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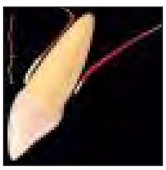
A Classification System for Crestal and Radicular Dentoalveolar Bone Phenotypes



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Pretreatment knowledge of crestal and radicular dentoalveolar zones and their associated thicknesses can improve risk assessment to meet esthetic and functional goals, particularly when discrepancies in anterior maxillary and mandibular arches exist and when an anterior protected articulation is to be achieved. This paper discusses a new classification of dentoalveolar bone phenotypes that differentiates the alveolar crestal zone from that of the radicular zone and classifies the thickness of facial bone at each compartment to aid in interdisciplinary dentofacial therapy risk assessment. The zone of crestal bone is defined as the region of the tooth alveolus measured from the cementoenamel junction (CEJ) to a point 4 mm apical. The dentoalveolar radicular zone is dependent upon the individual root length. It begins at a point 4 mm apical to the CEJ (base of the crestal zone) and extends the length of the tooth root. Dentoalveolar bone phenotype at both zones (crestal and remaining radicular alveolar aspect) can be categorized as either thick or thin. Thick is defined as ≥ 1 mm of facial bone width while thin is < 1 mm. (Int J Periodontics Restorative Dent 2013;33:289–296. doi: 10.11607/prd.1787)

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Proper treatment planning is essential for successful outcomes, particularly with interdisciplinary dentofacial therapy (IDT) cases of skeletally mature patients who require orthodontic tooth movement. As such, pretreatment assessment of the periodontium is commonly evaluated by clinical measures and conventional two-dimensional radiographic review. In IDT cases, particularly those involving the worn or malposed dentition, positioning teeth for an optimal anterior protected articulation may not be feasible as a result of the lack of available dentoalveolar bone along the entire root surface.[1,2]

Historically, periodontal risk assessment has been made from phenotype classifications that focus on alveolar crestal bone position and volume in its relation to gingival anatomy.[3–7] These classifications have attempted to relate alveolar crest anatomy to tooth form. Descriptions such as "high or low crest" or "flat vs scalloped vs pronounced scalloped" and "thick or thin" are descriptive terms commonly used. Anatomical descriptions related to tooth form also suggest tooth preparation considerations for planned

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prosthetic dentistry.[7,8] Such descriptions have determined the gingival width and/or thickness based on the ability to visualize a periodontal probe when placed through the gingival sulcus.[9] These determinants were based primarily on clinical evaluation or from human skull observations. Phenotype descriptions have also been applied to peri-implant anatomy, with decision-making trees used to provide the clinician with guidelines to achieve an esthetic outcome.[10,11] However, these descriptions do not consider the anatomy at the radicular aspect of the tooth root, which, in some circumstances, may suffer adverse iatrogenic sequelae with IDT involving orthodontics, such as labial tooth movement and/or root torquing.

Of late, cone beam computed tomography (CBCT) analysis has been used to determine facial bone presence or absence as well as its volume.[12] Braut and coworkers evaluated 125 CBCT scans in humans. They measured the presence or absence of facial bone at an axial slice 4 mm apical to the cementoenamel junction (CEJ) of maxillary anterior teeth (termed MP1) as well as at the midroot position (termed MP2). They reported that in roughly 90% of the 498 teeth evaluated, the facial bone was either thin (< 1 mm) or missing entirely.[13] These observations are significant not just for implant-related outcomes, but perhaps more importantly when orthodontic therapy is being proposed. Cook et al evaluated 60 patients to determine if there was an association between phenotype and labial plate thickness using CBCT imaging, diagnostic impressions, and clinical examinations in maxillary anterior teeth. They concluded that periodontal phenotype was correlated to existing labial plate thickness, alveolar crest position, keratinized tissue width, gingival architecture, and probe visibility.[14]

Unfortunately, crestal bone volume is not always continuous or synonymous with the radicular bone. As a result, each component of alveolar anatomy may need to be considered independently given the individual clinical situation and treatment plan. A classification system that would be able to identify and categorize facial bone thickness between crestal and radicular zones of these dentoalveolar compartments would be useful in risk assessment during IDT treatment planning.

The following is a classification system that can be used when CBCT imaging is a part of the diagnostic process that allows for differentiating and individualizing crestal from radicular dentoalveolar zones and categorizes the labial bone thickness of each.

This classification system can be useful for risk assessment and in decision making of IDT involving orthodontics as well as implant therapy. Improved treatment planning and risk assessment when managing skeletally mature dentitions with dentoalveolar or alveoloskeletal discrepancies in an IDT model can help guide clinicians to select treatment modalities that ultimately lead to minimizing the risks of adverse outcomes on the periodontium.

