White Paper on the Efficacy of the Osseo-Restore™ Appliance to Effect Skeletal Patency and Growth in The Anterior Maxilla

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Abstract

Introduction. Bone growth remodeling by bone deposition and resorption has a deep scientific research history, which in the present day requires to be put to purpose for understanding remodeling phenomena occurring over the subnasal region during orthodontic treatment;

Methods. A conebeam CT superimposition technique rendering an assessment of bone growth remodeling with an appreciation for its principles, combined with an understanding of the role of mechanical forces aids our understanding of craniofacial growth and development;

Results. Mechanical forces elicited by an orthopedic appliance in the biological range will stimulate normal growth remodeling in the growing child and compensatory remodeling in the adult non-grower;

Conclusions. Anterior alveolar remodeling may be specifically targeted to treat maxillary deficiencies provided that treatment forces do not exceed the biological range.

Highlights

Bone growth remodeling principles are central to an understanding of the developing human face.

During growth teeth drift by classic deposition-resorption remodeling mechanisms.

Changes in bone mass occur by seeking strain thresholds that remain patent through life.

Orthopedic appliances form bone over anterior maxillary roots when forces remain in the biological range.

Properly designed and managed orthopedic appliances can be safely applied to reverse maxillary deficiencies.

Recent claims on social media, e.g. [1], draw attention to orthodontic treatments using appliances that putatively eliminate bone in the subnasal region of the maxilla and expose roots of the anterior dentition. Claims such as this without scientific research obfuscate and contribute nothing but unbridled fear. Whilst acknowledging that proper research on the topic takes some time, we wish to respond by saying, 1) we have begun this research in earnest for the sake of documenting variation in morphogenetic responses to such treatments, and 2) to address immediately in this white paper the issue. To achieve the latter goal, we shall briefly review the history of bone growth remodeling research and then its application to the craniofacial complex. We will then dwell on the role of bone growth remodeling for promoting integration of the craniofacial complex and, in this context, recognize the role that remodeling plays in the repositioning of teeth during growth in the grower and non-grower. Bone strain as a goal to be achieved by bone remodeling processes is invoked as an axiom of hard tissue biology, which is violated when orthodontic treatment forces exceed the capacity of the bone to adapt.

While first experiments in bone growth took place in the 18th Century, the modern synthesis of its concepts began with Brullé and Hugeny [2], which then became the focus of research by eminent figures in the morphological, histological, and experimental sciences for about 100 years; e.g., [3-25] among others.

Bone growth remodeling is the fundamental mechanism bearing on skeletal morphogenesis, which involves coordinated surface patterns of bone deposition and resorption.* Prompted by displacement of bones by craniofacial orocapsular matrices, the coupled processes of bone deposition and resorption during growth achieve the changes in size and shape that are necessary to enclose their respective matrices and support their muscle attachments [26-28].

Enlow [29] benefited from these historical precedents in bone growth remodeling research and began publishing numerous papers and books alone and with colleagues that documented the principles of bone growth remodeling that would be used to chart the normal pattern of human facial growth and development. *These principles are central to an understanding of the anteriorly-facing surfaces of the developing human face, in particular that of the subnasal region, which is the topic of this communication and much speculation in the orthodontic community*.

Enlow [29,30] emphasized the *direction* in which bone surfaces were oriented to explain, for instance, that the outer flared metaphyseal cortex of a growing long bone was necessarily resorptive because this surface faced obliquely *away* from the growth direction. The metaphyseal endosteal aspect was explained to be depository because this surface faced obliquely *toward* the growth direction. Enlow [26,31,32] popularized these concepts in relation to the growth of the craniofacial skeleton, which emphasized the concept of “cortical” or “osseous” drift (bone growth movement through tissue space) and the “V principle” (gross morphological bone restructuring, shaping and enlargement) as the morphogenetic responses to displacement-based compensatory bone growth remodeling. Enlow [26,31,32] also proposed the employ of "Part - Counterpart" analysis from 2D lateral radiographs, the superimposition method of which permits the identification of deposition-resorption growth fields and thus a description of not only what happens, but how it happens in the anteriorposterior and superoinferior directions. The method has the benefit of demonstrating what compensatory remodeling phenomena are occurring over the subnasal region in both the growing child and the adult non-grower.

Today we have an enhanced understanding of bone formation processes from Boyde and Jones [33] and a wealth of knowledge on the molecular and cellular physiology of developing bone; e.g., [34-36]. This improved understanding underpins what we now know is the high level of anatomical integration among the parts of the growing oral region [37] that are consistent with Part - Counterpart analysis.

