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Anatomy and Physiology

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Overview of Gingival Tissue and Periodontium

Macroscopically, the dental organ appears to be limited to the dental crown surrounded by soft tissue, which is scalloped around a well delineated circular line called the cementoenamel junction (CEJ).

The morphology of the dental crowns change shape from the midline to the posterior dentition and with it, the function and dimension change. The soft tissue changes as well to accommodate these differences. That soft tissue will comprise two distinct parts, the mucosa and the keratinized tissue separated by the mucogingival line (MGL). In the keratinized zone, we have the attached gingiva and the marginal gingiva. The latter is a non-attached tissue that extends few millimeters from the margin to the junctional epithelium (JE), delineating the sulcus that is a gap on the inner side of the non-attached gingiva around the CEJ. JE is non-keratinized epithelium as it is on the border of the attached and non-attached gingiva.

In a microscopic cross-sectional view, we can appreciate the different parts of hard and soft tissue interacting together making the periodontium of the dental organ from its incisal tip apically (Figure 1.1). This figure shows the intricate components of the dental organ and the harmony needed to make this interaction work reminding us of a well-tuned opera. All of this hard and soft tissue requires irrigation from perfectly lined up blood circulation, which originates from an alveolar artery dividing itself in a periodontal ligament (PDL) branch, dental branch, and an intra-marrow branch. Inside the mucosa, an intricate circular system leads to a supra-periosteal artery crossing into the keratinized gingiva in a linear manner up to the gingival collar in which the three arteries, PDL, intra-marrow, and supra-periosteal form the gingival crevicular plexus (Figure 1.2).

Radiographically, the PDL space can be observed and its width ranges between 0.1 and 0.25 mm (Figure 1.3). Any widening beyond these margins is considered a “widening of the periodontal ligament,” which can be a sign of inflammation either from an early periodontal disease at the coronal level or excessive occlusal trauma.

This harmonious intricate system called the dental periodontium will be reviewed in this manual, wishing you great reading and enjoyment.

Embryonic Development

At approximately four to five weeks into embryonic development, there is downgrowth of the ectoderm of the primitive oral stomatodeum into the underlying ectomesenchyme. At the terminal end of this downgrowth, the cells form a knoblike structure or bud. Cells in the surrounding ectomesenchyme begin to concentrate around this bud.

Several weeks later, this ectodermal bud has developed into a cuplike structure with four distinct layers: an outer enamel epithelium (OEE), an inner enamel epithelium (IEE), a stellate reticulum (SR), and a stratum intermedium (SI). Directly beneath the IEE, cells of the underlying ectomesenchyme have condensed into a dental papilla (DP). Surrounding these two structures is a third condensation, the dental follicle (DF), which will give rise to most of the cementum, periodontal ligament, and alveolar bone.

At the apical extent of the root, the IEE and OEE have fused to form Hertwig’s epithelial root sheath (HES). More coronally, this root sheath breaks down to form islands of

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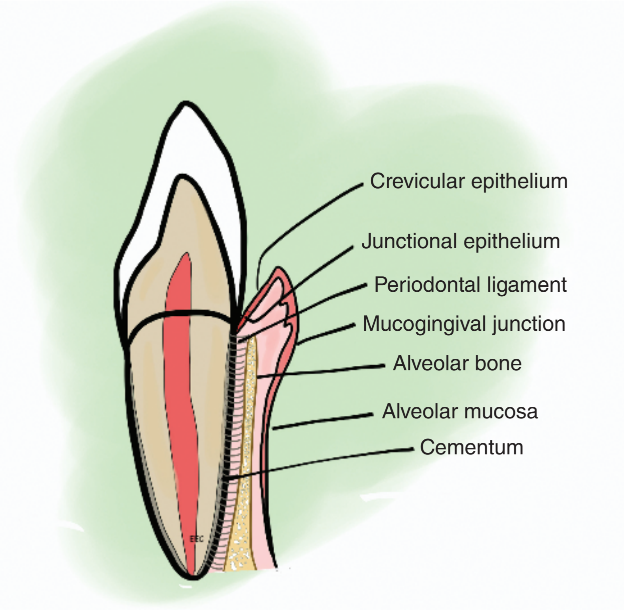

Figure 1.1 Different components of the periodontium in a cross section.

epithelial cells in the developing PDL space, the epithelial rests of Malassez (ERM). The breakdown of the root sheath and subsequent exposure of the dentin (D) to the DF allows cells in the DF nearest the developing root surface to differentiate into cementoblasts (CB) and lay down the first cementum matrix (CM). Further away from the tooth follicle, cells differentiate into fibroblasts and lay down the first bundles of collagen in the PDL (Figures 1.3–1.6).

