Periodontics
The Complete Summary

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The Complete Summary

Edited by

Fernando Suárez López del Amo, DDS, MS

Private Practice
Tacoma, Washington

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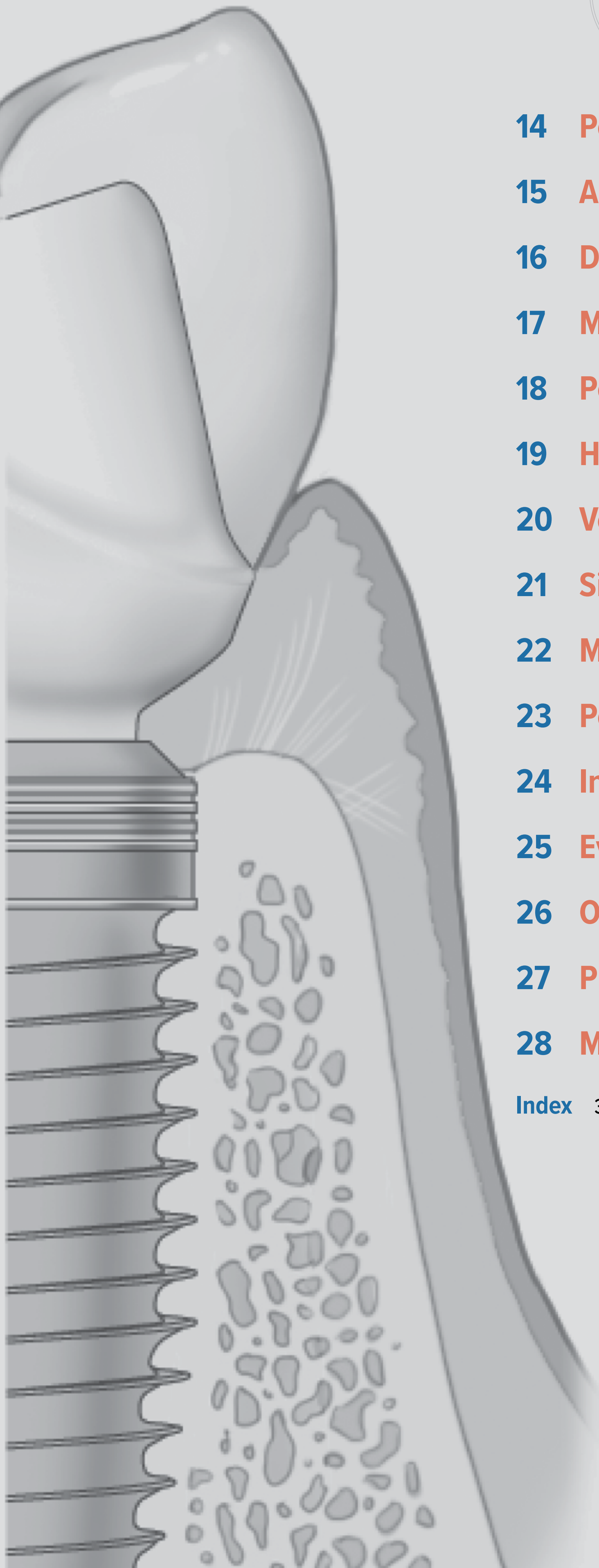

FOREWORD

In this day and age, an overwhelming influx of information is flooding the scientific literature. Separating wheat from chaff can be an arduous and demanding task for any oral health care professional, expert or novice, when reviewing the best available evidence in the fields of periodontics and oral implantology. A well-curated and comprehensive compilation of essential knowledge can be an invaluable compass to navigate what may seem to be an insurmountable ocean of data and concepts.

That is why I enthusiastically applaud Dr Fernando Suárez López del Amo for his vision and dedication in leading the efforts that have culminated in making this book, *Periodontics: The Complete Summary,* a reality. Knowing Fernando for more than a decade now, I have truly enjoyed witnessing his development and inexorable growth in becoming an excellent clinician, outstanding scholar, and tremendously effective teacher. It is rare for an individual of such virtues to also seek to engage and elevate the profession by generating quality didactic materials. This textbook is a clear representation of Fernando's commitment.

Spanning from the anatomy of periodontal and peri-implant structures to the management of medical emergencies, this book contains a cleverly weaved sequence of meticulously selected topics covering the most relevant literature pertaining to the diagnosis, prevention, and treatment of common periodontal and peri-implant diseases and conditions. Readers will notice that a great deal of attention was paid to scrupulously select and present pertinent information stemming both from classic and contemporary literature sources, providing it in a succinct and understandable manner. Although this book is primarily geared to serve as a guide for students throughout their formal training and in their preparation for standardized exams, more experienced professionals will also find it an excellent reference or "refresher" resource.

While Fernando is responsible for its genesis, organization, and successful completion, it must be acknowledged that this book is also the result of a collective endeavor carried out by a marvelous bunch of young and emerging clinicians, researchers, and educators from different geographic locations across the globe. It is exciting to see such a talented group coming together to generate an up-to-date and valuable compendium of foundational knowledge germane to periodontics and oral implantology. Congratulations to all of them for this superb contribution!

