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Understanding the Etiological Relationship Between Orthodontic Tooth Crowding and Mucogingival Pathologies, “Big Teeth in Small Jaws”

Colin Richman DMD

Department of Periodontics, Practice Limited to Periodontics (Focussed on SFT, LANAP/LAPIP/Oral-Systemic-Condition),
Diplomate, American Board of Periodontology, Augusta University, Augusta, Georgia, USA

Introduction

Profitt and Fields Jr (2000) postulated that malocclusion may be attributed to genetic and environmental factors. Beecher *et al.* considered malocclusion to be a condition of westernization (Beecher *et al.*, 1983). In this chapter, we will examine the role of anthropology, genetics, and diet as primary etiological agents associated with dental tooth crowding, a consequence of “big teeth in small jaws,” due to factors listed above (Figure 11.1a, b).

Fundamental Etiological Factors Associated with Orthodontic Tooth Crowding

Numerous theories have been proposed relative to the etiology and pathogenesis of orthodontic tooth crowding. These include:

Anthropological Factors

Historically, after attaining humanoid status and evolving from hunters to gatherers, to farmers and industrialized food-processing, from an epigenetic perspective our pre-humanoid jaws started “shrinking” (Cramon-Taubadel, 2011).

Also, from an anthropological perspective, as our knowledge base increased and continues to increase, the frontal lobe of our brain, which governs our humanity, expanded, and continues to expand, resulting in an ongoing associated expansion of our forebrain and associated skull. The consequence of this phenomenon is that our skulls are expanding at the expense of our shrinking jaws. Concurrently, our jaws are simultaneously being displaced in an inferior direction. This phenomenon is known as klinorhynch (Pajević *et al.*, 2019; Terris, 2005) (Figure 11.2a, b).

Genetic Factors

As humans became more “civilized,” we have transitioned from a genetically homogeneous to a genetically heterogeneous society. An example of this phenomenon might be demonstrated by the following example: Visualize an infant born to a large-statured (football-playing) father of perhaps Scandinavian origin with large jaws and associated teeth and a petite (ballerina) mother of Asian origin with small jaws, stature, and teeth. If this infant inherits the father’s large teeth and the mother’s petite small jaws, a major discrepancy could result from trying to

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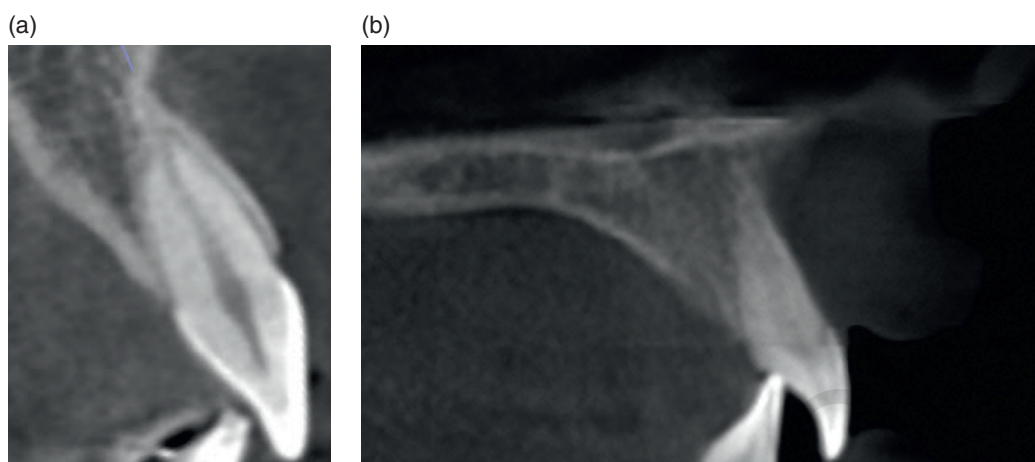


Figure 11.1 (a) Ideal facial and lingual alveolar bone morphology, exceeding 1.5 mm thickness at both the facial and lingual aspects. (b) Substantial facial bony dehiscence, with adequate lingual alveolar bone “big teeth in small jaws.”