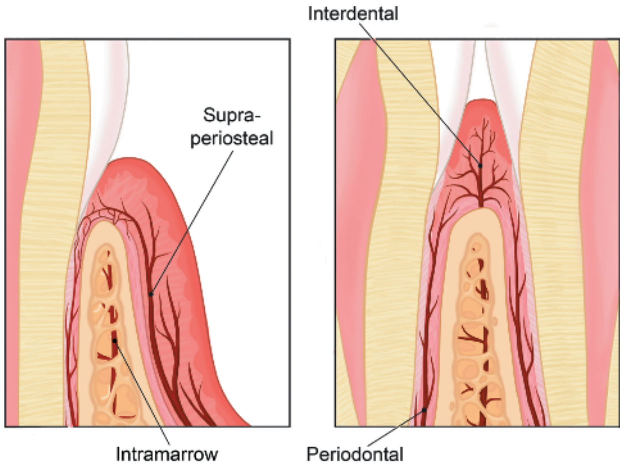

Figure 1.2 Vascularity in the periodontal ligament.

Formation of the Epithelial Attachment

After formed, the enamel is covered by an epithelium called the reduced dental epithelium (RED) extending

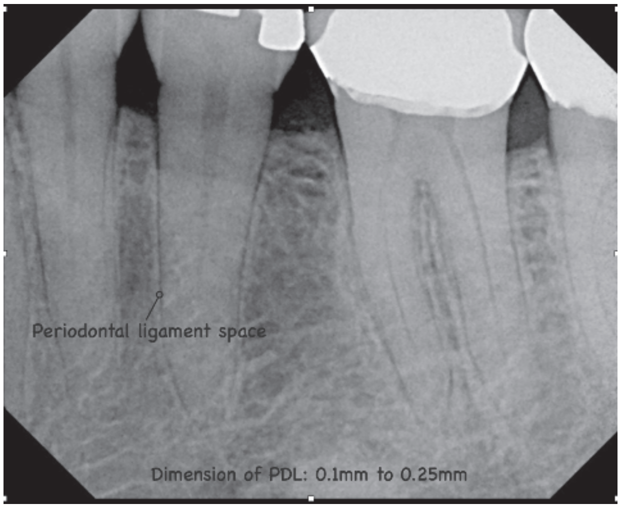

Figure 1.3 Dimension of periodontal ligament.

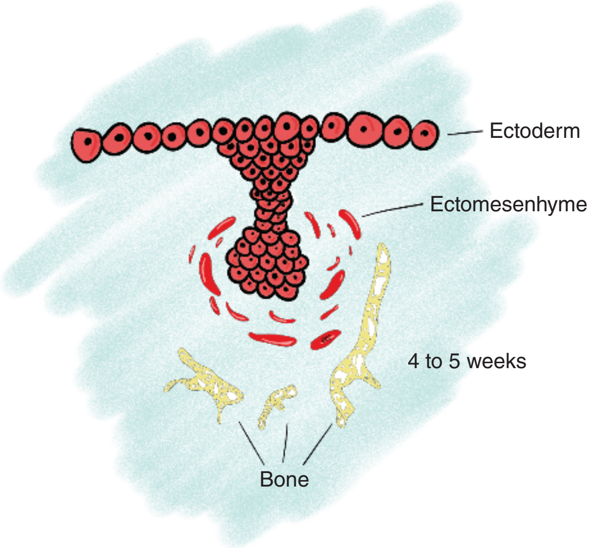

Figure 1.4 Bud stage in embryologic formation of the dental organ.

to CEJ. During eruption, the tip of the tooth approaches the oral mucosa leading to a fusion of the RED with oral epithelium (OE). Once the tip emerges, the RED is termed Epithelial Attachment. As the tooth erupts, the attached epithelium gradually separates from its surface creating a groove called the Gingival Sulcus.

Formation of the Cementum, Periodontal Ligament, and Alveolar Bone

The deposition of cementum on the root surface that gradually thickens toward the PDL space is somewhat similar

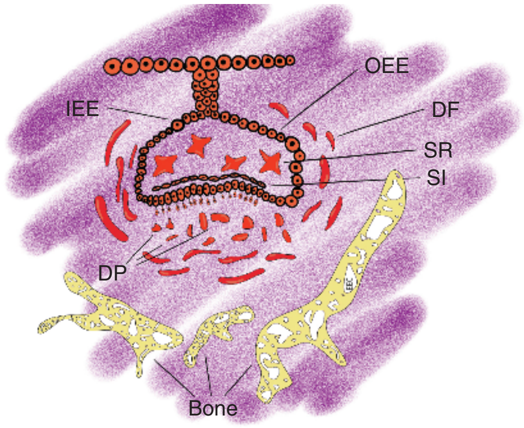

Figure 1.5 Bell stage in embryologic formation. (OEE: outer enamel epithelium; IEE: inner enamel epithelium; SR: stellate reticulum; SI: stratum intermedium; DF: dental follicle; DP: dental papilla).