With my best wishes,

Gustavo Avila-Ortiz, DDS, MS, PhD
Professor and Chair
Department of Periodontics
College of Dentistry
University of Iowa
Iowa City, Iowa

PREFACE

The fields of periodontics and oral implantology have greatly advanced and evolved over the last decades. Numerous investigations and developments have redefined the instruments, materials, and techniques used in daily practice, and we, the scientists and clinicians, should always be at the forefront of this continuous evolution. However, while remaining up to date is imperative to provide the best possible patient care, it is of utmost importance to acknowledge and understand the scientific discoveries and investigations previously performed. It is critical to appreciate the lessons learned decades ago to continue with the progression of the periodontal and dental implant fields. For this reason, I decided to embark on this project, and along with the outstanding contribution of a talented group of friends and colleagues, we have created this summary aimed at describing the underlying scientific basis and rationale for the numerous challenges and decisions that periodontists face in clinical practice. Special attention was given to provide the fundamental classic literature as well as newer and more current evidence.

The information presented in this book is a comprehensive review of the most essential knowledge pertaining to the different aspects of periodontics and oral implantology. From anatomy to medical emergencies, the 28 chapters summarize topics related to diagnosis, nonsurgical and surgical therapy, guided tissue regeneration, dental implants, and oral pathology. Students in the dental and periodontal fields will find this book of utmost value during their training. Nevertheless, this book was also conceived with the objective of being a source of information and consultation guide for more senior professionals, including investigators and clinicians.

ACKNOWLEDGMENTS

First, I would like to thank my parents, Antonio and Mónica, for their unconditional love, endless support, and encouragement. For showing me that with passion and sacrifice, everything is possible. I also want to thank Morgan for her love, patience, and support throughout these years from when the idea of creating the book first originated until the final chapter was proofread. I would most like to thank my mentors in Spain and at the University of Michigan, who instilled in me the love for this profession. I have been tremendously fortunate to have mentors throughout my career who have not only taught me dentistry and periodontics, but also served as inspiration and role models. Last but not least, I deeply thank all the authors and coauthors that have collaborated on this project. Their hard work and dedication have made the completion of this book possible. I also want to thank the staff of Quintessence Publishing and particularly Bryn Grisham, as well as Marieke Zaffron for her excellent work editing this book.

CONTRIBUTORS

Aaeshah Alkanderi, BMedSc, BDS, MS
Periodontist
Department of Periodontics
Jaber Al Ahmad Al Sabah Dental Specialty Center
Shuhada, Kuwait

Farah Asa'ad, BDS, MSc, PhD
Postdoctoral Researcher
Department of Biomaterials
Institute of Clinical Sciences
Sahlgrenska Academy
University of Gothenburg
Gothenburg, Sweden

Federico Ausenda, DDS, MS
Visiting Assistant Professor
Department of Periodontology
School of Dental Medicine
Tufts University
Boston, Massachusetts

Clinical Instructor
Department of Biomedical, Surgical, and Dental Sciences
University of Milan

Private Practice
Milan, Italy

Lucía Barallat, DDS, MS, PhD
Associate Professor
Department of Periodontology
The University Dental Clinic
International University of Catalonia

Private Practice Limited to Periodontology and Implant Dentistry
Barcelona, Spain

Alvaro Blasi, DDS, CDT
Adjunct Assistant Professor
Department of Restorative Sciences
Dental College of Georgia
Augusta University
Augusta, Georgia

Private Practice
Barcelona, Spain

Gonzalo Blasi, DDS, MS
Dean's Faculty
Division of Periodontics
School of Dentistry
University of Maryland
Baltimore, Maryland

Associate Faculty
Department of Periodontics
The University Dental Clinic
International University of Catalonia

Private Practice
Barcelona, Spain

Ignacio Blasi, DDS, MS, PhD
Dean's Faculty
Division of Orthodontics
School of Dentistry
University of Maryland
Baltimore, Maryland

Private Practice
Fairfax, Virginia

Private Practice
Barcelona, Spain

Miguel Romero Bustillos, DDS, PhD
Resident
Iowa Institute for Oral Health Research
Department of Periodontics
College of Dentistry and Dental Clinics
University of Iowa
Iowa City, Iowa

Carlos Parra Carrasquer, DDS
Clinical Assistant Professor
Assistant Program Director
Department of Periodontics
Texas A&M University College of Dentistry
Dallas, Texas

Emilio Couso-Queiruga, DDS, MS
Resident
Department of Periodontics
College of Dentistry and Dental Clinics
University of Iowa
Iowa City, Iowa

Anusha Reddy Etikala, BDS, MS
Private Practice Limited to Periodontics and Implant Dentistry
Seattle, Washington

Basel Elnayef, DDS, MS, PhD
Assistant Professor
Department of Oral and Maxillofacial Surgery
The University Dental Clinic
International University of Catalonia

Private Practice
Barcelona, Spain

Carlos Garaicoa-Pazmiño, DDS, MS
Associate Professor
Department of Periodontology
School of Dentistry
Oregon Health & Science University
Portland, Oregon

