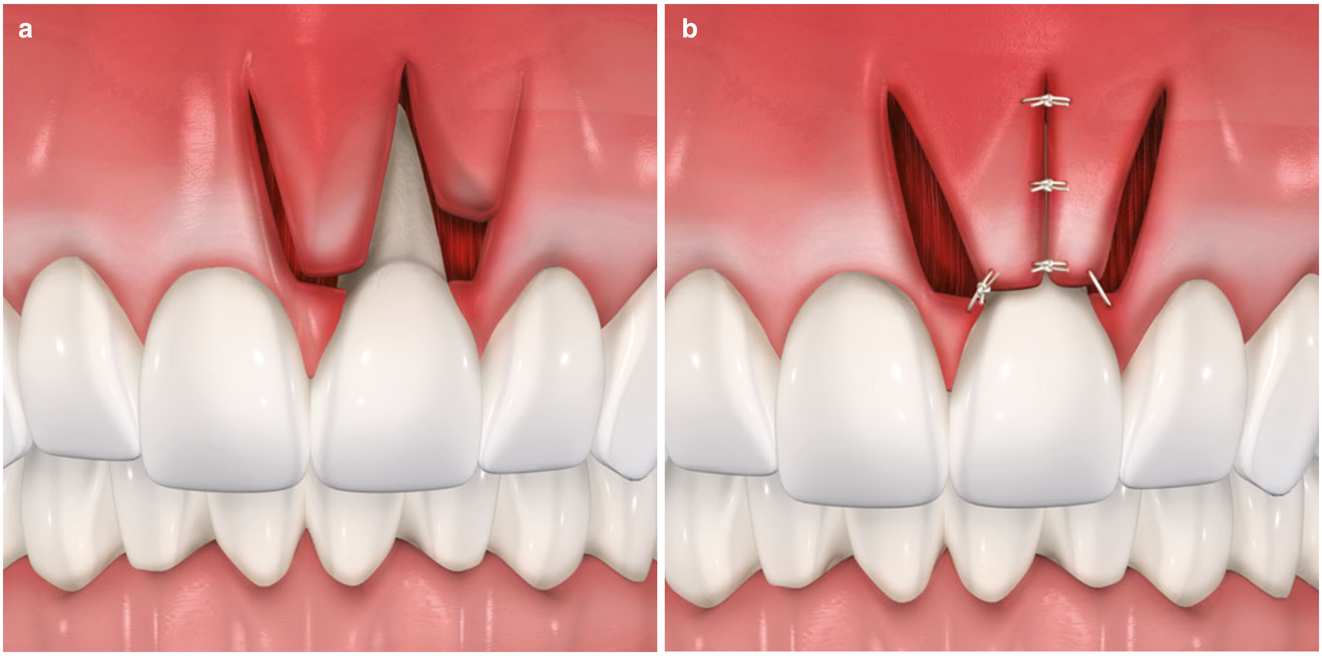

Fig. 2.28 (**a**, **b**)Double papilla pedicle flap

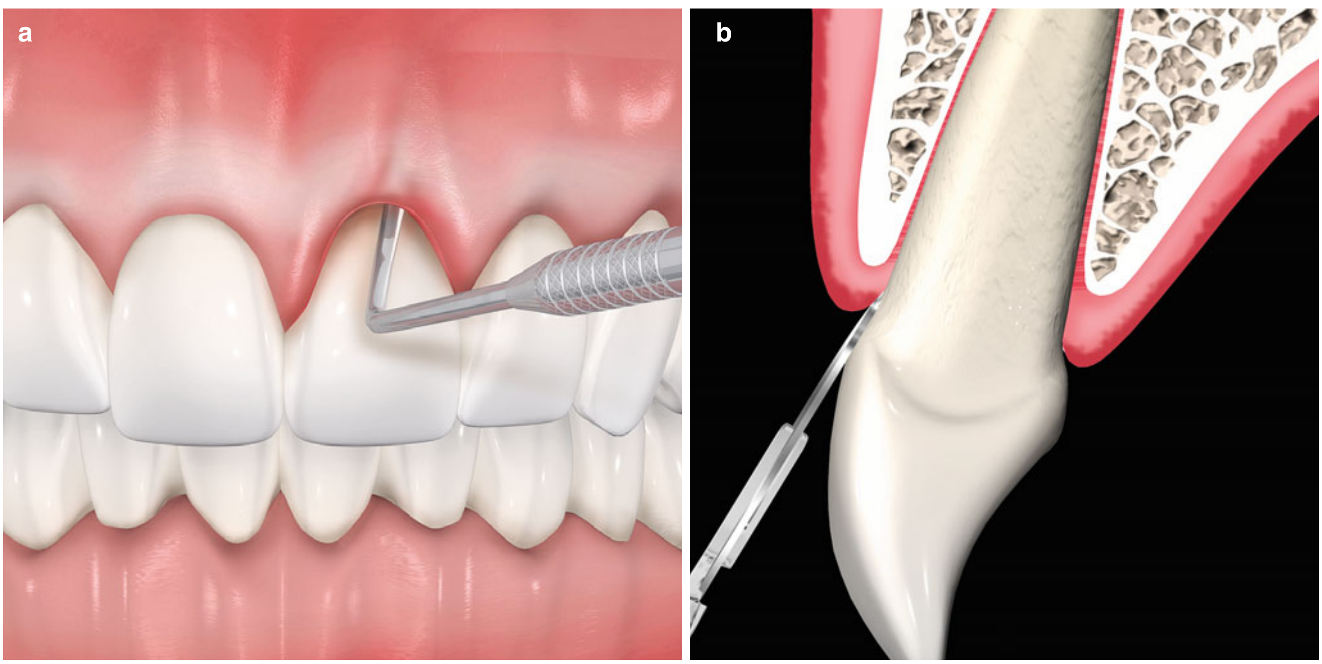

Fig. 2.29 (**a**, **b**) Envelope flap

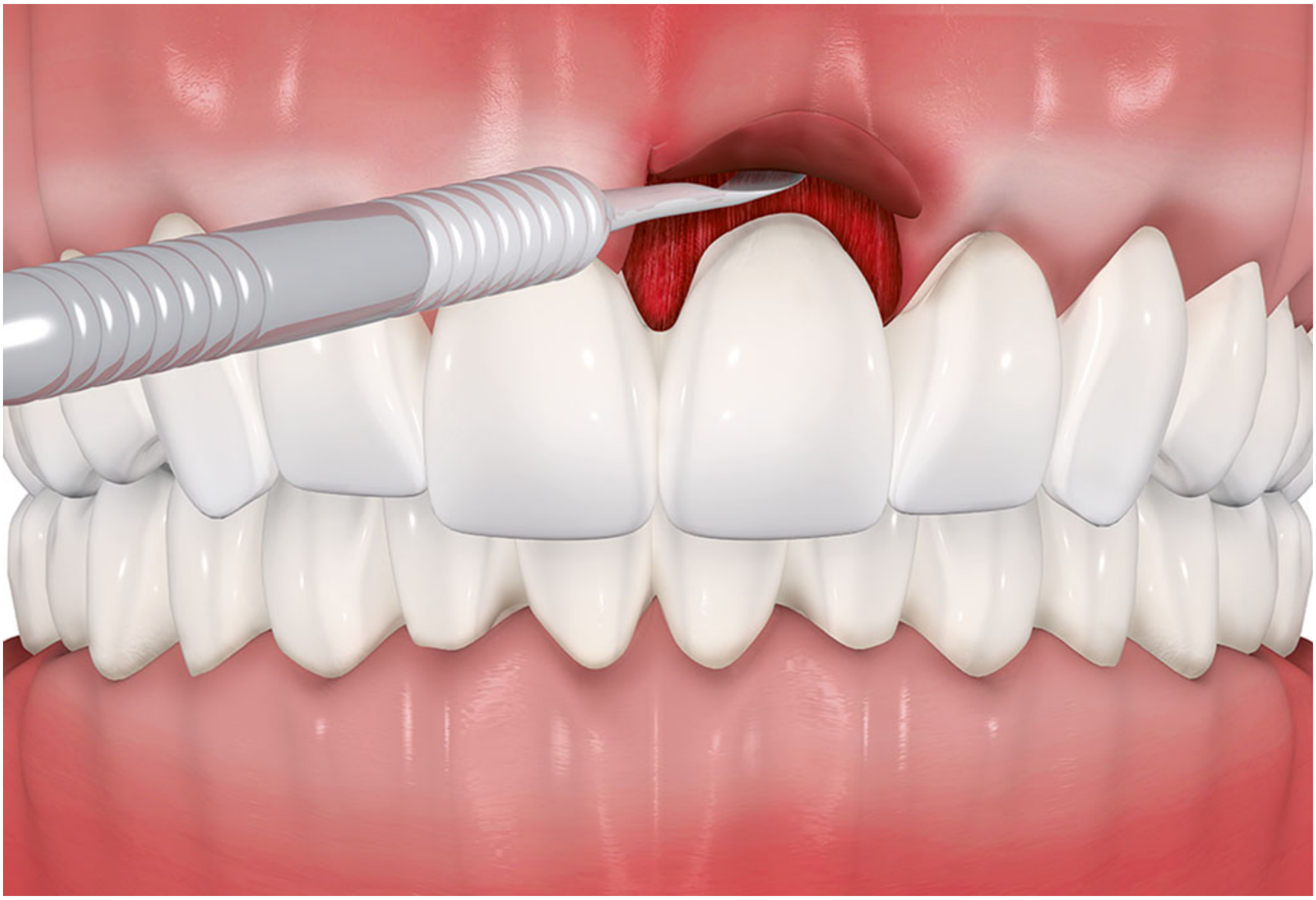

Fig. 2.30 Gingival flap

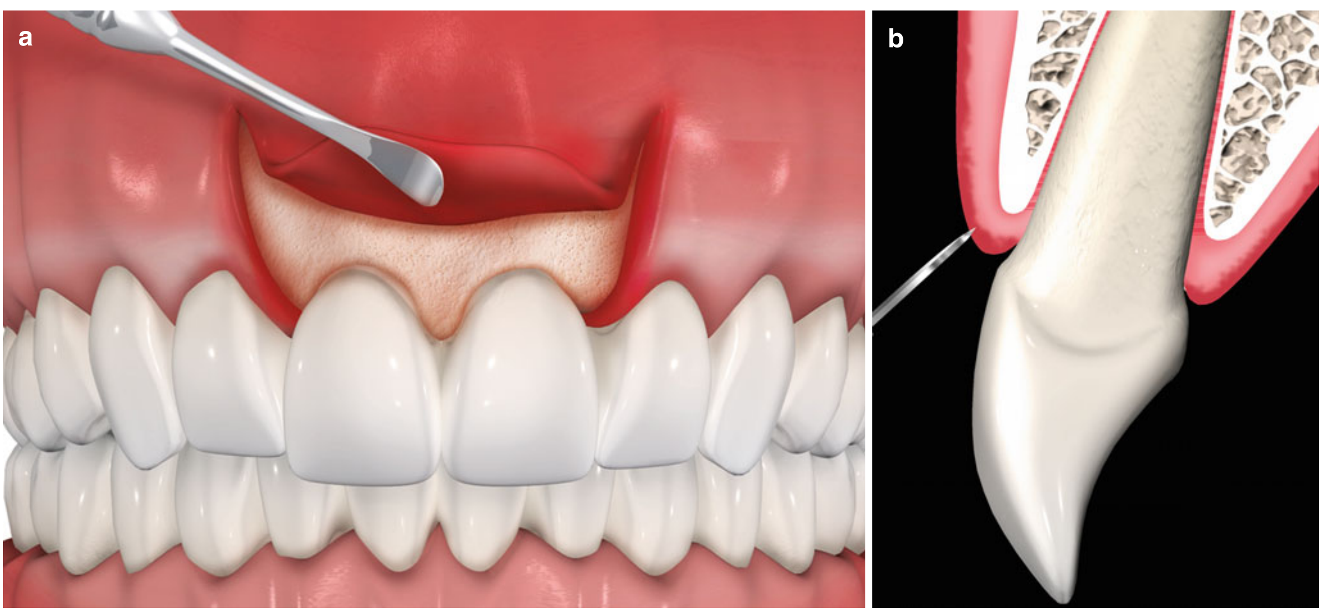

Fig. 2.31 Modified Widman flap

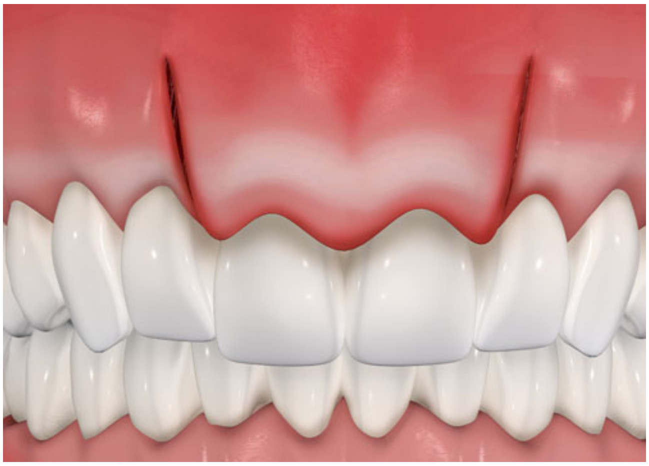

Fig. 2.32 Mucogingival flap

Fig. 2.33 Pedicle flap

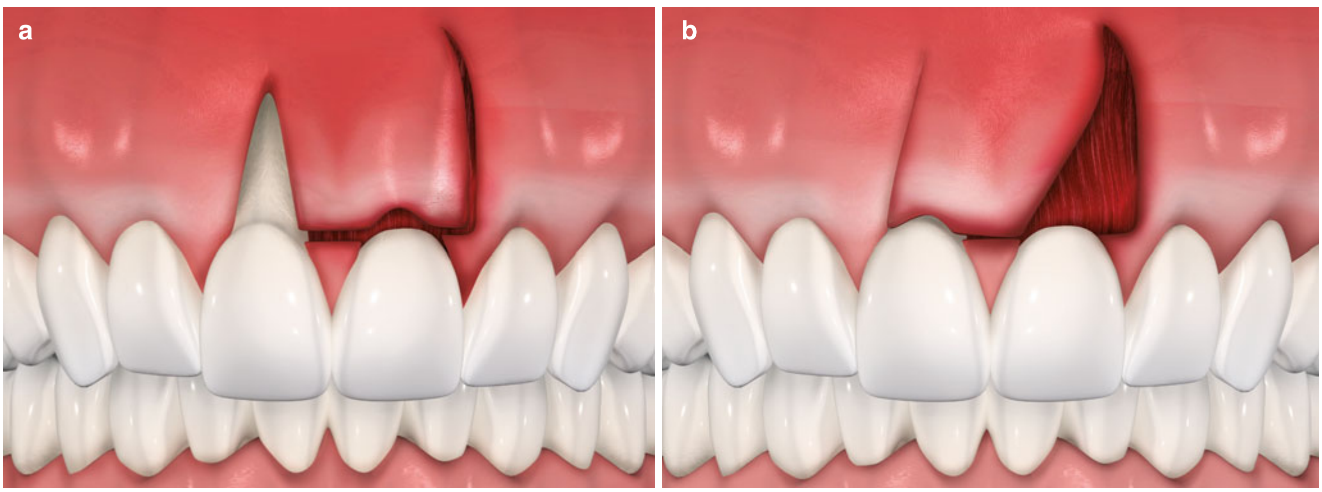

Fig. 2.34 (**a**, **b**) Positioned flap/sliding flap

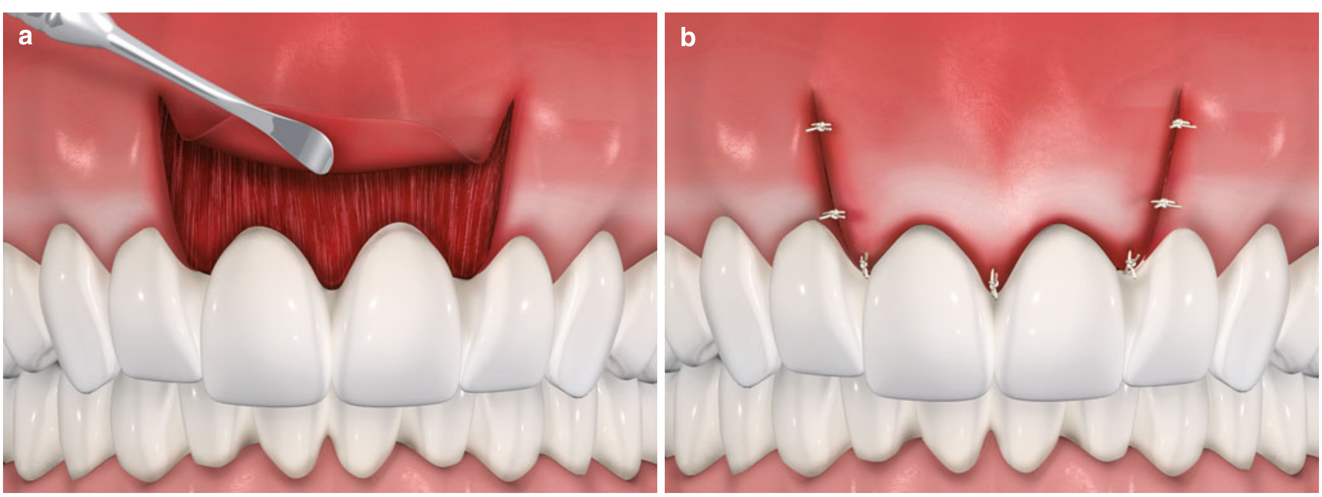

Fig. 2.35 (**a**, **b**) Replaced/repositioned flap

Apart of the types of flap or grafts used during the surgical procedure, as a general rule, other important pre-, trans-, and postsurgical steps should be accomplished as well:

- Before surgery: Any surgical procedure should be carefully planned, in terms of prognosis (Will the surgical procedure improve the functional and/or aesthetical outcomes of my patients? Will these outcomes be able to fulfill my patient's expectations?), limitations (What can and what cannot be achieved with the proposed therapy based on my patient's diagnosis? How should I proceed? Is there any local and/or systemic condition that can hinder the expected results?), adverse effects/complications (Is the procedure of choice safe? What are the involved risks associated to it?), and long-term stability (Can the results be maintained by long-term periods?). Overall, complete medical and dental histories should be obtained and carefully evaluated, as well as lack of periodontal inflammation and adequate plaque control (≤20 %) should be present. In addition, the patient must be aware of all technical steps to be performed and agree with procedure of choice.
- During surgery: All surgical steps should be followed (i.e., correct preparation of the surgical instruments (Figs. 2.36 and 2.37), patient's antisepsis and anesthesia, adequate surgical sequence, and precise suture). All types of surgery are based on incisions, that is, "a cut or surgical wound made by a knife, electrosurgical scalpel, laser, or other such instrument" [1]. Care should also be taken when selecting any particular type of incision. For instance, an "external bevel" incision aims to reduce the thickness of the mucogingival complex from the outside surface, as in a gingivectomy (i.e., "the excision of a portion of the gingiva; usually performed to reduce the soft tissue wall of a periodontal pocket" [1]), while an "internal bevel (or inverse, reverse or inverted)" one is indicated to reduce the thickness of the mucogingival complex from the sulcular side [1]. Also, the use of releasing incisions (those made to enhance the mobility of a periodontal flap [1]) should be carefully evaluated in areas of high aesthetic demands. Moreover, comprehensive instructions to the patient regarding hygiene and postsurgical care of the treated site as well as lack of hurry when performing "plastic procedures" should be emphasized in order to extract the maximum potential of each specific procedure.