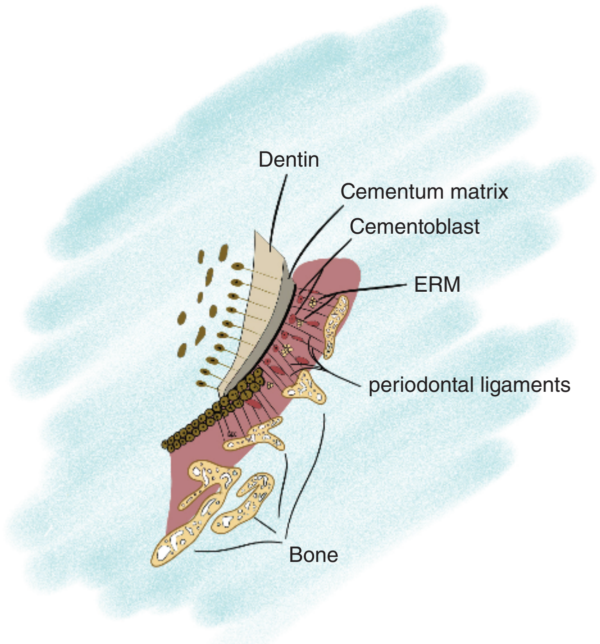

Figure 1.6 Apical formation of the different periodontal ligament. ERM, epithelial rest of malassez; HES, Hertwig's epithelial root sheath.

to the deposition of alveolar bone that thickens the alveolar bone support from the opposite side of the ligament space. As a result, the cementum does have some structural and biochemical similarities (as well as some critical differences) with alveolar bone.

As with the development of the alveolar bone proper, an organic matrix of cementum composed primarily of type I and type III collagen is secreted by a layer of formative cells (the cementoblasts) over the thin hyaline-like layer secreted by HES covering the root dentin. This fine fibrillar matrix calcifies to form a relatively uniform and well-organized layer of cementum free of cellular elements called primary acellular cementum. This first thin layer of mineralized cementum contains only the fibrillar matrix from the cementoblasts themselves. These fibers are therefore called intrinsic fibers of cementum.

As the cementum continues to thicken by apposition of cementum by the cementoblast layers, this thickening cementum will encounter and incorporate bundles of the forming periodontal ligament. These ligament bundles incorporated into the cementum surface will calcify along with the surrounding intrinsic fibers to form a significant portion of the more superficial layers of the cementum. These insertions of calcified ligament fibers are termed extrinsic fibers of the cementum. A similar entrapment and calcification process occurs on the forming alveolar bone side. The general term for these calcified insertions of bundles of ligament fibers into the cementum and bone are Sharpey's fibers. On the cementum side, these Sharpey's fibers are much thinner in diameter and insert at closer intervals when compared with the alveolar bone side.

These differences in the pattern of insertion have clinical importance in the distribution of forces that are generated within the PDL during occlusion, tooth movement, and traumatic forces. Specifically, these forces are more evenly distributed along the cementum surface and are more concentrated along the more widely spaced insertions on the alveolar bone side. As a result, in response to mechanical forces, there is generally a remodeling of the periodontal housing on the alveolar bone side and not on the cementum side. This prevents the possibility of significant cementum and root resorption. In addition, the root cementum is protected from this relatively extensive remodeling because it is avascular, and therefore not as exposed to osteoclast-like precursor cells in the circulation. Although small areas of microscopic cementum resorption and repair have been frequently observed in histologic sections, more extensive resorption of cementum is usually not seen unless there is a force on the tooth of a high enough magnitude, or duration, or both, that cannot be accommodated by the remodeling of the alveolar bone.

As the tooth completes actively erupting into the oral cavity and meets its opposing tooth in the other arch, the formation of cementum becomes somewhat less regular and organized. This type of cementum formation that occurs over the more organized primary cementum is called secondary cementum. It occurs mainly along the apical one third of the root. During the formation of secondary cementum, cells in the layer of secreting cementoblasts will often become entrapped within the CM. These entrapped cementoblasts become cementocytes similar in appearance to the entrapped osteoblasts that become osteocytes on the alveolar bone side. These areas of cementum that contain cementocytes are called cellular cementum. Layers of cellular cementum are generally seen in the apical one third of the root surface. In secondary cementum, these layers of cellular cementum often alternate with layers of acellular cementum.

Soft Tissue Physiology

Gingiva

The gingiva consists of free and attached tissue. The attached gingiva is the portion of the gingiva that is firm, dense, stippled, and tightly bound to the underlying periodontium, tooth, and bone. The free gingival margin is defined as the coronal border of the free gingiva that surrounds the tooth and is not directly attached to the tooth surface. The free gingival margin generally corresponds to the base of the gingival sulcus. It is present in 30–40% of adults and most frequently occurs in the mandibular premolar and incisor regions. The mucogingival junction (MGJ) represents the junction between the gingiva (keratinized) and alveolar mucosa (non-keratinized) (Lindhe 1983).