Alexandra Plonka Hosking, DDS, MS
Adjunct Clinical Lecturer in Dentistry
Department of Periodontics and Oral Medicine
School of Dentistry
University of Michigan
Ann Arbor, Michigan

Private Practice Limited to Periodontics and Implantology
Grosse Pointe Woods, Michigan

Theodoros Katsaros, DDS, MSD
Clinical Assistant Professor
Graduate Program Director
Department of Periodontics
College of Dentistry and Dental Clinics
University of Iowa
Iowa City, Iowa

Arash Khojasteh, DDS, MS, PhD
Chairman and Program Director
Department of Tissue Engineering and Applied Cell Sciences
Associate Professor
Department of Oral and Maxillofacial Surgery
Shahid Beheshti University of Medical Sciences
Tehran, Iran

Va[illegible]oshkam, DDS, MS
Private Practice Limited to Periodontics and Implantology
El Paso, Texas

Private Practice Limited to Periodontics and Implantology
Karaj, Iran

Guo-Hao Lin, DDS, MS
Health Sciences Assistant Clinical Professor
Department of Orofacial Sciences
School of Dentistry
University of California, San Francisco
San Francisco, California

Manoela Domingues Martins, DDS, PhD
Associate Professor
Department of Oral Pathology
School of Dentistry
Federal University of Rio Grande do Sul
Porto Alegre, Brazil

Alberto Monje, DDS, MS, PhD
Assistant Lecturer
Department of Periodontology
The University Dental Clinic
International University of Catalonia
Barcelona, Spain

Adjunct Clinical Assistant Professor
Department of Periodontology
School of Dentistry
University of Michigan
Ann Arbor, Michigan

Private Practice
Badajoz, Spain

Jose Nart, DDS, PhD
Professor
Chairman and Program Director
Department of Periodontology
The University Dental Clinic
International University of Catalonia
Barcelona, Spain

Vice President
Spanish Society of Periodontics and Osseointegration

Andrea Ravidà, DDS, MS
Resident
Department of Periodontics and Oral Medicine
School of Dentistry
University of Michigan
Ann Arbor, Michigan

Juan C. Rodríguez, DDS, MS
Private Practice
East Lansing, Michigan

Adjunct Clinical Assistant Professor
Department of Periodontics and Oral Medicine
School of Dentistry
University of Michigan
Ann Arbor, Michigan

Rachel Sheridan Sinacola, DDS, MS
Private Practice
Grand Rapids, Michigan

Adjunct Clinical Lecturer in Dentistry
Department of Periodontics and Oral Medicine
School of Dentistry
University of Michigan
Ann Arbor, Michigan

Fernando Suárez López del Amo, DDS, MS
Private Practice
Tacoma, Washington

Mu[illegible]a Tattan, BDS
Resident
Department of Periodontics
College of Dentistry and Dental Clinics
University of Iowa
Iowa City, Iowa

Lorenzo Tavelli, DDS, MS
Adjunct Clinical Assistant Professor and Research Fellow
Department of Periodontics and Oral Medicine
School of Dentistry
University of Michigan
Ann Arbor, Michigan

Vivian Petersen Wagner, DDS, PhD
Postdoctoral Researcher
Department of Oral Diagnosis
Piracicaba School of Dentistry
University of Campinas
Campinas, Brazil

Shan-Huey Yu, DDS, MS
Clinical Assistant Professor
Department of Periodontics and Oral Medicine
School of Dentistry
University of Michigan
Ann Arbor, Michigan

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ANATOMY

Miguel Romero Bustillos, DDS, PhD

The **periodontium** comprises the supporting structures of the dentition. It is composed of four main elements: gingiva, cementum, periodontal ligament (PDL), and bone. Understanding this dynamic network of tissues is pivotal for the proper performance of the many procedures related to periodontal therapy. This chapter describes the different structures of the periodontium from microscopic and macroscopic points of view.

The **attachment apparatus**, also known as *periodontal attachment*, is an aggregate of tissues with the main function of anchoring teeth to the alveolus. It consists of cementum, alveolar bone, PDL, and gingiva. Several terms are highly relevant with this regard and are described by the American Academy of Periodontology (AAP) *Glossary of Periodontal Terms* (see sidebar).[1]

Periodontium: Attachment Apparatus

PERIODONTAL LIGAMENT

The **PDL** is a specialized connective tissue located between the bony walls of the dental socket and the dental root. It surrounds the majority of the dental root and attaches the teeth to the alveolar bone. In the most coronal portion, the PDL is continued with the lamina propria of the gingiva. Characterized by its hourglass shape, this specialized connective tissue narrows at the middle part, with an average width ranging from 0.2 to 0.4 mm.[3] The PDL space decreases with age and increases under excessive load.

Origin

The PDL develops in a cell population from the dental follicle. As the crown approaches the oral mucosa, fibroblasts produce collagen fibrils without organized orientation. Later, prior to tooth eruption, the fibroblasts adopt an oblique orientation adjacent to the cementum. Finally, after this fibroblast arrangement, fibers with organized orientation are developed at the cementum surface as well as at the alveolar bone proper. These fibers will continue elongating until they reach each other at the middle portion of the

DEFINITIONS AND TERMINOLOGY

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.