Crestal and radicular dentoalveolar zones and associated bone phenotype classifications

The dentoalveolar crestal zone is defined as the region from the CEJ extending to a point 4 mm apical. The dentoalveolar radicular zone is dependent upon individual root length and is defined as the region from MP1 to the root apex. Crestal and radicular dentoalveolar bone phenotype can be assessed at any measurement slice within each zone (Fig 1). Both crestal and radicular dentoalveolar zones can be categorized as either thick or thin. Thick is described as ≥ 1 mm of bone thickness while thin is < 1 mm. The determination of dentoalveolar bone phenotype is made through cross-sectional CBCT imaging analysis for both the crestal and radicular aspects to enable the IDT team to better appreciate the realities of the entire dentoalveolar anatomical complex, which requires inter-arch and/or intra-arch modification by labial tooth movement or root torquing. Schematic diagrams, cross-sectional CBCT examples of each phenotype category, and clinical/anatomical correlations are demonstrated in Figs 2 through 17. A Punnett square diagram outlining the dentoalveolar bone phenotype categories and possible anatomical combinations is presented in Table 1.

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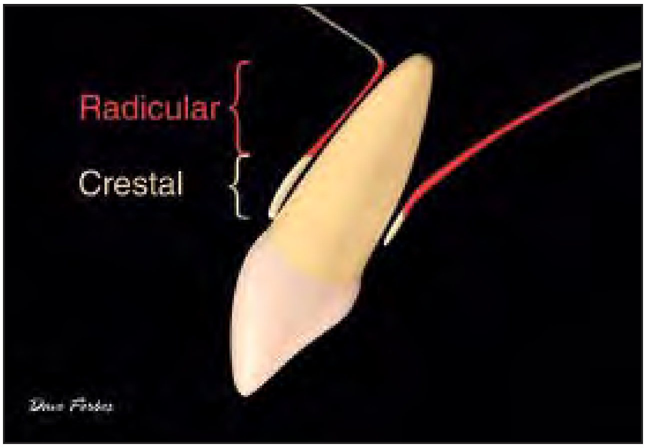

Fig 1 *Schematic representation of crestal and radicular dento-alveolar zones.*

Fig 2 *Schematic diagram of a thick/thick dentoalveolar pheno-type from a soft tissue clinical perspective.*

Fig 3 *Schematic diagram of a thick/thick dentoalveolar pheno-type from a hard tissue/surgical anatomical perspective.*

Fig 4 *Cross-sectional correlation of thick crestal* (red arrow), *thick* (orange arrow) *radicular phenotype.*

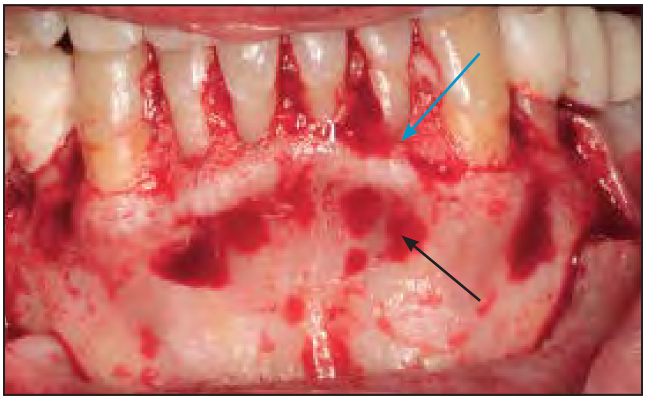

Fig 5 *Surgical/hard tissue correlation of thick crestal* (blue arrow), *thick* (black arrow) *radicular phenotype.*

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Fig 6 *Schematic diagram of a thick/thin dentoalveolar phenotype from a soft tissue clinical perspective.*

Fig 7 *Schematic diagram of a thick/thin dentoalveolar phenotype from a hard tissue/surgical anatomical perspective.*

Fig 8 *Cross-sectional correlation of thick crestal* (red arrow), *thin radicular* (orange arrow) *phenotype.*

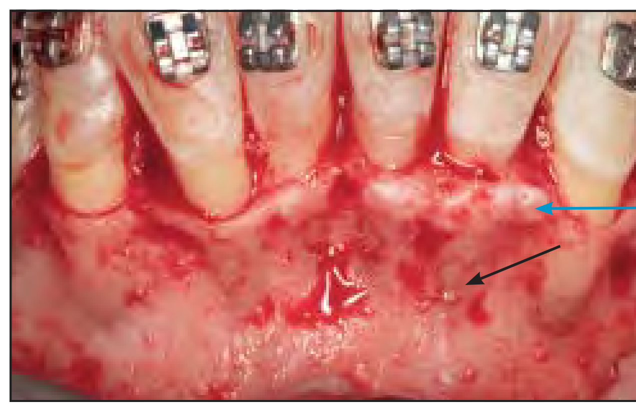

Fig 9 *Clinical correlation of thick crestal* (blue arrow), *thin radicular* (black arrow) *phenotype.*