Width and Thickness of the Gingiva

Bowers (1963) measured the widths of the facial attached gingiva in the primary and permanent dentitions of 240 subjects. The width of attached gingiva ranged from 1 to 9 mm. Values were greatest in the incisor regions (especially the lateral incisor) and the least in the canine and first premolar sites. The maxilla usually exhibited a broader zone of the attached gingiva than the mandible. Clinically healthy gingiva was noted in subjects with less than 1 mm of the attached gingiva, but the tissue was usually inflamed in areas of no attached gingiva. Buccal–lingual tooth position affected the amount of the attached gingiva present, and high frenum and muscle attachments were generally associated with narrow zones of attached gingiva. Facially positioned teeth had narrower zones of attached and keratinized tissue than well-aligned or lingually positioned teeth. As teeth moved lingually, an increase in the width of attached and keratinized tissue and a slight decrease in clinical crown height were observed. Teeth moving facially had a decrease in the width of the attached and keratinized tissue.

Voigt et al. (1978) measured the width of lingual attached gingiva in the mandible. The keratinized tissue ranged from 1 to 8 mm. Greatest widths were recorded on the first and second molars (4.7 mm), decreasing at premolar and third molar sites. The smallest widths were observed on the incisors and canines (1.9 mm).

Goaslind et al. (1977) measured the thickness of the free and attached facial gingiva in a population consisting of 10 males (ages 25–36). Results demonstrated considerable variation of gingival thickness among subjects and among areas within individual subjects. Free gingival thickness averaged 1.56–0.39 mm, increased from anterior to posterior and was directly proportional to sulcus depth. Thickness of the attached gingiva averaged 1.25–0.42 mm, increased from anterior to posterior in the mandibular arch, remained relatively constant in the maxillary anterior, and was inversely proportional to attached gingival width. The overall mean thickness for all areas was 1.41 mm.

Histological Composition

As discussed in the tooth development section, while tooth emerges and eruption continues, three distinct zones of epithelium form: outer epithelium, crevicular epithelium, and the JE. Each is different in stratification, organization, and function.

Like the epidermis, the OE has multiple layers:

1. **Stratum basale**: one to two layer of cuboidal-shaped cells that divide and migrate to the superficial layers
2. **Stratum spinosum or prickle cell layer**: spinous-shaped cells with large intercellular spaces
3. **Stratum granulosum**: flattened granular cells with flattened and condensed nuclei, increased accumulation of keratohyalin granules, and intracellular and extracellular membrane-coated granules
4. **Stratum corneum**: flattened cells packed with keratin; nuclei may be undiscernible known as orthokeratinized or may have visible dense nuclei called parakeratinized; cells shed and are replaced by cells from the deeper layers migrating upward.

In both the basal and prickle cell layers connect to each other via desmosomes, which appear microscopically as a thickening. Each half is made of a hemi-desmosome that attach to underlying cell through intermediate filaments. Within the oral gingival epithelium, there are several other cells not derived from keratinocytes. These include melanocytes that transfer melanin pigment granules to the surrounding basal layer of keratinocytes, Langerhans cells that are part of the reticulo-endothelium system and are responsible for processing and presenting foreign antigens to the immune system, and Merkel cells that may be responsible for perception of sensation in the gingiva.

On the outer layer, in 45% of the patient, stippling is noticed. It used to be thought that its presence is a sign of health but later it was refuted. Based on Karring and Loe (1970), the stippling coincides with the intersection with epithelial ridges. Epithelial (rete) ridges represent areas of epithelial proliferation into the underlying connective tissue (CT). These are believed to promote anchoring of epithelium to the CT by increasing the surface area of attachment. They are more pronounced in the gingiva than in the alveolar mucosa.

The CT of the gingiva consists of cells, fibers, and ground substance (proteoglycans [PGs] and glycoproteins [GPs]). Cells constitute about 5% of the CT and include fibroblasts (65%), mast cells, PMNs, macrophages, lymphocytes, and plasma cells. Fibers account for approximately 60–65% of the CT, with collagen predominating reticulin and elastic fibers. Ground substance comprises 35% of the CT and consists of protein-polysaccharide macro-molecules made up of PGs and GPs. The PGs contain glycosaminoglycans (GAGs) as the polysaccharide units that are covalently bonded to one or more protein chains. PGs are usually large molecules in the ground substance that function to regulate diffusion and fluid flow through the matrix, acting as molecular filters. GPs function in cell-to-cell and cell-to-matrix interactions. Fibronectin (FN) is the principal GP in CT, serving to orient fibroblasts to collagen and provide protein attachment for cell–matrix adhesions. FN may influence the migration of fibroblasts and play a crucial role in maintaining structural integrity of CT. Laminin (LN) is the attachment GP for epithelial cells, which mediates attachment of these cells to the basement membrane and preferentially binds type IV collagen.