Alveolar process: The compact and cancellous bony structure that surrounds and supports the teeth.

Attached gingiva: The portion of the gingiva that is firm, dense, stippled, and tightly bound to the underlying periosteum, tooth, and bone.

Attachment apparatus: The cementum, periodontal ligament, and alveolar bone.

Biologic width: The dimension of soft tissue composed of a connective tissue and epithelial attachment extending from the crest of bone to the most apical extent of the pocket or sulcus. This term was recently redefined as "supracrestal tissue attachment."[2]

Bundle bone: A type of alveolar bone, so-called because of the "bundle" pattern caused by the continuation of the principal (Sharpey) fibers into it.

Fibroblast: The predominant connective tissue cell; a flattened, irregularly branched cell with a large oval nucleus that is responsible in part for the production and remodeling of the extracellular matrix.

TABLE 1-1 Principal periodontal ligament fibers[4,5]

	Location	Origin	Insertion	Orientation	Function
Alveolar crest fibers	Between CEJ and alveolar bone crest	Cementum	Alveolar crest	Mostly bucco-lingual but also mesiodistal	Prevent extrusion of the teeth and resist lateral tooth movements
Horizontal fibers	Directly apical to the crest	Cementum	Alveolar bone proper	Horizontal across the PDL	Prevent lateral tooth movement
Oblique fibers	Middle two-thirds of the PDL	Cementum	Alveolar bone proper	Oblique in a coronal direction	Resist apically directed chewing forces
Apical fibers	Apical portion of the PDL	Apical portion of cementum	Apical portion of alveolar bone proper	Irregular fashion in horizontal or vertical dimension	Resist forces of luxation
Interradicular fibers	Furcation region	Interradicular cementum	Interradicular coronal portion of alveolar bone proper	Vertical and horizontal	Resist tooth tipping, torquing, and luxation
Transalveolar fibers	Primarily crestal region	Cementum	Cementum of adjacent tooth	Horizontal	Provide support and stability, prevent tooth movement

CEJ, cementoenamel junction.

Free gingiva: The part of the gingiva that surrounds the tooth and is not directly attached to the tooth surface.

Gingival groove: A shallow, V-shaped groove that is closely associated with the apical extent of free gingiva and runs parallel to the margin of the gingiva. The frequency of its occurrence varies widely.

Gingival papilla: The portion of the gingiva that occupies the interproximal spaces. The interdental extension of the gingiva.

Hertwig epithelial root sheath (HERS): An extension of the enamel organ (cervical loop) Determines the shape of the roots and initiates dentin formation during tooth development. Its remnants persist as epithelial rests of Malassez in the periodontal ligament.

PDL. The orientation of the fibers will be determined by the location within the PDL (Table 1-1).[4,5]

Composition

The PDL is formed by different cell types. The fibroblasts are the most abundant as they are responsible for the metabolism of the extracellular components. Within this heterogeneous population of fibroblasts within the PDL, osteoblast-like fibroblasts are also present, and these are rich in alkaline phosphatase.[6,7] In addition, the PDL contains stem cells, epithelial cell rests of Malassez, cells from the blood vessels, and cells associated with the immune and nervous systems.

The extracellular matrix of the PDL consists of collagenous and noncollagenous proteins. Collagen type I is the most abundant, and it is also the primary constituent of the Sharpey fibers, together with collagen II, V, VI, XII, and XIV.[8] Other noncollagenous proteins present in the PDL are tenascin, fibronectin, vitronectin, elastin, and glycoproteins. In addition, hyaluronate, heparan sulfate, chondroitin sulfate, and dermatan sulfate are the glycosaminoglycans identified in the PDL. Dermatan sulfate is the principal glycosaminoglycan, while versican and decorin are the main proteoglycans.[8,9]

ALVEOLAR BONE

One of the two mineralized tissues that comprises the attachment apparatus is the alveolar bone. Just like any other type of bone in the human body, it is composed of a mineralized matrix and a nonmineralized connective tissue. Within the mineralized tissues, calcium is the most prevalent mineral in the form of hydroxyapatite. The alveolar bone, also known as **alveolar process**, consists of spongy bone, cortical plates, and the **alveolar bone proper** (Table 1-2). The crest of the alveolar bone refers to the most coronal portion of it, and its distance from the cementoenamel junction (CEJ) in a healthy periodontium is within the range of 1 to 3 mm.

The alveolar bone is created following an intramembranous ossification with ectomesenchymal cells from the dental follicle intervening in the developmental process. The presence of teeth is essential for the development of the alveolar bone. As such, in absence of a PDL, the alveolar bone proper will not develop.[5]

The alveolar bone houses the teeth, providing protection and support and allowing proper functioning during mastication, absorbing and distributing the occlusal forces. The primary function of the alveolar bone is to provide a structure where the Sharpey fibers of the PDL anchor to keep the tooth in position and function.