- After surgery: To provide all the support to the patients, in terms of maintaining them in the strict hygiene program established. It should be considered that the oral microbial environment at the oral cavity may modify the wound healing of a surgical site. Thus, any focus of infection (e.g., periodontal pockets) should be extirpated, optimal oral hygiene standards should be accomplished, and the use of effective antiseptic agent should be indicated [54]. For example, patients must be prescribed 0.12 % chlorhexidine digluconate and instructed to rinse gently twice a day for 14–21 days, and sutures may be removed between 8 and 21 days, depending on the procedure performed. It is important to highlight that patients should contact their clinicians in case of doubts or complications/adverse effects. Also, during this period, they should be instructed not to brush the teeth in the treated area. Analgesics and antibiotics may be prescribed if needed, and all patients should be seen every week for 4 weeks; then once a month for 4 months. At 4 months postsurgery, all patients should be oriented to follow regular periodontal maintenance care with individualized time intervals, based on the patient's characteristics (e.g., level of dental biofilm control, smoking habits, manual skills, cooperation) [54]. Regarding oral wound healing, Sculean et al. [55] described that (1) it has been seen that the gingival and palatal mucosa does not seem genetically and not essentially functionally determined [55]; (2) the granulation tissue originating from the periodontal ligament or from *lamina propria* can stimulate keratinization, but it seems that the deeper the connective tissue at the palatal vault, the smaller is the potential of keratinization (i.e., connective tissue harvested from areas immediately below the keratinized layer has a superior potential of keratinization) [55]; and (3) the epithelial healing of surgically treated sites looks accomplished 1–2 weeks postsurgery (for root coverage procedures, the physical integrity of a maturing wound between the flap and the root surface is completed 2 weeks after surgery [55].