Epithelial–Connective Tissue Interaction

Karring et al. (1975) examined the role of CT in determining differentiation of the epithelium by implanting CT from the palates of monkeys (with the epithelium removed) into pouches created in the buccal alveolar mucosa. Three to four weeks later, the grafts were exposed and allowed to re-epithelialize from surrounding non-keratinized alveolar mucosa. The sites with CT transplants from the palate healed with a keratinized surface displaying the same characteristics as normal gingival epithelium. The results of this study demonstrated conclusively that the determinant for epithelial differentiation (keratinization or non-keratinization) is the underlying CT and is not the functional stimuli as previously thought.

Gingival Fiber Groups

Hassell (2000), described the gingival collagen fibers and divided them into five principal and six minor groupings.

The principal groupings:

a. Dentogingival
b. Alveolo-gingival
c. Dento-periosteal
d. Circular
e. Transseptal

The secondary grouping:

a. Periosteogingival
b. Interpapillary
c. Transgingival
d. Intercircular
e. Intergingival
f. Semicircular

The dentogingival fibers extend from the cementum into the lamina propria laterally. Alveolo-gingival fibers “fan” coronally into the lamina propria from the periosteum at the alveolar crest. The dento-periosteal fibers extend from the cementum (close to CEJ) into the periosteum at the alveolar crest. Circular fibers circumscribe the tooth and are present in the attached gingival coronal to the alveolar crest and in the free marginal gingiva. The transseptal fibers extend mesially and distally, inserting into the cementum of the adjacent teeth coronal to the alveolar crest.

Alveolar Mucosa

The alveolar mucosa covers the basal part of the alveolar process and continues without demarcation into the vestibular fornix and the floor of the mouth. It is movable and loosely attached to the periosteum.

The main difference with the gingiva is the vascular network distributed within the periosteum of the alveolar mucosa. It is densely arranged, consisting of arterioles, venules, and a large number of capillaries. This difference in distribution of vessels is considered to reflect the histological difference. In the attached gingiva, the CT is firmly attached to the alveolar process and that is mainly due to its function which is to resist the compression and friction of mastication (Squier and Hill 1985). In contrast, the lamina propria and submucosal tissue beneath the alveolar mucosa have a fibrous structure consisting of many elastic fibers that are loosely attached to the periosteum to handle the vascular meshwork that is mainly circular and stacked. According to Lozdan and Squier (1969), the marked difference in elastic tissue content between the gingiva and alveolar mucosa was used as a reference to define this transition and the position of the MGJ.

Junctional Epithelium

As discussed earlier in the tooth development, with the tooth eruption, the OE and the reduced enamel epithelium (REE) fuse and the JE is formed. In periodontal health the JE consists of a single or multiple layers of non-keratinizing cells adhering to the tooth surface and functions as a security seal-barrier at the base of the sulcus.

Sabag and Saglie (1981) described the attachment of epithelium to the cementum root surface to be mediated by four to eight hemidesmosomes per micron at the coronal zone of epithelial attachment and two hemidesmosomes per micron in the apical zone. Because of this arrangement, the authors suggested that the coronal zone of the cemental surface may exhibit enhanced adhesion of epithelial attachment when compared with the apical zone Gargiulo et al. (1961) studied the dimensions and relations of the dento-gingival junction in man. The mean average length of the epithelial attachment (phases I–IV) was 0.97 mm with a range of 0.71–1.35 mm mean average.

Histologically, Ten Cate (1989) found that the immature character of the JE was characterized by the presence of hemidesmosomes that are necessary for epithelial attachment but are not seen in gingival and sulcular epithelium.

Biotype

The periodontal biotype and its clinical significance have fascinated clinicians and researchers since the early twentieth century. As early as 1923, Hirschfeld conducted an anthropometric study on human skulls, in which he noted the existence of a thin alveolar contour. He postulated that such a thin bony contour was likely accompanied by a thin gingival form. Later on, in 1969, Oschenbein and Ross classified the gingival anatomy as either flat or pronounced scalloped. They suggested that flat gingiva was related to square tooth forms and pronounced scalloped gingiva was related to tapered tooth forms. In 1977, Weisgold asserted that a thin, scalloped gingival architecture has an increased susceptibility to recession.

Later in 2009, De Rouck et al. illustrated the presence of two distinct gingival biotypes. The first type was thin-scalloped, making up one-third of the study population. These subjects typically had a slender tooth form, a narrow zone of keratinized tissue, and tended to be females. The second type was described as thick-flat, occurring in two-thirds of the study population. These cases were comprised of a more square tooth form, a broad zone of keratinized tissue, and were typically found in males.