The chemical composition of alveolar bone is 65% hydroxyapatite and 35% organic material such as collagen and noncollagenous proteins (eg, osteocalcin, bone sialoprotein, phosphoprotein, osteonectin, and bone morphogenetic proteins).

Microscopically, two different types of mature bone can be observed based on the organization: *(1)* the lamellar bone, containing osteons which consist of a blood vessel surrounded by concentric lamellae, and *(2)* the **bundle bone** where PDL fibers (Sharpey fibers) anchor. In the bundle bone, lamellae can be found parallel to adjacent marrow spaces, and the disposition is parallel to the tooth surface.

CEMENTUM

Cementum is the second mineralized tissue of the attachment apparatus. It is an avascular mineralized connective tissue that surrounds the dentin at the level of the dental root. Its primary function is to allow for the anchorage of Sharpey fibers that will keep the tooth in the alveolus as well as to adapt and protect during tooth wear and movement. The thickness of cementum increases with age. Also, apical portions of the dental root present with thicker cementum than the coronal counterparts.[5] The CEJ is the anatomical area where the crown meets the root. Schroeder and Scherle[10] described three types of relationships between cementum and enamel: edge to edge; cementum covering the enamel; or a gap between both structures where dentin is exposed. The most prevalent interrelation is cementum covering the enamel, followed by edge to edge and gap.[11]

Based on the presence of cementocytes embedded in its extracellular matrix, the cementum can be classified as cellular or acellular. In addition,

Lamina propria: In the mucous membrane, the connective tissue coat just beneath the epithelium and basement membrane. In skin, this layer is known as the *dermis*.

Mucogingival junction: The junction of the gingiva and the alveolar mucosa.

Osseointegration: A direct contact, at the light microscopic level, between living bone tissue and an implant.

Periodontal ligament (PDL): A specialized fibrous connective tissue that surrounds and attaches roots of teeth to the alveolar bone. Also known as the *periodontal membrane*.

Periodontium: The tissues that invest and support the teeth, including the gingiva, alveolar mucosa, cementum, periodontal ligament, and alveolar supporting bone. Also known as the *supporting structure of the tooth*.

Rete pegs: Ridge-like projections of epithelium into the underlying stroma of connective tissue that normally occur in the mucous membrane and dermal tissue subject to functional stimulation.

TABLE 1-2 Features of alveolar bone

	Location	Thickness	Composition	Characteristics
Alveolar bone proper	Wall of the socket	0.1 to 0.4 mm	Lamellated and bundle bone	• Perforated, carrying interalveolar nerves and blood vessels. • Radiographically identified as cribriform plate or lamina dura.
Spongy bone	Between alveolar bone proper and cortical plates	More volume present in maxilla at interdental and interradicular septa. Very limited in buccal sites followed by lingual and palate sites.	Trabeculae surrounded by marrow that contains adipocytes and pluripotent stem cells	• Highly vascularized. The amount and organization will determine the classification. • Regular or irregular orientation of trabeculae can be identified based on the location.
Cortical plates	Outline the alveolar process	Variable from posterior to anterior sites. Buccal thinner than lingual.	Osteons and interstitial lamellae	• Poor intrinsic vascularization. Highly remodeled in the most coronal portion after tooth extraction.

TABLE 1-3 Features of the different types of cementum

	Location	Thickness	Contain cells	Intrinsic collagen fibers	Extrinsic collagen fibers	Developed by
Acellular afibrillar cementum	Coronal part, covering enamel surface. One of the components of acellular extrinsic fiber cementum.	1 to 15 µm	No	No	No	Cementoblasts
Acellular extrinsic fiber cementum	Cervical third of the root	30 to 230 µm	No	No	Yes (composed of bundles of Sharpey fibers)	Cementoblasts and fibroblasts
Cellular mixed stratified cementum	Apical third of the root and furcation. Tip of the apex.	100 to 1,000 µm	Yes	Yes	Yes (composed of bundles of Sharpey fibers)	Cementoblasts and fibroblasts
Cellular intrinsic fiber cementum	Filling resorption lacunae of the root	Varies	Yes	Yes	No	Cementoblasts

the fibers that form the cementum will contribute to the classification of the different types[5] (Table 1-3).

As in the formation of the PDL, cementum starts developing in a prefunctional stage prior to the eruption of the tooth. After the crown is formed, the cells of the inner and outer enamel epithelium that constitute the cervical loop will proliferate deeper into the ectomesenchyme driving the development of the dental root. This structure is known as the **Hertwig epithelial root sheath (HERS)**. The most apical portion of the HERS, which encloses the dental papilla, is known as the *epithelial diaphragm*. Cells from the HERS induce the differentiation of the dental papilla cells in a coronoapical direction to become odontoblasts that will form the dentin of the root. The number and morphology of the dental roots will be determined by the disposition of the HERS. The cementum, the mineral portion of the root facing the PDL, is formed by cementoblasts that are believed to originate from the ectomesenchymal cells of the dental follicle after the disintegration of the HERS. Cells from the HERS produce different proteins and mediators to induce the differentiation of the dental follicle cells into cementoblasts. Fibroblasts in the area produce bundles of collagen fibrils that form fringe fibers, and these are anchored to the tooth by the deposition of a mineral matrix by cementoblasts.