This integration is not something static, but rather dynamic throughout life. In growing individuals the remodeling of the periosteal subnasal alveolar region is resorptive, growing rearward in compensation for displacement of the maxilla anteriorly. The alveolar periosteal bone is not eliminated because bone formation occurs on the contralateral surfaces of the root sockets and behind the teeth on the palatal alveolar cortex; *teeth are not passively displaced with the jaws as they grow, but rather they drift by classic deposition-resorption remodeling mechanisms within their sockets*. In the adult non-grower the same is true, and though this is not strictly occurring as an ontogenetic growth program, it is primary growth elicited as a bone's adaptive response to mechanical loading.

It is axiomatic that an alteration in the mechanical forces on *any* bone of the body will cause that bone to respond. Bone construction and reconstruction is regulated by sensing of the ambient strain environment [38], so much so that strain is said to be the 'goal' of bone size and shape change [39]. A bone that fails to experience its strain threshold will reduce its mass, and a bone that experiences peak strains above its threshold will gain mass [40]. Both reductions and gains in mass do so by seeking the appropriate strain threshold for that bone, a process that remains patent throughout life.

If mechanical forces originating from an orthopedic appliance are used to generate anteriorward tooth movement, the only mechanisms available for such movement are those of the classic deposition-resorption remodeling mechanisms discussed here. Mechanical forces in the biological range will cause cortical drift of the tooth roots through bone tissue space to accommodate the desired position directed by the force, and further, the adjacent alveolar bone may also increase in mass in order to balance the perceived strains and to bring the bone back to its appropriate threshold. Posterior teeth encroaching anteriorly because of applied forces will cause growth that includes bone formation on the periosteal subnasal surface. The contralateral surfaces within the anterior aspects of the root sockets will be resorptive, and thus by cortical drift the roots will shift or rotate anteriorly; rotation occurs because the anchoring bands are typically positioned on the first permanent molars at mid-crown height, and forces driven forward at the level of height of contour may obliquely reorient the anterior crowns whilst leaving the root tips near to their original position. 10 3, 3 14

Figure 1-2 are conebeam CT scans that illustrate these phenomena on a growing 9 yrs and 4 mo old child treated with a Osseo-Restore™ removable appliance for 10 mo, and an individual whose growth was complete and that received an Osseo-Restore™ fixed appliance for 4 mo and then ControlledArch™ System orthodontics for 12 mo. The superimposition technique follows that of Enlow [31], which is fundamentally based upon growth boundaries, with all landmarks being implemented in the 3D rendering software, Anatomage (Santa Clara, CA). This method allows before-and-after growth/treatment differences to be visualized, measured, and related specifically to bone deposition-resorption remodeling activities. The child in Figure 1 had been diagnosed as exceeding growth in the vertical dimension relative to that of their horizontal development. As judged by the protrusive nature of the midface in the older blue profile in relation to the earlier profile in warm colors, treatment with the removable appliance primarily stimulated growth of the maxilla anteriorly. Normal bone resorption over the nasoalveolar clivus for this age accompanied a small downward relocation of the subnasal region, but otherwise forming bone predominated, which is not the typical remodeling pattern for a growing child [26,31,32]. In Figure 2, of the individual whose growth had ceased, orthodontic forces uprighted several teeth and caused an inferior and outward relocation of the maxillary alveolus by ca. 1-3 mm. A modest amount of resorption on outer alveolar and deposition over palatal surfaces of the alveolar bone will have made this relocation possible. A small inferior relocation of the tooth-bearing portion of the mandible also occurred.

Should mechanical treatment forces exceed the biological range, the rate of bone formation will not outpace resorption. Accelerated bone repair can reach 1.7 μm/day [41], but bone resorption is capable of removing bone by up to 25 μm/day [42]. Given such a discrepancy, the periosteal alveolar cortex will be eliminated and the subnasal roots will be exposed within, for instance, only one-three months if the biological range of forces is chronically exceeded. Nevertheless, caution must be exercised when suggesting that tooth roots have been exposed from conebeam CT scans. Labial alveolar cortical bone in places can range from ca. 100-600 μm in thickness [43], and x-ray voxel edge effects (i.e., voxels not fully containing bone) will fail to visualize and reconstruct the bones' mineralization completely, particularly as the bone thickness diminishes to the set voxel size of the scanner. In addition, newly formed bone mineralization density, while increasing rapidly in the first weeks of formation, takes months-to-years to be nearly complete [44-46] and thus this bone will be underrepresented and poorly visualized in conebeam CT scans.

Conclusion

The clinical implications contained within craniofacial growth and development studies may be immediately appreciated in the application of specialized dental appliances, e.g., the Osseo-Restore™ appliance, which stimulates signals for modification of anterior alveolar bone within biologically safe boundaries as described above. Properly designed and managed orthopedic appliances such as this capable of stimulating appropriate signal systems, which we are only now beginning to understand, can be predictably and safely applied to potentially reverse epigenetic maxillary deficiencies.