In a 2010 systematic review, Fu et al. detailed the different clinical methods of diagnosing biotype and the differences noted between the two, as illustrated in the following table:

Characteristics	Thin	Thick
Profile	Highly scalloped soft tissue and bone contours	Relatively flat soft tissue and bone contours
Soft tissue texture	Delicate, friable	Dense, fibrotic
Width of keratinized and attached gingiva	Narrow	Wide
Bone thickness	Thin; presence of bony dehiscences and fenestrations	Thick; presence of ledges
Reaction to insults	Reacts readily with recession	Relatively resistant to gingival recessions; reacts with pocket formation or intrabony defects

Periodontal Biotype

One way to describe individual differences as they relate to the focus of this review is the periodontal "biotype." The biotype has been labeled by different authors as gingival or periodontal biotype, morphotype, or phenotype. In this review, it will be referred to as periodontal biotype. The assessment of periodontal biotype is considered relevant for outcome assessment of therapy in several dental disciplines, including periodontal and implant therapy, prosthodontics, and orthodontics. Overall, the distinction among different biotypes is based upon a multitude of anatomic characteristics of the components of the masticatory complex, including:

1. Gingival biotype, which includes in its definition gingival thickness (GT) and keratinized tissue width (KTW)
2. Bone morphotype (BM)
3. Tooth dimension

A recent systematic review Zweers et al. (2014), using the parameters reported previously, classified the biotypes in three categories:

Biotype	Crown form	Cervical convexities	Location of contacts	Zone of KT	Tissue quality	Alveolar bone quality
Thin scalloped	Slender, Triangular	Subtle	Incisal	Narrow	Clear, thin	Thin
Thick flat	Square	Pronounced	Cervical	Broad	Thick, fibrotic	Thick
Thick Scalloped	Slender	Variable	Variable	Narrow	Thick, fibrotic	Variable

The strongest association within the different parameters used to identify the different biotypes is found among GT, KTW, and BM. These parameters have been reported to be frequently associated with the development or progression of mucogingival defects, gingival recession in particular. Keratinized tissue width ranges in a thin biotype from 2.75 (0.48) mm to 5.44 (0.88) mm and in a thick biotype from 5.09 (1.00) mm to 6.65 (1.00) mm. The calculated weighted mean for the thick biotype was 5.72 (0.95) mm (95% CI 5.20; 6.24) and 4.15 (0.74) mm (95% CI 3.75; 4.55) for the thin biotype. Gingival thickness ranges from 0.63 (0.11) mm to 1.79 (0.31) mm. An overall thinner GT was observed with canine teeth and ranged from 0.63 (0.11) mm to 1.24 (0.35) mm, with a weighted mean (thin) of 0.80 mm (0.19).

When discriminating between either a thin or thick periodontal biotype, in general, a thinner GT can be found in a thin biotype population regardless of the selected study. Bone morphotype (BM) resulted in a mean buccal bone thickness of 0.343 (0.135) mm for thin biotype and 0.754 (0.128) mm for thick/average biotype. BMs have been radiographically measured with cone-beam computed tomography (CBCT).

Anatomy Is Destiny

Anatomy

A healthy periodontium is largely derived from a physiologic equilibrium among essential elements conducive to a stable environment against chronic deterioration. As a therapeutic objective it is in fact these components that, once identified, are recreated surgically or non-surgically.

To that end osseous surgery, for example, results ideally in the artificial recreation of a physiologic architecture of bone and its relation to the overlying soft tissue. A surgically recreated periodontal environment is where presumably health may be maintained with a reasonable regimen of home care and office hygiene visits.

Of the components that must be given due attention in the understanding of periodontal health disease and subsequent treatment, the anatomy of the natural dentition is a key.

A thorough student of the fundamentals of periodontics cannot escape the uncanny near mathematical system, which exists and binds basic dental anatomy as its most recurrent variations articulate and coexist with the elements of the periodontium, namely, soft tissue and bone. To that end we will concentrate primarily on the radicular anatomy of the permanent human dentition and some relevant aspects of coronal anatomy as well.

Understanding "the system" is one way to see clearly through the maze that represents periodontal health and resting equilibrium, disease, and the recreation of a remissive state through treatment. This chapter is an attempt to review some of the more salient features of dental anatomy as they relate to periodontal parameters.

Root Surface Anatomy

Facial and palatal or lingual root surfaces are for the most part convex to flat. The relative position of these root surfaces as well as their inherent geometry make these surfaces more accessible and less prone to the accumulation of biofilm, presumably with adequate home care and hygiene. Interproximal and interradicular root surfaces are primarily concave to flat; these surfaces on the other hand, because of their relative position in the arch and because of their shape are more likely to be susceptible to periodontal breakdown.

Proximal and interradicular surfaces however because of their outline, which is generally concave, and their inter proximal or interradicular position are in fact less amenable to maintenance and more prone to periodontal breakdown than facial or lingual surfaces.

This pattern tends to worsen anteroposterior for at least two reasons:

Anterior teeth are inherently accessible for hygiene, whereas posterior teeth would be more problematic in that respect. Inter proximal contacts and corresponding septa are also generally broader from the anterior part of the arch back. This particular anatomy makes the posterior contact area, the area initially susceptible to an etiological insult and lesion more difficult to access.