When the tooth is near to entering its functional stage, a shift in the formation of cementum can be seen from acellular extrinsic fibrillar cementum to mixed stratified cementum. The rate of growth of cementum is 1.5 to 3 μm per year.[12]

Even though the previously described formation of cementum is the most accepted theory, an alternative hypothesis has been proposed. This theory suggests an enhanced role of the HERS in the formation of cementum through the differentiation of HERS cells to become cementoblasts.[13]

The chemical composition of cementum is similar to bone with approximately one-third organic material, one-third mineral phase, and one-third water. The primary inorganic structure of cementum is also hydroxyapatite crystals. The organic material is composed of collagen, glycoproteins, and proteoglycans (Box 1-1).

BOX 1-1 Organic chemical composition of cementum

Collagenous proteins	Collagen I (90%) Collagen III (5%)
Noncollagenous proteins	Glycoproteins Glycolipids Proteoglycans Enamel-related proteins

GINGIVA

The oral mucosa is composed of the mucosal tissues that cover the mouth, and it can be classified as masticatory mucosa (gingiva and hard palate), lining mucosa (alveolar mucosa, floor of the month, and internal surface of lips), and specialized mucosa (tongue). The lining or alveolar mucosa extends inside the cheeks, floor of the mouth, as well as soft palate, and it is characterized by the presence of a basal layer (which is positive to the expression of keratin 5, 14, and 19), an intermediate layer, and a superficial layer expressing keratin 13 and 4.[14]

The gingiva (masticatory mucosa) is composed of **free gingiva** and **attached gingiva**, and it is characterized by the presence of keratin in the most superficial layer. Histologically, four layers of cells have been described (Fig 1-1):

1. Stratum basale, which is characterized by the expression of keratin 5 and 14
2. Stratum spinous, named due to the spinous morphology of the cells in this layer
3. Stratum granulosum, characterized by the presence of round cytoplasmic granules
4. Stratum corneum with cornified cells

Gingiva has different names and presents with slight morphologic differences depending on the tissue that it covers (ie, free gingiva or attached gingiva; Fig 1-2).

Free gingiva

Free gingiva is the portion of the gingival epithelium that extends from the free gingival margin to the gingival groove (see Fig 1-2). The **gingival groove** is defined as the "shallow linear depression on the gingiva surface that demarcates the free gingiva and the attached gingiva."[1] The free gingiva covers the teeth at the vestibular and lingual sites following the contour of the tooth and the dental papilla. In normal conditions, the free gingiva presents as a coral pink color. The location of the gingival groove is determined by the position of the CEJ, and it is present in 4% to 54% of teeth with differences based on tooth type.[15,16]

Attached gingiva

Attached to the tooth and/or alveolar bone, the attached gingiva is delimited by the gingival groove at the coronal end and the mucogingival junction at the apical end. In healthy conditions, it also presents with a coral pink color. A morphologic characteristic of the attached gingiva is the stippling or orange peel appearance. The stippling corresponds to small epithelial ridges and is developed in areas of high keratinization. When the attached gingiva is inflamed, it loses the superficial stippling, and the color turns to a darker red.[15,17,18]

The **mucogingival junction**, which is the interphase between the attached gingiva and the oral mucosa, is located between 3 to 5 mm apical to the alveolar crest, and it has been shown to be stable over the years in reference to the base of the mandible or floor of the nose. Consequently, an increase in attached gingiva with age has been associated with the continuous eruption of the dentition.[19,20] The dimensions of the attached gingiva have been investigated in classic studies by Bowers[21] and Voigt

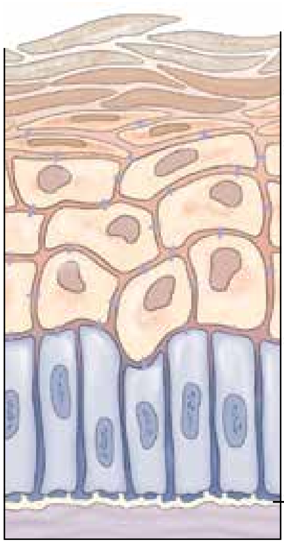

Fig 1-1 Layers of keratinized gingiva.

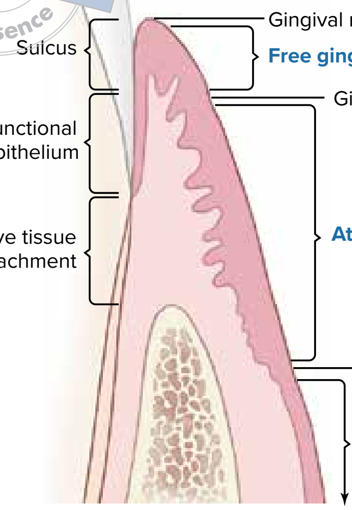

Fig 1-2 The gingiva.

et al.[22] In the maxilla, the sites with the greatest width of attached gingiva are the central and lateral incisors. There is a decrease in canines and first premolars, and a slight increase over the second premolar and molar locations. In the mandible, the incisors also present with the greatest amount of attached gingiva with a sharp decrease around the canines and first premolars. At the second premolar site, the attached gingiva increases, and a decrease at the mandibular molar area is also observed. On the lingual aspect, the molar area presents with the greatest attached gingiva followed by premolars, incisors, and canines.