Figure 11.2 Klinorhynch: a downwardly oriented facial skeleton in relation to the cranial base, frequently resulting in skeletal–dental problems. Associated with anthropological epigenetic changes with increasing anterior frontal bone expansion and decreasing midfacial volumetric structure. (a) Homo heidelbergensis, 300,000–600,000 years ago (Figure 11.11a). (b) Homo sapiens, 300,000 years ago up to and including the present (Figure 11.11b).

accommodate the large teeth into the small jaws when considered from a three-dimensional (3D) perspective. Cone beam computerized tomography (CBCT) analysis enables clinicians to evaluate these anatomical relationships in 3 dimensions from the clinical perspective. (Peck *et al.*, 1998).

Advances in dentofacial phenotyping the comprehensive characterization of hard and soft tissue variations in the craniofacial complex together with the acquisition of large-scale genomic data have started to unravel genetic and epigenetic mechanisms underlying facial variation (Moreno, Uribe and Miller, 2015; Neela *et al.*, 2020).

Dietary Factors

A classical study by Corruccini and Lee evaluated malocclusion development in the next-generation offspring of Chinese laborers when they were transported from China to the United Kingdom. In this review, as the genetic factors of the immigrant parents remained unchanged relative to their genetic status, it was noted that within one generation the deterioration in the offspring's tooth alignment suggested environmental influences, such as diet to be a factor (Beecher *et al.*, 1983). (Corruccini and Lee, 1984) studied squirrel monkeys, who were either raised on a naturally tough/rough or artificially softened diet. Significant craniofacial and occlusal development between hard and soft diet animals was found, including in the soft diet group's maxillary arch narrowing, palatal arching, crowded and displaced teeth, and retarded cranial bone mineralization. They suggested that a similar situation occurs in humans and that dietary consistency may be an important factor in human craniofacial growth.

Corruccini, Potter and Dahlberg, writing in the *American Journal of Biological Anthropology*, compared the occlusal variables and arch measurements on Pima American Indians. The study consisted of two groups, one of older individuals raised on traditional diets and the other of younger individuals

raised on refined commercial foods typical of modern urbanized communities. The permanent dental occlusion was significantly more variable in the younger group. Other variables noted in the younger group included narrower palates correlating with a general trend among industrialized populations, including among experimental animals fed soft diets (Corruccini *et al.*, 1983). A treatise in *Nature Magazine* reviewing the impact of dietary factors on malocclusion includes a comprehensive review of the contemporary literature on this topic. The reader is referred to this publication for supplemental information (Kahn and Ehrlich, 2019).

Comparative Anatomical Observations Relative to Other Mammalian Species Nurtured and Living in Their Natural Habitats

This author has acquired from various natural history museums around the world, clinical data of mammalian species born, nurtured, and living in their natural environment in the wild (unpublished data). Over 1,000 different crania and matching mandibles have been evaluated using calibrated clinical photography. These mammals range from field mice to African elephants and numerous other mammalian species of varying stature. (Museums include Europe, Arctic Circle, North America (multiple), and South Africa). When reviewing these data, it is noted that less than 0.5% of specimens examined demonstrate dehiscences, fenestrations, dental tooth crowding, and/or impactions. It is rare to identify more than one abnormal factor listed above in any examined specimen. Figure 11.3a–c are representative of the ideal and non-compensated dentitions of herbivore examples (gorilla), carnivore (panther), and omnivore (brown bear).

Vasculature of the Gingival Tissues

From a genetic perspective both the maxilla and mandible are derived from five precursor bones, which eventually fuse to form the maxilla and the mandible. Relative to the theme of



Figure 11.3 Representative images demonstrate ideal mammalian occlusion, various species with no evidence of malocclusion or impactions plus abundant supporting alveolar bone. (a) Ideal tooth relationship and occlusion on Gorilla (herbivore). (b) Ideal tooth relationship and occlusion on Panther (carnivore). (c) Ideal tooth relationship and occlusion on Brown Bear (omnivore).

this narrative, consideration will only be given to the alveolar bone component of both bones.

Alveolar bone consists of a dense outer bone cortical plate, both on the buccal and lingual aspects, covered with periosteum, in turn, protected by attached and unattached gingival tissues.

An inner bony component lining the tooth sockets is substantially perforated, where the perforations, known as Volkmann's canals, facilitate the passage of end branches of the vascular system to provide appropriate blood supplies to the overlying spongy bone and gingival tissues.

Spongy bone lies between these two layers (Figure 11.4).

