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Alveolar Architecture and Thickness In Relation To Sagittal and Vertical Skeletal Pattern of the Face; A Review on Current Findings

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Abstract: *Alveolar bone architecture and thickness plays an important role in orthodontics. The primary stability of miniscrews from one side, and the risk of dehiscence and fenestration form the other side exhilarates the importance of skeletal dimensions. Thickness and height of buccal and lingual cortical bone layers may be altered in conjunction with alignment of teeth, inclination of root and occlusal forces. Clinicians must know that cortical bone is thicker in the mandible compared to the maxilla both on the buccal and lingual sides, and also cortical bone is thicker in the posterior region compared to the anterior region on the buccal side. Differences in cancellous bone thickness between different sagittal facial patterns and differences in cortical bone thickness between different alveolar regions should be taken into consideration when planning orthodontic tooth movements. Differences in cortical bone thickness might be explained by masticatory function;weakened masticatory muscles produce smaller biteforces, which lead to less strain on the associated bones. Anterior dentoalveolar height in both the maxilla and the mandible are larger in long-face patients compared to short-face ones. buccal cortical bone thickness varies depending on the sites between and within the jaws, and vertical skeletal pattern. The thickness of mandibular and maxillary buccal cortical bone increases toward the apical area in all regions under regardless of vertical skeletal pattern. As the buccal cortical bone is thinner in high-angle patients, difficulties may be encountered in achieving primary stability during miniscrew treatment.*

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I. Introduction

Alveolar boundary conditions are the depth, height, and morphology of alveolar bone relative to tooth root dimensions, angulation, and spatial position[1]. Applying inappropriate orthodontic forces to a tooth canaffect alveolar boundary conditions adversely,resulting in dehiscence and fenestration. Maximizingalveolar boundary condition remodelingand minimizing unwanted sequelae for each patient is a desired orthodontic goal. Orthodontic forces move teeth within the alveolar bone of the maxilla and mandible. Failure to staywithin the alveolar bone hassignificant and oftenirreversible negative sequelae, such as dehiscence and fenestrations[2]. Among the hard tissue limitations are areas of sclerosed bone, inferior aspect of the palate (especially in deep bite patients) as well as the labial and lingual cortical plates at the level of the root apex[3]. Alveolar bone dimensions, more particularly buccal andlingual cortical bone thicknesses, are important factors that affect the stability and success of miniscrewswhich are commonly used by many orthodontists[4]. Miniscrews require mechanical retention to bone rather than osseointegration with bone to provide anchorage. Being stronger and more resistant to deformation, cortical bone provides higher anchorage for miniscrews and it is responsible for their primary stability[5].

With the advent of 3-dimensional imaging modalities such as conventional computed tomography (CT) and cone-beam CT (CBCT), practitioners can now visualize and measure the true 3-dimensional anatomy ofpatients. CBCT also allows measurements to be made in planes of space not available or accurately depicted in traditional radiographs.CBCT can be used to quantitatively assess alveolar bone height and thickness with high precision and accuracy.[6]

The morphology of the craniofacial region is dominantly controlled by genetic factors. However, functional demands can have a significant effect on craniofacial growth and development[7]. Facial divergence has been related to the masticatory muscles and the association between the hyperdivergent growth pattern and muscular hypofunction has previously been reported[8]. Skeletal open bite is associated with unfavorable craniofacial growth patterns, such as posterior or clockwise rotation of the mandible and excessive vertical growth of the craniofacial skeleton. In non-growing patients, orthognathic surgery with orthodontic treatment may be required to correct a severe vertical skeletal discrepancy. In some mild skeletal open bite cases, conventional orthodontic treatment can be utilized to camouflage the vertical skeletal discrepancy. Posterior tooth intrusion may cause counterclockwise rotation of the mandible. Temporary anchorage devices, such as miniplates or miniscrew implants, play important roles in skeletal anchorage during maxillary and mandibular posterior tooth intrusion[9,10].

Thickness and height of buccal and lingual cortical bone layers may be altered in conjunction with alignment of teeth, inclination of root and occlusal forces[11]. The verticalgrowth pattern has been shown to influence alveolar bone thickness and many researchers have reported that hypodivergent individuals have thicker alveolar bone morphology compared to hyperdivergent individuals[12]. Skeletal Class II and skeletal Class III malocclusions, which affect the patient's facial appearance, masticatory function and mental health, are the most common malocclusions in orthodontic patients. Differences in cancellous bone thickness between different sagittal facial patterns and differences in cortical bone thickness between different alveolar regions should be taken into consideration when planning orthodontic tooth movements and anchorage mechanics[11]. This review study is aimed to provide the latest standpoints about alveolar architecture and cortical thickness or width in relation to sagittal and vertical skeletalpattern of the face.