Based on the location and microscopic appearance, the gingival epithelium can be classified into three types: oral, sulcular, and junctional epithelium.

Oral epithelium

The oral epithelium is a keratinized stratified squamous epithelium that extends from the mucogingival junction to the free gingival margin. In some areas of the most superficial layer, the stratum corneum, the cells maintain their nuclei and are considered parakeratinized. If no nuclei are present in the stratum corneum, this epithelium is considered orthokeratinized. In addition to the keratinocytes, other cells can be found in the oral epithelium, such as melanocytes, which give pigmentation to the epithelium; Langerhans cells, which play a role in the immune response; and Merkel cells, which are important for sensory function.

Sulcular epithelium

This is the epithelial tissue located in the sulcus, and it extends from the free gingival margin to the most coronal portion of the junctional epithelium. It is a nonkeratinized stratified squamous epithelium.

Junctional epithelium

The junctional epithelium extends apically from the base of the gingival sulcus following the tooth structure, and it is a nondifferentiated stratified squamous epithelium.[23] In healthy situations with no history of periodontal disease or gingival deformities, the deepest portion of the junctional epithelium is located around the CEJ. It has a triangular shape with the base at the bottom of the sulcus and a vertex located apically. The base of the junctional epithelium has a layer 20 to 30 cells thick, which decreases in number to become a bilayer at the level of the CEJ.[24] The junctional epithelium is attached to the tooth surface through hemidesmosomes, while the connections in between the epithelial cells are established by desmosomes, adherents, gaps, and tight junctions.[25]

The gingival epithelial tissue lies over connective tissue establishing finger-type indentations of epithelial tissue

TABLE 1-4 Main connective tissue fibers[5,28]

	Subclassification	Origin	Direction
Dentogingival fibers	Subgroup A	Cementum	Free gingiva
	Subgroup B	Cementum	Attached gingiva
	Subgroup C	Sweep down and across the crest	NA
Alveologingival fibers	NA	Periosteum	Free gingiva and attached gingiva
Circular fibers	NA	Encircle each tooth within the connective tissue	
Dentoperiosteal fibers	NA	Cementum apical to the dento-gingival fibers	Crest of the alveolar bone. Some fibers may insert into muscles of the vestibule.
Transseptal fibers	NA	Cementum	Cementum of adjacent tooth

NA, not applicable.

termed *ridges*. This connective tissue subjacent to the epithelium of the attached gingiva is known as **lamina propria**. The lamina propria is a highly vascularized tissue with two known portions: the papillary layer, which is the most superficial, and the reticular layer. In the papillary layer, the interphase between the connective tissue of the lamina propria and the epithelium follow a wavy morphology with projections of connective tissue called *papillae* and epithelial ridges known as **rete pegs**. The interface between the sulcular epithelium, the junctional epithelium, and the connective tissue is characterized by the absence of rete pegs. The lamina propria consists of 57% to 60% connective tissue fibers/fibrous proteins, 5% to 8% cells, and 35% other components such as blood vessels, nerves, and ground substance of the intercellular matrix.[5,26]

The main cell type in the lamina propria is the **fibroblast**, which is the main cell responsible for the formation and remodeling of the connective tissue. The main fibers of the lamina propria are comprised by collagen type I, III, IV, and V, with minor presence of elastic fibers and oxytalan fibers. The fibers in the gingiva follow a specific orientation and are classified into different bundles. The main connective tissue fibers are dentogingival, alveologingival, circular, dentoperiosteal, and transseptal (Table 1-4 and Figs 1-3 and 1-4).[5,27,28] In addition, secondary connective tissue fibers are periosteogingival, interpapillary, transgingival, intercircular, semicircular, and intergingival.[29] The main as well as the secondary fibers are part of the connective tissue attachment.

The interface between the connective tissue and the epithelium is a specialized form of extracellular matrix named the *basement membrane* or *basal membrane*. The basal membrane consists of a highly crosslinked matrix of collagen and glycoproteins such as laminin, perlecan, and entactin, and it is composed of several layers. Under electron microscopy, three components can be differentiated: the lamina lucida, the lamina densa, and the lamina reticularis.[27]

The interdental gingiva or papilla refers to the soft tissue that occupies the space between the teeth and consists of an epithelium with a subjacent dense connective tissue. The shape of this interdental gingiva is determined by the morphology of the teeth and the CEJ. In anterior sites, it presents with a pyramidal shape, whereas in posterior sites, it presents with a concave shape. The epithelium that covers this concave portion is known as the *col epithelium*.[28,30]