Also as periodontal disease progresses, the formation of osseous craters or for that matter any type of intrabony lesion is now more likely to form where broad posterior septa are initially present. This adds to the overall inaccessibility of these areas. Again the reasons why crater formation is more probable with broader septa is the purpose of a subsequent part of the book where the biologic fundamentals of disease progression and healing will be entertained.

Anterior Teeth

We know anterior teeth for the most part to be single rooted with a mostly conical radicular shape apico-coronally. They are relatively accessible for debridement because of their forward position in the arch. From the point of view of a periodontist the fact that anterior teeth have conical roots implies the following:

Vertical loss of attachment becomes exponentially more severe as it progresses apically on an increasingly fluted radicular area. Also, as periodontal disease increases in severity, these may become more difficult to restore and recreate an esthetic outcome, particularly in the maxillary anterior segment where fluted divergent roots lead to black inter proximal triangles with a receded periodontium. Anterior teeth with an accentuated facial or buccal parabolic contours are more difficult to restore as opposed to teeth with a flatter profile. Coronal anatomy of anterior teeth is usually described as square, ovoid, or tapered/triangle. Square crowns are usually associated with relatively broad inter proximal contact areas in all three dimensions. For this particular anterior tooth morphology the soft tissue biotype is usually thick.

Square crowns are more often short apico-coronally. These may be indicative of altered passive eruption, a condition where adult teeth that are fully erupted have a soft tissue margin positioned more coronal than the norm. These square shaped teeth tend to be associated with broad interproximal septae where interproximal craters are more likely to form. Esthetics are a consideration when periodontal disease is present and resective periodontal surgical treatment is not planned unless a prosthetic commitment is secured to address contingent issue, usually of anesthetic nature.

Ovoid or triangular shaped anterior teeth coronally present with a contact that is more point than area. These are associated with corresponding thinner interproximal septae.

As a result interproximal craters are not as probable as with square shaped crowns. Also with more ovoid shaped teeth, the tissue biotype and the alveolus tend to be thinner; soft tissue recessions are therefore likely with either periodontal disease or treatment.

Mandibular anterior teeth have relatively small contact points. These teeth, which are typically short and squarish have a thinner osseous septum and thin alveolar bone as well as a thin soft tissue biotype; as a result, these teeth are prone to recessions. Mandibular anterior teeth however are not in the esthetic zone and thus marginal soft tissue recessions may not be critical (Glickman 1953).

Developmental Anterior Grooves

Maxillary incisors will sometimes present with a facio-gingival developmental groove.

Although this condition is more frequently found on the palatal surface of maxillary incisors, it has sometimes been observed on the facial aspect of these teeth. These usually present as a narrow developmental groove that courses over the cingulum area from a point coronally.

The groove itself is anatomically prone to localized periodontal breakdown. Prognosis and treatment alternatives depend largely on the severity and the geometry, the number of bony walls for example, of the lesion associated with the anatomical groove.

Canines have bulbous prominent roots both mandibular and maxillary. As a result the alveolar bone is thin and the biotype associated with these is relatively thin alveolus and soft tissue biotype. These facts have an impact of treatment approach and should be addressed with caution as tissue manipulation may result in recessions from fenestrations and dehiscence likely to be present with a thin buccal wall. Cone beam imagery may be useful in arriving at the correct diagnosis (Lee and Lee 1968; Everett and Kramer 1972; Kogon 1986; Avital et al. 1988).

Premolars

Premolars are relatively small teeth coronally and may deceivingly appear, perhaps as a result of their relative size coronally to be single rooted.

The maxillary first premolar is the classic example as to why that is not the case. In the majority of cases, the first premolar is bifurcated, has two roots associated with a short root trunk or, in the least, a deep mesial groove. With that in mind, assumptions should not be made regarding the anatomy of premolars rather they should be looked at individually with no pre conceived notion (Dababneh and Rodan 2013).

For the purpose of diagnosis, prognosis, and treatment, furcation involvements have been classified and categorized according their degree of severity itself a measure of the clinical penetrability of a calibrated periodontal probe.

For the most part it is the horizontal involvement that has been used as a measure of prognosis and treatment potential. In one particular publication however the vertical component of the furcation involvement was addressed in terms of severity and potential for treatment. Again in subsequent chapters, the issue of furcation involvement will be revisited as it is related to periodontal disease, prognosis, and treatment alternatives (Hamp et al. 1975; Tarnow and Fletcher 1984).

The Root Trunk

The root trunk is essentially a measure of the distance between the CEJ to the anatomical roof of a furcation area. It is also an estimate of the anatomical potential of a furcated multirooted tooth to periodontal breakdown. A short root trunk is more susceptible to a furcation involvement than a long root trunk; in effect, the latter provides more leeway in the face of periodontal breakdown. When a tooth with a long root trunk is affected with a furcation involvement, that is indicative of a severe periodontal condition and an unfavorable prognosis. Once an anatomical furcation becomes clinically detectable, this represents a significant prognosis downturn for the given tooth. Treatment options and treatment outcomes are, as we will see inn subsequent chapters of this book, severely compromised and will depend as the literature supports it, on the severity of the lesion Gargulio (1961).