Fig 10 *Schematic diagram of a thin/thick dentoalveolar phenotype from a soft tissue clinical perspective.*

Fig 11 *Schematic diagram of a thin/thick dentoalveolar phenotype from a hard tissue/surgical anatomical perspective.*

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Fig 12 *Cross-sectional correlation of post–bone augmentation for IDT with a resulting thin crestal* (red arrow), *thick radicular* (orange arrow) *phenotype.*

Fig 13 *Clinical correlation of post–bone augmentation for IDT with a resulting thin crestal* (blue arrow), *thick radicular* (black arrow) *phenotype.*

Fig 14 *Schematic diagram of a thin/thin dentoalveolar phenotype from a soft tissue clinical perspective.*

Fig 15 *Schematic diagram of a thin/thin dentoalveolar phenotype from a hard tissue/surgical anatomical perspective.*

Fig 16 *Cross-sectional correlation of thin crestal* (red arrow) *and thin radicular* (orange arrow) *phenotype.*

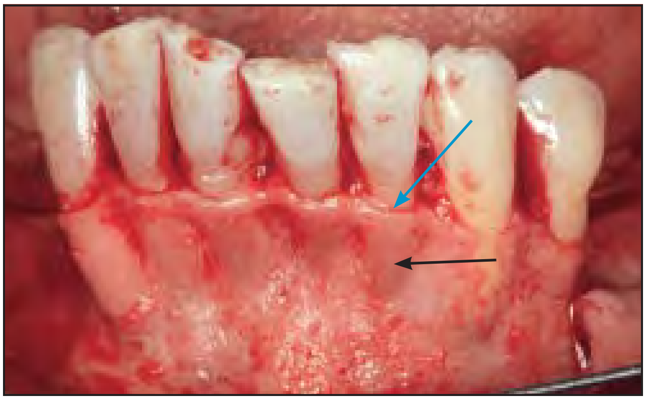

Fig 17 *Clinical correlation of thin crestal* (blue arrow) *and thin radicular* (black arrow) *phenotype.*

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Table 1 Crestal and radicular dentoalveolar bone phenotype categories and possible anatomical combinations presented as a Punnett square

THICK–THICK

	Phenotype: Thick	Phenotype: Thin
Crestal Zone	X	
Radicular Zone	X	

THIN–THICK

	Phenotype: Thick	Phenotype: Thin
Crestal Zone		X
Radicular Zone	X	

THIN–THIN

	Phenotype: Thick	Phenotype: Thin
Crestal Zone		X
Radicular Zone		X

THICK–THIN

	Phenotype: Thick	Phenotype: Thin
Crestal Zone	X	
Radicular Zone		X

Crestal zone = CEJ → 4 mm apical; Radicular zone = base of crestal zone → apex; thick phenotype = $\geq$ 1 mm of facial bone; thin phenotype = < 1 mm of facial bone.

Discussion

IDT is defined as the ultimate use of the expertise and skills inherent in the various dental disciplines.[15] The goal of IDT is to optimize the esthetic and functional needs of the patient. Often times, such cases require orthodontic tooth movement to position teeth while also minimizing iatrogenic tissue loss. Unfortunately, the anatomical reality is that traditional clinical analysis of the crestal gingival phenotype can be a misleading indicator with which to properly assess dentoalveolar risk, especially in IDT, as crestal and radicular bone thickness may be mutually exclusive. Thus, dentoalveolar bone along the entire root surface may be insufficient to position the teeth into the optimal inter-arch and intra-arch space while maintaining them within the orthodontic walls, ultimately affecting risk for adverse iatrogenic sequelae.[1,2]

Unfavorable dentoalveolar or alveoloskeletal anatomy may limit ideal tooth movement unless alternative orthodontic approaches are performed, particularly in IDT cases of skeletally mature patients presenting with a worn or malaligned dentition. Such complex cases may require significant intra-arch space to be regained to restore clinical crown dimensions for natural tooth morphology and/or for coordinating inter-arch relationships to develop anterior protected articulation occlusal schemes that improve force management. Techniques such as periodontally accelerated osteogenic orthodontics (PAOO) and surgically facilitated orthodontic therapy (SFOT) and have broadened the scope of IDT.[16–19] These IDT opportunities have enhanced orthodontic capabilities by facilitating tooth movement through corticotomy and alveolar decortication surgery while simultaneously increasing the availability of dentoalveolar bone by particulate bone grafting.[16–20] Further, the use of CBCT imaging is becoming more popular for expanded diagnostic inquiry and presurgical assessment in skeletally mature patients involved in IDT.[13,14] As a result, traditional phenotype classifications used in the diagnostic treatment planning process may be inadequate because they consist primarily of clinical assessments that do not consider the entire dentoalveolar anatomy, namely the radicular bone. The crestal and radicular anatomical information made possible through CBCT imaging provides critical information for the IDT team, especially since such therapy routinely involves orthodontic tooth movement. In addition, cross-