The component of alveolar bone housing the teeth is known as the alveolar process. The junction of the alveolar bone with the basal bone on the facial aspect of each jaw is the "A" point in the maxilla. The "B" point represents the same position in the mandible (Figure 11.5). The vascularity of the basal bone for both jaws is more robust than the vascularity of the facial and lingual alveolar bone, especially in the case of orthodontic tooth crowding. In these situations, facial alveolar blood supply may be compromised or deficient, especially when



Figure 11.4 Anatomy of periodontium.

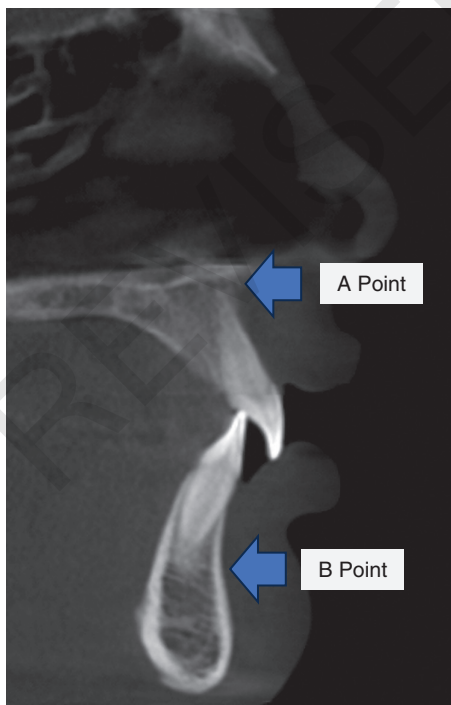


Figure 11.5 Cephalometry with points A and B.

associated with dehiscences and fenestrations. This results in a relatively thin avascular layer of bone, known as bundle bone. This situation is more frequently noted on the facial aspect of crowded teeth (Figure 11.1b).

Typically, the blood supply to gingival tissues is derived from three major sources:

Vessels radiating from branches of the interdental vascular channels located in the interdental bony segments. These vessels enter the facial and lingual alveolar plates and then exit through foramina to nourish the overlying gingival tissues.

Vessels derived from the major neurovascular bundles, for example, the facial artery, lingual artery, and greater palatine artery, eventually terminate anastomosing in the supra-alveolar gingival tissues.

Vessels emanating from the dental artery, before it enter the tooth, traversing through the periodontal ligament, then entering the tooth side of the alveolar bone, and exiting that bone to nourish overlying gingival tissues (Figure 11.6). These branches emanating from the major vessels of the maxillary and mandibular bones, arterioles, and venules, eventually traverse foramina through the facial and lingual alveolar bone, to provide an appropriate blood supply, and thus nourishment for long-term gingival health (Figure 11.15).

The Clinical Significance of Dehiscences and Fenestrations

A fenestration is described as a bone defect or deficiency, exposing root structure but having an intact marginal bone component (Figure 11.7a).

A dehiscence is described as a break in continuity of the alveolar bone overlying a root surface (Figure 11.7c). These conditions are manifest, when there is a discrepancy between the thickness of the alveolar bone and the thickness of the tooth in the buccolingual (sagittal plane), in other words, “thicker teeth in thinner alveolar bone.” One or more teeth

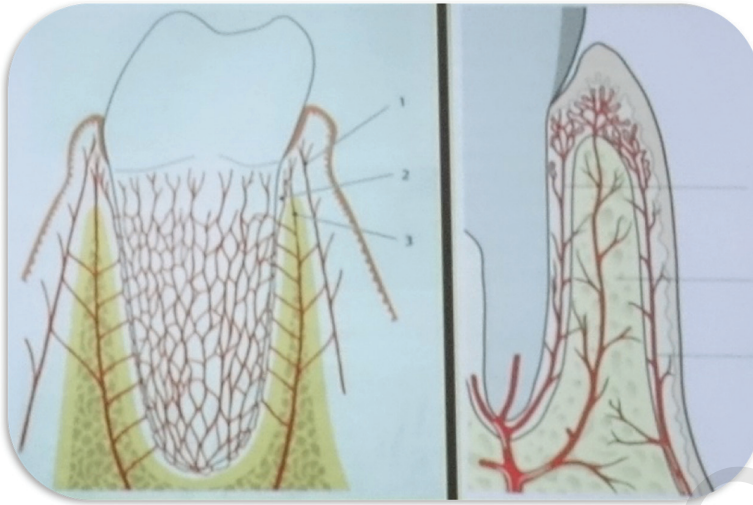


Figure 11.6 Vascularity of the periodontal tissues image.