*Because of disparities of terminology in the literature, the term remodeling is qualified here to describe 'growth remodeling' , often referred to as modeling, versus 'secondary remodeling', which often refers to Haversian replacement of bone or the repair/maintenance of bone removed because of fracture or requirements of mineral homeostasis.

Author Contributions

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Acknowledgments

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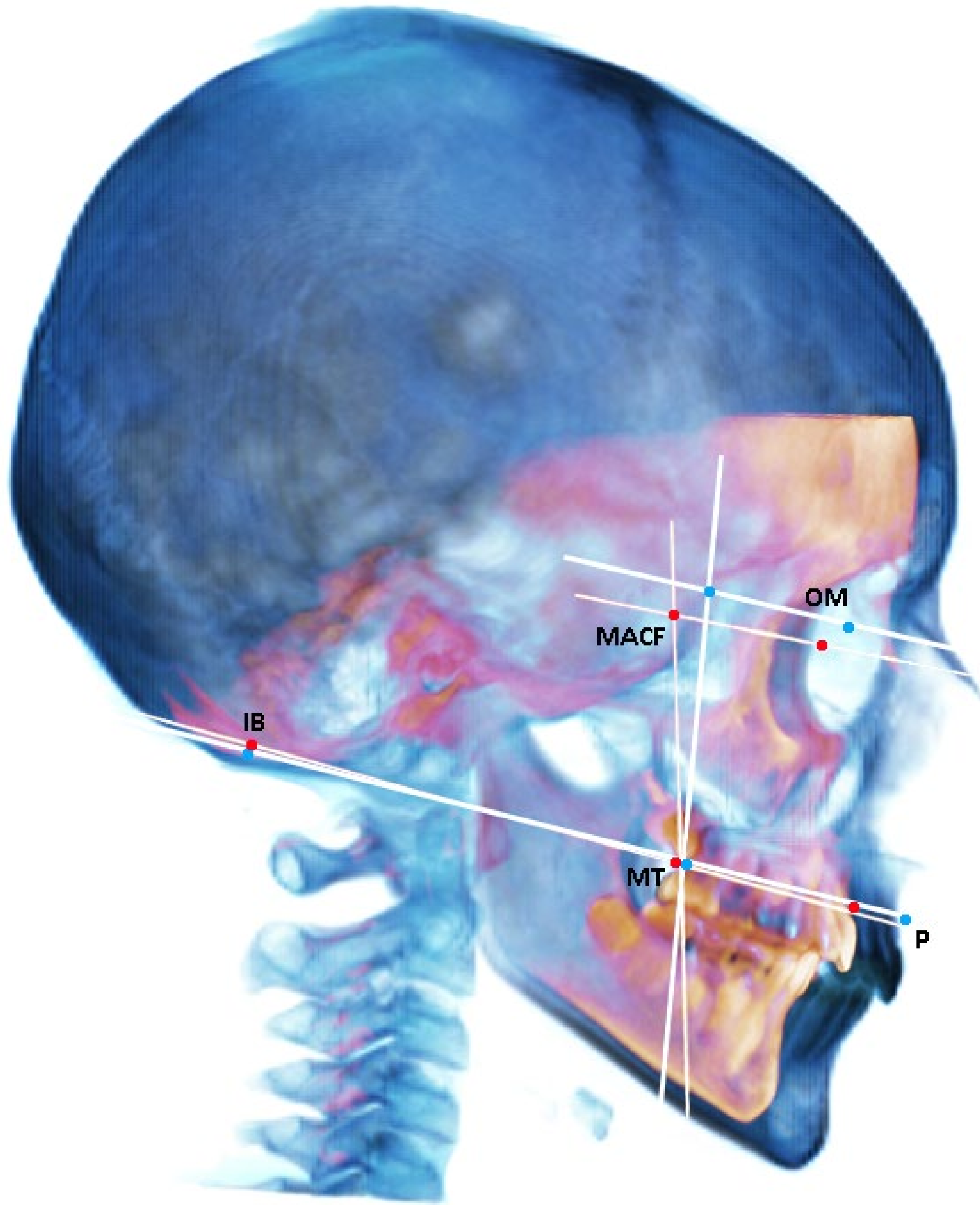

Figure 1

Younger (yellow) and older (blue) conebeam CT scans superimposed according to the method described by Enlow [31], which describes what surfaces were forming and resorbing during growth. Landmarks include: junction between middle and anterior cranial fossae (MACF), orbital midpoint)OM), inferior brain (IB), maxillary tuberosity (MT, and prosthion (P), The disposition of the older scan indicates that growth of the maxilla was in the anterior direction, without a downward contribution. This result confirms that the therapy stimulated anterioward growth and displacement and that the subnasal region was characterized by forming bone on its surface, not resorbing bone as is typical of the growing child [31], which would have led to rearward and downward growth. Note also the elevation of the orbits in this superimposition, which indicates significant deposits at sutures of the midface, displacing the upper face upward. The mandible has grown in harmony with the maxilla.