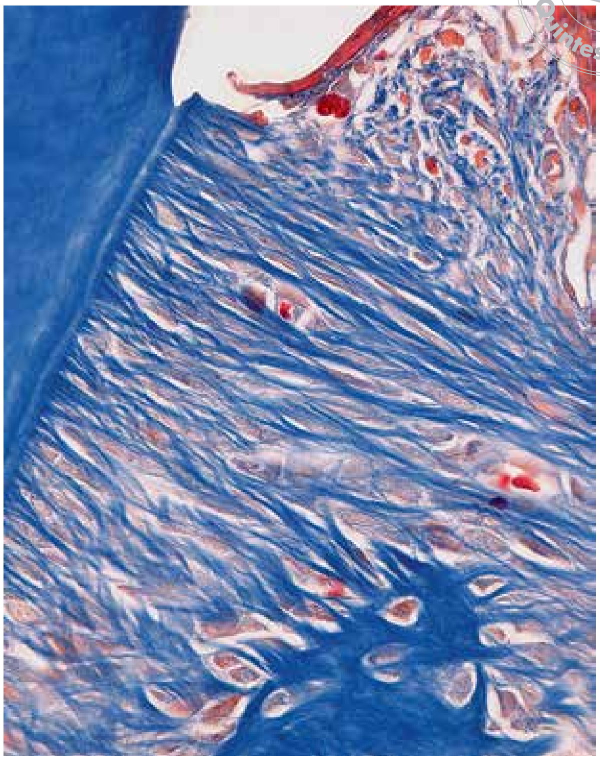

Fig 1-3 Dentogingival fibers in a mouse model (100× magnification).

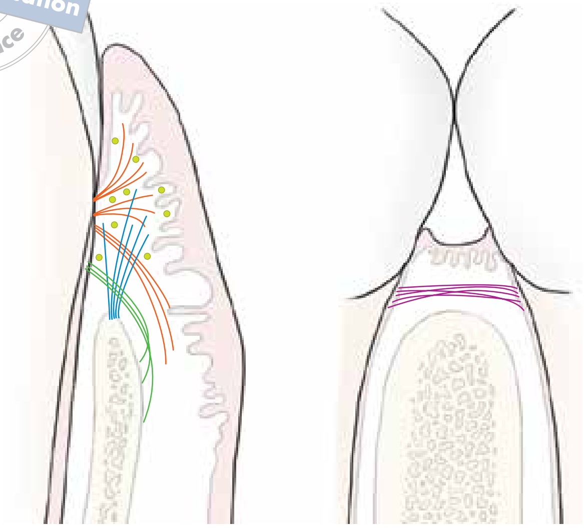

Fig 1-4 Gingival fibers.

TABLE 1-5 Classic studies on the dimensions of supracrestal tissue attachment and sulcus

	Sulcular epithelium (mm)	Junctional epithelium (mm)	Connective tissue (mm)
Gargiulo et al[32]	0.69	0.97	1.07
Vacek et al[33]	1.34	1.14	0.77

SUPRACRESTAL TISSUE ATTACHMENT

The junctional epithelium and connective tissue attachment together are known as the *supracrestal attached tissues* (formerly referred to as **biologic width**).[2,31] The dimensions of these structures were investigated by Gargiulo et al[32] and Vacek et al[33] in human cadavers reporting an average distance of 2.04 mm and 1.91 mm, respectively (Table 1-5).

A meta-analysis by Schmidt et al[34] in 2013 concluded that the biologic width ranges from 2.15 mm to 2.30 mm, with posterior teeth having longer junctional epithelium and the dimension of connective tissue attachment being larger in buccal and lingual surfaces compared with interproximal sites.[34]

Peri-Implant Attachment Apparatus

The replacement and restoration of the missing dentition by means of dental implants has become a routine procedure in daily practice. As such, a plethora of systems with different macro- and microstructures are available on the market. However, independently of the design, the proper functioning of dental implants is primarily based on the process of **osseointegration**. This phenomenon is defined as the direct contact between the surface of a loaded implant and vital bone.

Considerable differences exist between the structures giving support to dental implants and natural dentition, the most important being the lack of PDL for osseointegrated implants. However, at the most coronal portion, some similarities can be found. Similar to the supracrestal attached tissues in the natural dentition, implants also present in their most coronal portion with a sulcus epithelium, junctional epithelium, and connective tissue.[35] In 1991 in an animal model, Berglundh et al[35] described the differences in the arrangement of collagenous fibers in the connective tissue between teeth and implants. Essentially, while the collagenous fibers run perpendicular to the axis of the tooth, they run parallel to the surface of an implant. The composition of the connective tissue also seems to differ between implants and teeth. As such, more collagen and fewer cells have been found around dental implants in comparison with teeth.[35] Moon et al[36] also described that although generally a reduced number of cells have been found in the peri-implant tissue, a cell-rich zone is present in the connective tissue adjacent to the implant-abutment surface with high concentration of fibroblasts.

The absence of PDL space around dental implants also determines the lack of vascularization from this structure. Consequently, the blood vessels that irrigate the peri-implant mucosa are terminal branches from the periosteum. On the other hand, both natural dentition and dental implants present with a vascular plexus adjacent to the junctional epithelium.[37]

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