In addition, it should be highlighted that the choice of any soft tissue augmentation/reduction procedure is grounded on five basic factors inherent to all surgical procedures: (1) rate of success/odds of failure, (2) reproducibility, (3) health condition, (4) patient's compliance with the proposed treatment plan, and (5) cost–benefit [1–7]. Whenever one or more of these conditions are lacking, the treatment plan should be revised, and preferably the patient should not be submitted to any surgical procedure at all.

Fig. 2.36 Basic surgical instrument set used for periodontal plastic surgery (**a**) additional instruments may be included based on the type of surgical procedure (**b**) instruments positioned in a functional/logical sequence (**c**)

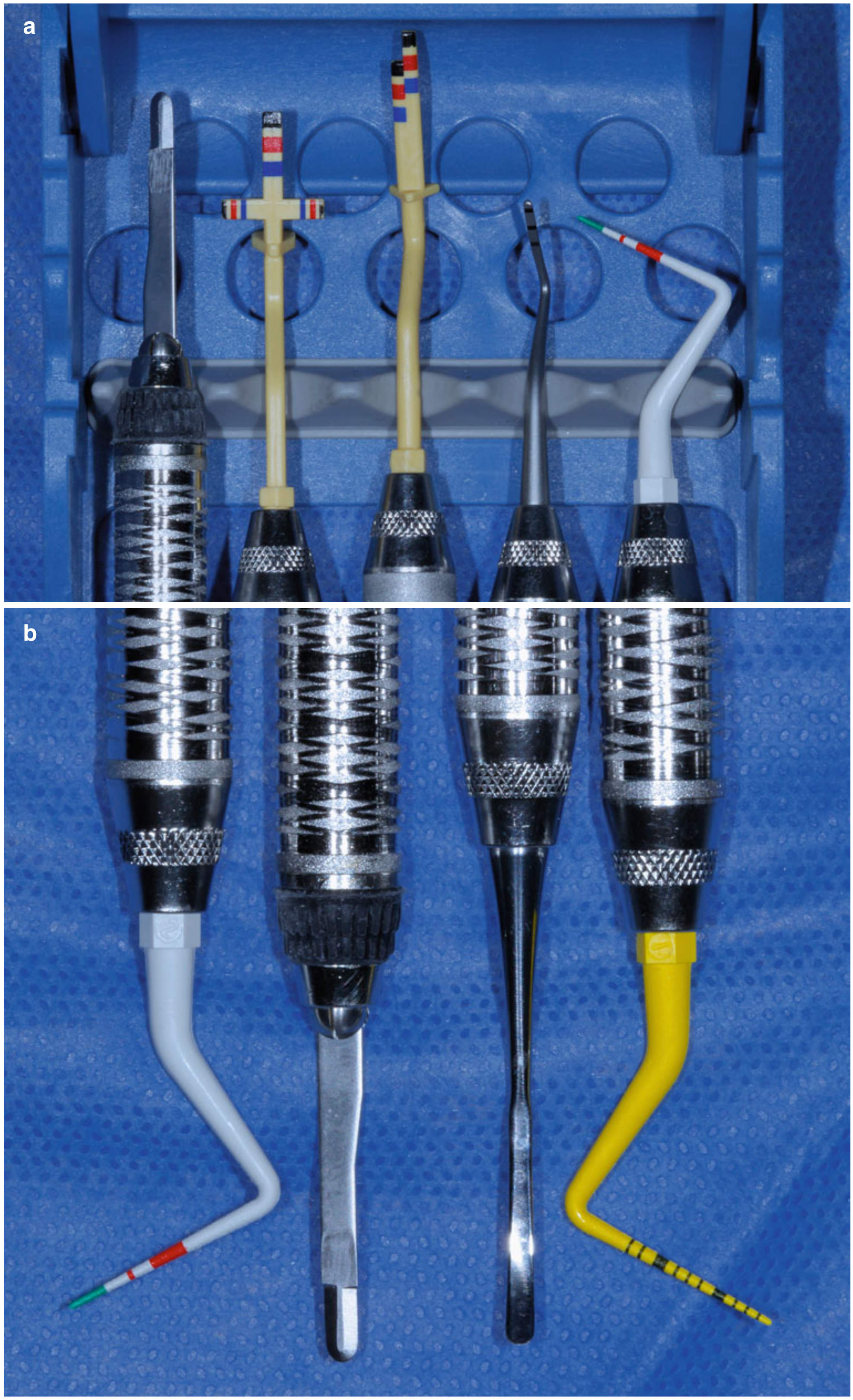

Fig. 2.37 (**a**, **b**) Set of instruments used for clinical crown lengthening procedures

2.7 Clinical Concluding Remarks: "What Is the Importance of the Anatomical Characteristics of the Periodontium, and Mainly the Gingival Tissue, on My Treatment Planning?"

The decision-making process for the "plastic" surgical treatment of gingival tissues, similar to any other periodontal therapy, requires a solid knowledge of the anatomical characteristics of the periodontal tissues. Altogether with them, a correct treatment planning will involve rational procedure selection, attention to basic surgical principles, and mainly the cooperation of the patient. It should be clear in mind that independently of the best source of materials, instruments, and even the quality and expertise of the clinician, selection of a procedure not accounting the local anatomy of the periodontium will decrease the potential of success of the procedure, or even promote additional harms to the patient.

It should also be considered that soft tissue augmentation procedures may involve the use of autogenous grafts (i.e., free gingival grafts and subepithelial connective tissue grafts) that are undoubtedly harvested from donor sites presenting adequate/enough quantity of available tissue, but also the selection of any "donor area" is based on the location of the recipient site and clinician's own preferences [54]. Preferably, the harvesting technique should provide adequate quantity of tissue but reduced trauma, pain, and minimum adverse effects/complications as well.