Figure 11.7 Dehiscences and fenestrations. (a) Fenestration. (b) Dehiscence and Fenestrations. (c) Dehiscences. (d) Ideal alveolar bone structure, well aligned teeth, no dehiscences or fenestrations. Source: Courtesy of Smithsonian Museum, Washington DC.

demonstrating one or more dehiscences and/or fenestrations are noted in 85% of patients with a crowded dentition, usually on the facial aspect of the tooth (Volchansky and Cleaton-Jones, 1978; Volchansky and Vieira, 1981; Rupprecht *et al.*, 2001; Volchansky *et al.*, 2004). In Figure 11.7b, the canine represents a typical dehiscence, whereas the first premolar represents a typical fenestration. The lateral incisor demonstrates both dehiscence and fenestration. When considering the long- or short-term consequences of dehiscences or fenestration, one needs to be cognizant of the gingival blood supply to these tissues (see above). For comparative purposes, Figure 11.7d represents ideal alveolar buccal and lingual bone, in a well-aligned dentition. Figure 11.8 represents a clinical example of both dehiscences and fenestrations identified at the time of surgical orthodontic treatment.

It is postulated by this author that if the facial alveolar bone is deficient through the presence of one or more tooth dehiscences, the blood supply to the immediately overlying gingival tissue may be compromised limiting the natural process of cellular maintenance and replenishment and eventually gingival recession. The natural process of cell replenishment, occurring throughout the body might be compromised and reach a state of imbalance, due to a limited essential blood supply in that area. Fundamentally, from the clinical perspective, it is not possible to identify gingival recession without the underlying

presence of a bony dehiscence. However, a patient may present with bony dehiscences, without visual evidence of gingival recession. The recession may manifest years or even decades later (Richman, 2011; 2017).

Tooth Eruption Patterns

Dry skull images reveal that teeth in the primary dentition tend to erupt in a relatively vertical manner. However, if there is a discrepancy between the mesiodistal dimensions of the teeth and the available alveolar bone, the deciduous teeth may become crowded and seek a slightly more anterior orientation to fit into the available alveolar jawbone. In a review article, gubernacular canals are identified as anatomical canals, connecting the dental follicle of an unerupted tooth to the overlying gingival epithelium at the site of intended eruption (Chaudhry and Sobti, 2021), and are identified as lingual to the deciduous teeth. When the permanent teeth erupt, they do so from a lingual to buccal orientation and direction. They will continue to erupt until they find an appropriate passive position in the dental arch, moving in a facial direction. However, if the available alveolar bone is restricted in the horizontal mesiodistal plane, dental tooth crowding will occur once the teeth have “pushed” as far facially, as they are able to. This may incur invasion and perforation of the facial alveolar bone plate, with the development of dehiscences and fenestrations, described above.

Subsequently, if orthodontic tooth alignment is instituted for this subject to correct the crowded dentition, (deciduous, mixed, or permanent), the treatment of the crowded dentition will require further facial movement of the teeth, further engaging the facial bony plate and compromising the already thin, relatively avascular facial bony plate, described as the lamellar or bundle bone, and further increase the risk for future gingival recession and associated consequence.



Figure 11.8 Clinical consequences of dehiscences demonstrating reduced vascularity to the overlying tissues.

Consequences and Management Strategies, Including Phenotype Modification

Recent publications describe the treatment concept known as *phenotype modification* (Beauchamp *et al.*, 2020; Kao *et al.*, 2020; Wang *et al.*, 2020). As a component of data gathering prior to initiating orthodontic tooth movement (TM), 3D cone-beam computerized tomography (CBCT) techniques are utilized to evaluate the relationship between the available alveolar bone and the teeth (Kapila and Nervina, 2015) (Figure 11.9). We are interested in the sagittal or buccolingual aspects of this relationship. Januario *et al.* (2011) have identified that approximately 90% of their surveyed patients have a facial alveolar bone thickness of less than 0.9 mm. At least 50% of this group have a facial bony thickness of <0.5 mm. This bone, described as bundle bone, is relatively avascular due to its narrow dimensions and embryonic origin. Therefore, prior to initiating orthodontic TM, if these conditions are identified, it would be expedient to surgically augment the compromised facial alveolar bone prior to initiating orthodontic TM. In other words, we would be converting the thin phenotype to a more robust thicker phenotype, more resistant to breakdown, as the tooth is orthodontically moved from its natural position to a more favorable and desired position in the dental