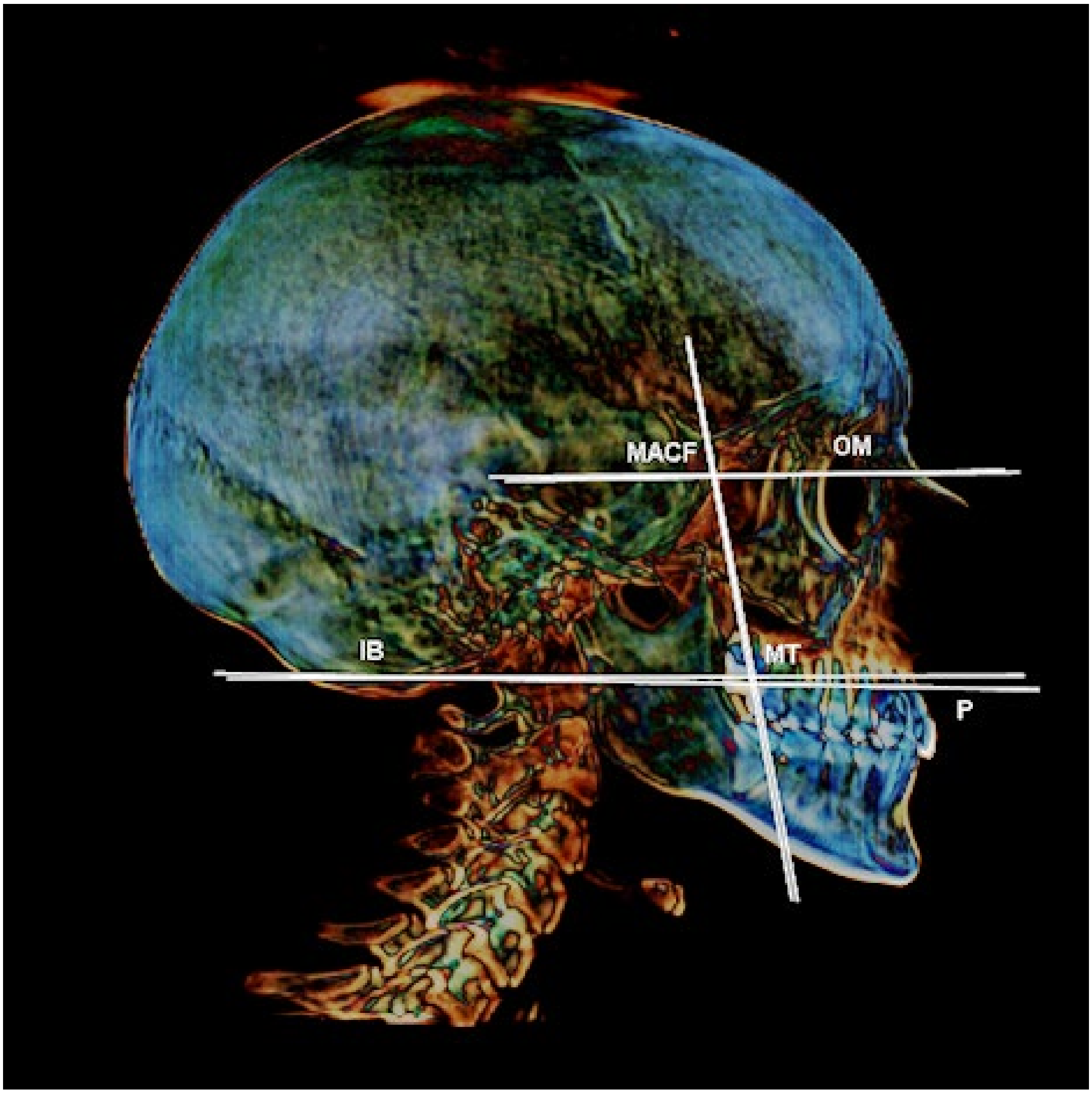

Figure 2

Younger and older conebeam CT scans superimposed according to the method described by Enlow [31], which describes what surfaces were forming and resorbing during growth (see Fig. 1 for key to labels). The inferiorward relocation of the blue-green-colored subnasal region indicates that the teeth and bone were relocated with a descending alveolus. The difference in height is indicated by the decent of the upper central incisor in white, and white along the intercuspal row of teeth. This was accompanied by an uprighting of the roots of the maxillary dentition, wherein before treatment is indicated by roots shaded in yellow. The maxillary unerupted third molar also rotated into its correct occluso-cervical orientation just behind MT point.