Maxillary First Molars

As is the case in general for molar teeth, their anatomy has been reported and is described in terms of the first molar. This includes the first maxillary molar.

The first maxillary molar typically has three roots, a mesiobuccal, a distobuccal, and a palatal.

As such, three anatomical furcations are present: a buccal, a mesial, and a distal.

If the root trunk of the maxillary first molar is measured from the CEJ to the roof of each anatomical furcation, the literature indicates that the buccal root trunk is the shortest followed by the mesial and the distal, respectively. One should note however that the furcation on the buccal is midway from mesial to distal; the distal furcation is directly below the contact area so midway bucco-palatally, whereas the mesial furcation is slightly off center. These all have significant implications with respect the susceptibility to periodontal disease as well as treatment implications.

The surface area of each of the three maxillary first molar roots has been reported with the mesiobuccal, the palatal, and the distobuccal roots usually in that order of decreasing size.

As with any furcated or multirooted teeth intraradicular root concavities are present with maxillary molars. Because of the three roots here as opposed to the two roots for mandibular molars, furcation involvements tend to be unidirectional for mandibular molars. For maxillary molars however, the presence of three furcations means that these can be affected internally rather than simply from the furcation entrance. This adds to the potential on prognosis and the ability to treat or maintain these areas.

One should note that root anatomy should be seen not only as it relates to each individual tooth in isolation but also with respect to their relative position in the arch. For example, the maxillary first molar often presents with a distobuccal root that angles distally and buccally. That may lead to a thin alveolar buccal housing where a fenestration or dehiscence are to be considered. Also the distal divergence of the distobuccal root often results in a thin interdental septum with the adjacent second molar. This has significant implications in terms of disease progression and treatment alternatives. Such anatomical relationships may potentially found anywhere in the arch (Herman et al. 1983; Gher and Dunlap 1985; Roussa 1998).

Mandibular First Molars

First molars represent the classic anatomy for mandibular molars with variations expected for second molars and particularly third molars.

The mandibular first molar typically has two roots, a mesial and a buccal, with two corresponding anatomical furcations, a buccal and a lingual. The root trunk, measured from the CEJ to the roof of the furcation, is shorter on the buccal then on the lingual then on the buccal. Root trunk length has implications both in terms of prognosis and treatment. When furcation involvements are diagnosed as opposed to shorter root trunk, that is indicative of more loss of attachment and therefore a more unfavorable prognosis in terms of treatment. A shorter furcation however can be more of a potential challenge with respective to any type of resective osseous surgery where the anatomical furcal entrance is closer to the CEJ apicoronally. This constitutes a physical limit to the apical positioning of the alveolar margin. This would include a crown lengthening for example where the establishment of the biologic width may be the intended objective but where the length of the root trunk may represent a limiting factor.

The furcal entrance is usually wider on the buccal than on the lingual although the literature indicates that in most instances the furcal entrance is narrower in diameter then instruments used for debridement. Both roots of the mandibular molar are usually kidney shaped in a horizontal cross with the interproximal and intraradicular root surfaces being more concave on the mesial then the distal root. Because both roots are concave on the furcal aspect, this access for debridement is challenging endeavor. Also the fact the mesial root is more kidney shaped has often led clinicians to favor the distal root over the mesial root in root resection procedures because it is comprehensively more treatable periodontally and restoratively. In some instances and with good judgement, root surfaces may be reshaped with fine diamonds to modify their anatomy to a more treatable or maintainable one.

One additional important aspect of intra furcal root anatomy is the intermediate bifurcational ridge, which runs in a mesio distal direction. Its position within the furcation can potentially interfere with an accurate clinical estimate of a given furcation involvement (Everett et al. 1958; Bower 1979a,b; Gher and Vernino 1980).

Cervical Enamel Projections (CEPs)

CEPs may be described as fingerlike extensions of enamel from the coronal portion of the tooth at various depths beyond the CEJ. Because they are enamel in their composition their soft tissue interface is not a CT attachment but a long JE. As such they are often the focus of localized periodontal breakdown. CEPs are classified according their proximity to the furcation area, the most severe being one that is actually within a furcation.

Intermediate CEPs are found most commonly on the buccal aspect of mandibular second molars mostly as class II projections.

Cementicles and enamel pearls are usually small isolated globules made of cementum or enamel respectively. They can be detected usually within the body of the PDL and are of little known significance. Accessory canals have been described coursing laterally to the periodontal ligament. The potential for these as pathways for cross contamination is not clear from the available literature (Swan and Hurt 1976; Masters and Hoskins 1984; You and Tsai 1987; Moskow and Canut 1990).

It may be important to note the following as far the enamel relates to the cementum at the CEJ: sixty percent of the cementum and enamel overlap; thirty percent form a butt joint; ten percent are separated by a gap (Gutman 1978).

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