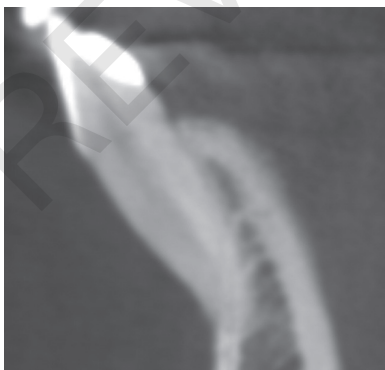


Figure 11.9 Representative CBCT image, buccolingual orientation.

arch, usually, but not always associated with arch expansion. Grafting agents would include both hard and soft tissue biologically compatible grafting materials. Figure 11.10a represents a CBCT scan, sagittal view through the mandibular left central incisor, of a 12-year-old male patient, prior to phenotype modification through the process of surgically facilitated orthodontics (SFO). Figure 11.10b represents the posttreatment image of the same patient 1-year post phenotype modification treatment. Figs. 11.11a, b represent the mandibular canine of a different patient, both pre and 1-year posttreatment.

Brugnami *et al.* (2018), in a classic publication, demonstrated the benefit of combining corticotomy procedures with simultaneous xenogeneic bone grafting agents. They treated adult patients following their standard protocol of orthodontic expansion therapy combined with simultaneous periodontal and corticotomy therapy. They divided their subjects into two groups. Group 1 served as the test group and received a graft material covered with a resorbable collagen membrane on the pressure side of the arch, whereas group 2 received corticotomies only without bone grafting or a resorbable membrane. All treated teeth were translated horizontally to expand the patient's constricted arches, in a facial direction to a position beyond the original bony housing.

Following completion of TM updated post-treatment records were obtained, analyzed, and compared with the original records. Their conclusion suggested that "a corticotomy in combination with xenogeneic grafting has the potential to increase the scope of conventional orthodontic treatment, by allowing for expansive movements beyond traditional limits." Further studies are needed to determine if the orthodontic TM guides the tooth through the grafted bone, as noted with traditional non-grafted sites, or moves the newly grafted bone together with the adjacent tooth. It is this author's clinical observation that the later occurs when a tooth site presents with no gingival recession, even though a dehiscence

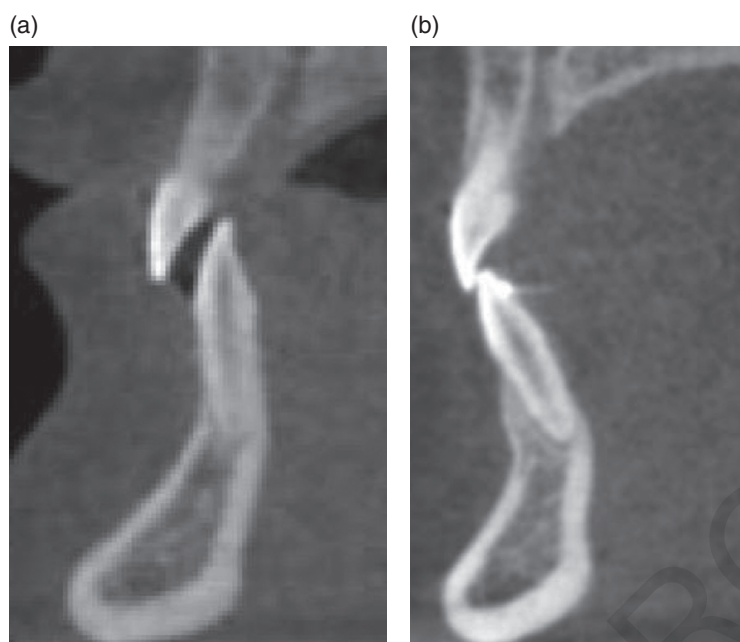


Figure 11.10 SFO treatment mandibular central incisor. (a) Pretreatment. (b) Posttreatment.