In relation to sagittal skeletal pattern

Several studies had demonstrated that the morphological features of alveolar bone were affected by vertical and sagittal facial type[13]. Handelman found that the lingual bone level of mandibular incisor apex was wider in Class I and Class II groups than in the Class III group[3]. On the other hand a significant relationship between facial type and alveolar bone thickness and height also has been reported[8].

In a recent study by Coşkun[11], no significant difference was found between skeletal class 1, class 2, and class 3 groups for buccal cortical bone, and lingual cortical bone thickness measurements. However, significant differences were observed between skeletal class 1, class 2, and class 3 groups for cancellous bone thickness. Cortical bone was observed to be significantly thicker in the posterior region compared to the anterior region on the buccal side both in the maxilla and the mandible in all three groups of this study. The importance of these findings would be the gradual thickening of the cortical wall, which is a key point in orthodontic posterior expansions and torque adjustments. He also found cortical bone is thicker in the mandible compared to the maxilla both on the buccal and lingual sides, and also cortical bone is thicker in the posterior region compared to the anterior region on the buccal side[11]. Baysal et al[4] found that labial alveolar bone thickness of lower incisors was significantly higher in the Class I group compared with that of the Class II group. The bone level lingual to the mandibular incisor apex is believed to be narrower in the Class III group than in the Class I or Class II groups[3]. Kook[14] has reported that the apical alveolar bone was significantly thinner in skeletal Class III malocclusion subjects than it was in normal occlusion subjects, except for the maxillary incisors.In an evaluation of bone thickness and density in the lower incisors' region in adults with different types of skeletal malocclusion, Al-Masri[15] found apical buccal thickness in the four incisors is higher in class II and I patients than in class III patients. There were significant differences between buccal and lingual surfaces at the apical and middle regions only in class II and III patients[15].

Yagci[16] detected dehiscence and fenestration on the CBCTs of sagittal Class I, II, and III presentingnormal vertical growth pattern. They reported that there was less restriction for moving the mandibular incisors in the labiolingual direction, and tooth tipping should be preferred to bodily movement in Class II patients; whereas, in our study, similar patient group presented <1 mm of bone thickness on the CEJ and mid- root regions[16]. Continued to that, Eraydin[17] found that in all dentofacial types, gingival recessions or dehiscence may occur on the labial alveolar bone of Class I and Class II.In all dentofacial types, fenestrations may be detached on the labial alveolar bone of Class I, II, or III. There is poor bonethickness on the labial or lingual side of all Class II with either vertical facial type[17].

In a recent cross-sectional study by Ma[13] found that the mandibular bony morphology in high-angle patients with skeletal Class III malocclusion was thinner than that in high-angle patients with skeletal Class II malocclusion. He also found that the root of maxillary central and lateral incisors was placed more labially in patients in high-angle skeletal Class II than it was in patients in high-angle skeletal Class III, especially in the lateral incisors.

Based on evaluation of Saudi subjects, AlHadlaq[18] discoveredsignificant differences of the anterior alveolar dimensions between males and females with Class I, Class II, and Class III skeletal maxillomandibular classification. When controlling for the gender, significant differences of the anterior alveolar dimensions were detected between individuals with Class I nor- mal jaw relationship and individuals with Class II or Class III jaw relationship. In addition, Class II jaw relationship subjects were demonstrated to have multiple significantly different anterior alveolar dimensions when compared to subjects with Class III jaw relationship[18].

As mentioned before, the alveolar bone thickness impacts the orthodontic treatment planning in different ways. A practitioner must consider the limits due to danger of dehiscence and fenestration before any alteration in the anatomical and morphological conditions of alveolar complex. Skeletal Class I, Class II, and Class III individuals presents differences in the buccolingual inclination of their upper incisors and all lower teeth. Skeletal Class I individuals had reported to experience higher dehiscence prevalence in the upper buccal and posterior buccal regions[19]. Ultimately, Dehiscence prevalence is reported to be higher in the lower buccal region while Fenestration has a higher prevalence in the upper buccal region. Dehiscence and fenestration prevalence was reported to be higher in the anterior buccal region[19].