It can be noted that here are few studies regarding the presence and absence of interdental papilla. Most of them do not present previous statistical power tests. In addition, there is a lack of grouping in the papilla site in the anterior and posterior teeth. Despite these limitations, when treating papilla recession or an aesthetic area with veneering or any prosthetic treatment, a distance of 4 mm between the contact point and bone crest should be respected, and, when a restorative alveolar interface procedure is indicated on preprosthetic periodontal surgery, the distance between roots should be between 1 and 2 mm. In addition, it is important to establish a functional contact point immediately after the crown lengthening procedure in order to optimize a subsequent prosthetic treatment.

Continued research is necessary to improve the effects of soft tissue substitutes [56]. Thus, each of these issues should be carefully reviewed before initiating a periodontal plastic surgical procedure.

Critical Summary of the Results of Systematic Reviews

Systematic reviews conclusions: For the biologic width, there is no consensus of "universal dimension" of this complex, but this is certainly associated to the marked heterogeneity among included studies (i.e., methods/specimens examined and outcome measures selected for analysis) [57]. For the periodontal biotypes, weak to moderate associations between the tooth, gingiva, and osseous proportions and positive relationship between gingival thickness, keratinized tissue, and bone morphology may be expected [33].

Summary of the reviews and critical remarks: Fourteen studies were included in the first review [57], but several shortcomings related to included studies prevent an adequate assessment of the outcomes of these studies. In addition, most of the information available on other studies regarding the anatomical characteristics of the periodontium is not compiled using systematic approaches. Due to the nature of this studies (many of them histological), it is reasonable to consider the information available relevant and clinically useful. Similarly, only some cross-sectional studies could be retrieved for analysis in the second review, and the proposed classifications did not present clear definitions [33].

Evidence quality rating/strength of recommendation (ADA 2013) [58]: Expert opinion for – Evidence is lacking; the level of certainty is low. Expert opinion guides this recommendation.

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