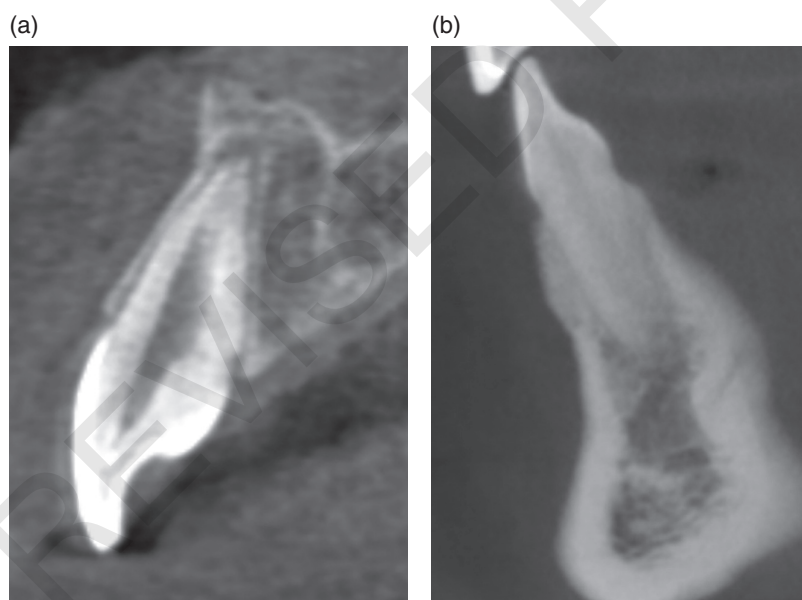


Figure 11.11 SFO treatment mandibular canine. (a) Pretreatment. (b) Posttreatment.

or fenestration may be present, prior to the initiation of orthodontic treatment. This does not seem to be the case in the presence of preexisting gingival recession prior to initiation of orthodontic TM. Although studies do not yet

support the concept of heterogeneous grafting prior to initiation of orthodontic treatment, clinical evidence strongly favors this approach (Richman C, personal observations). This suggests that an intact periodontal ligament,

consisting of unexposed and uncontaminated cementum, intact Sharpey's fibers, intact bundle bone, and an appropriate intact periosteum are essential components for generating supplemental bone to facilitate arch expansion. This author specifically uses the term "generating," rather than "regenerating" as an adequate thickness of supporting alveolar bone on the pressure side did not exist prior to the initiation of orthodontic TM and treatment (Figures 11.9 and 11.12).

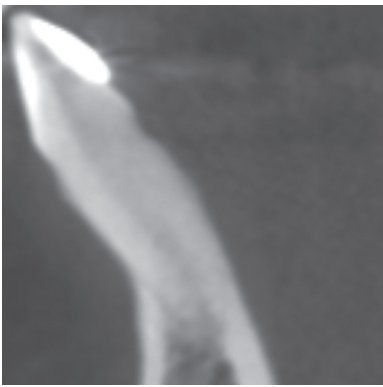


Figure 11.12 Sagittal image representing both facial and lingual alveolar bone deficiency in a typical crowded dentition, prior to orthodontic therapy.

Figure 11.13a represents a 35-year-old female patient following Surgically Facilitated Treatment (SFT) surgery and phenotype modification. The first image represents the pretreatment status of the deficient facial alveolar bone in the maxillary tooth because of the condition "big teeth in small jaw," whereas Figure 11.13b depicts the same patient 6 years later with a stable and robust facial bony plate.

This author previously defined a clinical index for determining the relative discrepancies between alveolar bone width and tooth width, when viewed in a sagittal orientation. At the time of publication as well as up to the present, numerous orthodontic diagnostic and treatment planning tools were/are available for evaluation of tooth/alveolar bone discrepancies in the mesiodistal orientation as well as arch width dimensions. However, this author was not aware of available instruments to assess sagittal bone/tooth width discrepancies.

The introduction of the Radiographic Supporting Bone Index (RSBI), an assessment tool, currently remedies this clinical situation (Richman, 2011).

RSBI-A represents a minimum thickness of 1.5 mm on the midfacial or midlingual aspect



Figure 11.13 Adult demonstrating robust newly generated facial alveolar bone 6 years following SFO treatment. (a) Pretreatment. (b) Posttreatment, 6 years later. *Source:* Courtesy of Dr. Stephen Rimer, Boca Rotan, Florida.

of a tooth scheduled for orthodontic TM, relative to the pressure side when evaluated in the buccolingual orientation on a CBCT scan. Based on data obtained from the dental implant literature, it is assumed that this volume of supporting alveolar bone should adequately survive orthodontic TM requiring less than 1.5 mm displacement, on the pressure side. (Figure 11.14a, lingual aspect). This entity represents a low risk of future gingival recession following completion of orthodontic TM.