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sectional, axial, sagittal, and soft tissue analysis through CBCT imaging allows a more objective view of risk assessment when compared to more traditional radiographic modalities commonly used in IDT.[21–23] The dentoalveolar bone phenotype zones and classification system proposed here is useful for framing the data obtained by CBCT analysis to improve treatment planning in IDT cases. The classification system is particularly helpful when treating cases that involve a dentoalveolar discrepancy between the anterior maxillary and mandibular arches and when optimal anterior protected articulation is to be achieved.

Pretreatment knowledge of dentoalveolar bone thickness along the entire tooth alveolus, especially the radicular zone, coupled with the planned orthodontic tooth movement to meet the esthetic and functional outcome goals of the patient and restorative doctor, would help to determine whether the patient was a candidate for conventional therapy or if enhanced orthodontic approaches are indicated to prevent gingival and bony problems. Since many cases will present with limited crestal and/or radicular dentoalveolar facial bone (< 1 mm),[13,24] such identification would properly identify risk and call for consideration of alternative orthodontic therapy (such as PAOO or SFOT). These techniques could be used to increase the radius of the dentoalveolar bone for expanded tooth movement capabilities as well as to minimize the incidence of iatrogenic sequelae when tooth movement requires exceeding the known limits of the orthodontic walls.[1,2] Because dentoalveolar bone thickness is not always continuous or synonymous between (or even within) each zone along the tooth alveolus,[24] the system proposed here can help to more accurately assign risk and provide a more correct interpretation of total alveolar anatomy from which treatment planning can best serve the IDT team and patient in meeting outcome goals. Enlow and Moyers[25] and Hoyte and Enlow[26] have shown that during growth, resorptive and depository fields exist in the facial skeleton and that after growth, muscle pressure continues to exert a slow resorptive effect, most notable of which is from the peri-oral musculature. These resorptive fields and associated effects on the dentoalveolar complex should be considered particularly when facial tooth or root torquing movements are planned. They are also influenced by peri-oral muscle position and mass, and the continuous pressure exerted over time may, in part, be responsible for the radicular dentoalveolar bone thickness differing from that at the crest in such cases.

To date, phenotype classifications involving CBCT imaging to aid in dentoalveolar risk assessment for IDT are lacking. Richman suggested that tooth volume and/or tooth position within the alveolar housing was strongly correlated to gingival recession.[27] He evaluated 72 teeth in 25 patients where gingival recession > 3 mm was evident using clinical examination, photography, and CBCT evaluation. He reported that where gingival recession was > 3 mm, all teeth showed prominent facial contours and had associated alveolar bone dehiscences, suggesting a discrepancy exists in these conditions between tooth size and alveolar bone dimensions. In addition, he proposed a radiographic-supporting bone index (RSBI) to facilitate evaluation of the dentoalveolar bone supporting the mucogingival complex. The RSBI categories do not, however, separate the crestal from the radicular aspect of the tooth alveolus.

The crestal and radicular dentoalveolar zones and associated bone phenotype classification system can be uniquely applied for the skeletally mature IDT patient who requires orthodontic tooth movement. It provides a platform for an objective analysis and discussion related to risks imposed on the periodontium. Furthermore, this classification system helps to delineate the limits of traditional orthodontic tooth movement for both dentoalveolar zones in an effort to minimize the occurrence and severity of iatrogenic sequelae.

The dentoalveolar bone phenotype classification concept proposed here not only uniquely differentiates and individualizes crestal from radicular zones but classifies facial alveolar thickness at any level within each zone to provide the IDT team an opportunity to better assign pretreatment risk, particularly when orthodontic tooth movement is involved. The classification proposed is simple, requires CBCT analysis, categorizes labial bone thickness of each zone where tooth movement may have

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consequences, and helps assist in expanding IDT opportunities for improved outcomes in more demanding cases. It further supports the team approach concept inherent with IDT involving tooth movement for skeletally mature patients.

Conclusion

This article presents a new classification system that individualizes and differentiates the crestal from the radicular dentoalveolar bone complex as well as classifies the thickness of each zone. It is a dentoalveolar bone phenotype classification system that incorporates CBCT imaging as a part of the diagnostic process to help better assign risk in the IDT treatment planning process when tooth movement is planned, reduce gingival and bony complications from orthodontic IDT, and, ultimately, improve IDT outcomes for skeletally mature patients.

Acknowledgment

The authors report no conflicts of interest related to this paper.

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