In relation to vertical skeletal pattern

There are 3 basic types of vertical facial patterns: low-angle, averageangle, and high-angle.The forms of the mandible and the maxilla—specifically, the density and thickness of the cortical plate—adapt to masticatory forces[20,21]. A relationship between muscle forces and bony adaptation could explain the correlations that have been reported between muscle function and cortical bone thickness[12]. Facial divergence has also been related to the masticatory muscles. A naturally occurring example is found in subjects with muscular dystrophy[22]. Their weakened musculature directly affects the structure and position of the maxilla and the mandible. Previous studies have shown associations between increased facial divergence and decreased muscle function[23,24].Differences in cortical bone thickness might be explained by masticatory function;weakened masticatory muscles produce smaller biteforces, which lead to less strain on the associated bones. Medullary thickness does not appear to be much affected by facial divergence; this is reasonable if thestrains produced by the musculature primarily affect the cortical bone. Interradicular cortical bone 5 mm below the alveolar ridge is, at most sites, thicker in hypodivergent than in hyperdivergent subjects. Since medullary thickness does not differ consistently between hypodivergent and hyperdivergent patterns, differences in total alveolar ridge thickness are due primarily to differences in cortical bone thickness. Lingual cortical bone is thicker than buccal bone throughout the maxilla and the mandible, except between the mandibular first and second molars. Maxillary lingual and mandibular buccal cortical bone thicknesses increase from posterior to anterior. Mandibular cortical bone is thicker than maxillary cortical bone[12].

dentoalveolar compensation mechanism acts in the maxilla and mandible by enlarging the vertical size of the frontal dentoalveolar heights in long-face subjects and, conversely, reduces it in short-face subjects. Anterior dentoalveolar height in both the maxilla and the mandible are significantly larger in long-face subjects compared to short-face subjects[8]. Beckmann et al. found that a long-faced person generally will have a larger area of the maxillary alveolar and basal bone that coincides with a longer maxillary alveolus with no significant deviation of its shape[25].

According to Sadek[8] research, no significant differences were found for measurements of alveolar height in the posterior region in both arches. High-angle group presented thinner alveolus anteriorly in the maxilla and at almost all sites in the mandible. High angle subjects can be at increased risk of moving incisors beyond alveolar bone support when subjected to marked antero-posterior incisor movement[8].

Some studies[26,27] have suggested the palate as an alternative region for miniscrew implant placement due to the dense palatal bone, sufficient palatal cortical bone thickness, and the presence of few vital anatomical structures. Recently in a research for quantitative evaluation of palatal bone thickness in patients with normal and open vertical skeletal configurations using CBCT, it was reported that Class I malocclusion with open vertical skeletal configuration may affect palatal bone thickness, so the placement of temporary anchorage devices or miniscrew implants in the palatal area in such patients should be performed with caution[10].

In terms of interradicular width, Inter-radicular cortical bone is reported to be thinner in high-angle subjects, compared to the low- and normal-angle faces, in the posterior region of the maxilla and mandible on the buccal side as well as palatally in the maxilla mesial and distal to the lateral incisor. High-angle subjects tended to have more sites with cortical bone thickness less than 1 mm[28].

As concluded by Veli[29] that buccal cortical bone thickness varies depending on the sites between and within the jaws, and vertical skeletal pattern. The thickness of mandibular and maxillary buccal cortical bone increased toward the apical area in all regions under investigation regardless of vertical skeletal pattern. As the buccal cortical bone is thinner in high-angle patients, difficulties may be encountered in achieving primary stability during miniscrew treatment[29]. Generally Adult high-angle patients had significantly lower values than did low-angle patients in all mini-implant insertion sites in both the maxillary and mandibular alveolar bones. Clinicians should be aware of the probability of thin cortical bone plates and the risk of mini-implant failures at maxillary buccal alveolar mini- implant sites for high-angle patients, and mandibular buccal alveolar mini-implant sites between the canine and first premolar for normal and high-angle patients[30].

II. Conclusion

Dimensions and thickness of alveolar is of great importance in orthodontics. Practitioners must be aware of those and how to assess them because forced tooth movements must be achieved within the normal anatomical boundary of bony structures to prevent dehiscence and fenestrations. Also, to prevent failure of temporary anchorage devices, assessment of cortical thickness in the jaws and interradicular spaces cannot be avoided during treatment planning. To date literatures have reported variety of significant differences among alveolar sites regarding the thickness and other dimensions, either from sagittal or vertical skeletal point of view.

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