RSBI-B represents a dimension of <1.5 mm but >0.5 mm on the pressure side. It is assumed that this might carry a definitive risk of post-orthodontic dehiscence and or fenestration formation with an increased risk of future gingival recession if the amount of orthodontic TM exceeds the dimensions of the available bone. Future recession might occur because of further compromise to the facial alveolar blood supply, due to destruction of the already compromised facial bony plate, essentially composed of relatively avascular bundle bone (Figure 11.14a, facial aspect). This situation is frequently noted in a crowded dentition and represents a moderate to high risk of future

gingival recession, following completion of orthodontic TM, relative to the pressure side.

RSBI-C represents a dimension of alveolar bone <0.5 on the pressure side (Figure 11.14b, facial aspect). This is a high-risk situation for future gingival recession as well as future orthodontic instability (Ferguson *et al.*) when moved further facially while undergoing phenotype modification.

From a clinical perspective, Figure 11.10a represents a high-risk RSBI-C, prior to phenotype conversion therapy, whereas Figure 11.10b depicts the same tooth converted to a low-risk RISBI-A following phenotype conversion therapy, using hard and soft tissue augmentation procedures, 6 years posttreatment.

In conclusion, from an anthropological and a genetic perspective, over time, we note a reduction in alveolar bone volume, frequently both arches, resulting in tooth crowding, and subsequent gingival recession in many patients, due to the reduced availability of nutrient vasculature. Figure 11.15 represents a 500-year-old skull with ideal arch form and ideal vascularity. All teeth are intact and well aligned. There are abundant vascular foramina in and around each tooth socket contributing

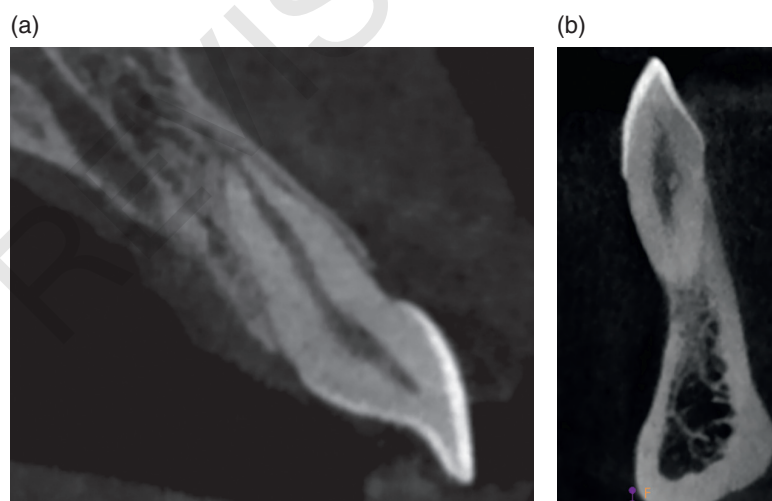


Figure 11.14 Sagittal images demonstrating features of the RSBI bone index. (a) RSBI-A, lingual, and RSBI-B, facial. (b) RSBI-C, facial.



Figure 11.15 Robust vascularity. Numerous Foramina. *Source:* Courtesy of Museum of Natural History, Carnegie Mellon University, Pittsburg.

to a robust blood supply to both alveolar bone and gingival tissues. Figure 11.16 on the other hand, represents an adult patient demonstrating significant crowding, dehiscence formation, and deficient facial alveolar bone. This

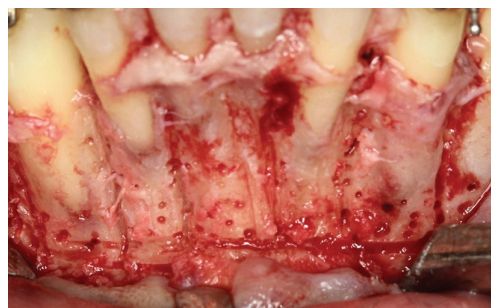


Figure 11.16 Clinical image of a patient with a crowded dentition, demonstrating severe dehiscences and fenestrations. Surgically Facilitated Treatment is noted with corticotomies prior to hard and soft tissue augmentation.

intraoperative image demonstrates the process of corticotomy development as part of the SFT procedure prior to hard and soft tissue grafting prior and the initiation of active orthodontic expansion therapy (Ahn *et al.* 2016).

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