ORIGINAL ARTICLE

Mandibular arch form: The relationship between dental and basal anatomy

Valerie Ronay,[a] R. Matthew Miner,[b] Leslie A. Will,[c] and Kazuhito Arai[d]
Vienna, Austria, Boston, Mass, and Tokyo, Japan

Introduction: We investigated mandibular dental arch form at the levels of both the clinically relevant application points of the orthodontic bracket and the underlying anatomic structure of the apical base. The correlation of both forms was evaluated and examined to determine whether the basal arch could be used to derive a standardized clinical arch form. **Methods:** Thirty-five mandibular dental casts (skeletal and dental Class I) were laser scanned, and a 3-dimensional virtual model was created. Two reference points (FA, the most prominent part of the central lobe on each crown's facial surface, and WALA, a point at the height of the mucogingival junction) were selected for each tooth from the right to the left first molars. The FA and WALA arch forms were compared, and the distances between corresponding points and intercanine and intermolar widths were analyzed. **Results:** Both arch forms were highly individual and the tooth values scattered. Nevertheless, a highly significant relationship between the FA and WALA curves was found, especially in the canine (0.75) and molar (0.87) areas. **Conclusions:** Both FA and WALA point-derived arch forms were individual and therefore could not be defined by a generalized shape. WALA points proved to be a useful representation of the apical base and helpful in the predetermination of an individualized dental arch form. (Am J Orthod Dentofacial Orthop 2008;134:430-8)

The size and shape of the dental arches have considerable implications for orthodontic diagnosis and treatment planning. These factors have an effect on space available, stability of the dentition, and dental esthetics. Furthermore, the definition of arch form would improve the understanding of malocclusion and assist clinicians in producing orthodontic results that are consistent with the natural laws of biologic variation. Although most arch form studies have looked at similar patient samples—subjects with orthodontically untreated ideal occlusions—few come even close to agreement about the natural shape of the dental arch. It is commonly believed that the dental arch form is initially shaped by the configuration of its supporting bone.[1] Nevertheless, 2 opposing theories about modifying the dental arch form have coexisted for 100 years.[2,3]

The bone-growing theory is that the supporting bone grows in response to normal stimulation, such as mastication, if the teeth are aligned in the ideal position. Angle[4] reported stable orthodontic treatment results of his expanded crowding patients and first advocated the bone-growing theory. In the latter part of the 19th century a basic biologic principle was introduced called Wolff's law in which the bone structure changes in response to external force. According to this theory, tooth size is controlled by heredity, but size and shape of the supporting bones depend largely on environmental stimuli including eruption of the teeth, pressure from tongue and cheek, and mastication. For example, a small mandible can result from the lack of healthy jaw function and indicates degeneration.[5] This approach resulted in fewer extractions and is often called the nonextraction theory.

According to the "apical base" theory, the size and shape of the supporting bone are largely under genetic control, and there is a limit to expansion of a dental arch. In 1925, Lundström[6] proposed a new term—apical base—to describe the limits of expansion of the dental arch and wrote extensively on this topic. He stated that the apical base (1) is not changed after loss of teeth, (2) is not influenced by orthodontic tooth movement or masticatory function, and (3) limits the size of dental arch. If the teeth are orthodontically moved beyond this limit, labial or buccal tipping of the teeth,[6] periodontal problems,[7] or an unstable treatment result[8] could be expected.[2] One of Angle's students, Tweed,[9] also observed unstable results after nonextraction treatment with Angle's mechanics

[a]Student, Clinic of Dentistry, Vienna University, Vienna, Austria.
[b]Assistant clinical professor, Department of Developmental Biology, Harvard School of Dental Medicine, Boston, Mass.
[c]Professor and graduate program director, Department of Orthodontics, Tufts University School of Dental Medicine, Boston, Mass.
[d]Assistant professor, Department of Orthodontics, Nippon Dental University, Tokyo, Japan; visiting professor, Department of Developmental Biology, Harvard School of Dental Medicine, Boston, Mass.
Reprint requests to: R. Matthew Miner, One Lyons St, Dedham, MA 02026; e-mail, r_miner@hsdm.harvard.edu.
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during the 1930s. He established his diagnostic analysis in favor of extraction and refined the mechanics for extraction treatment. Simultaneously, another Angle student, Begg,[10] also changed to the extraction technique and sought anthropologic evidence for extraction treatment because of less mastication required in modern diets. Since then, this theory was confirmed by case reports, and most orthodontists are now convinced of the validity of this theory.[11,12] However, an objective limit for buccal or labial tooth movement in any patient, especially those with mild crowding, is still not available today.[2]

As the frequency of extraction orthodontic treatment has decreased over the last 30 years, a new bone-growing theory has emerged. Esthetic preference for fuller profiles, temporomandibular disorder problems,[2] and the emergence of functional appliance therapy[13] were contributing factors, but, most significantly, it was found that extraction did not insure stability.[14] With stability not guaranteed, extraction treatment lost much of its perceived advantage. Recently, the clinical results of a new orthodontic appliance were reported.[15] Its developer claimed that buccal tooth movements without tipping could be achieved with his biocompatible appliance with extremely light forces. Computed tomography images of expanded teeth from severely crowded dental arches were shown, and apparently healthy alveolar bone was demonstrated as evidence for this bone-growing theory. Most clinicians, however, still explain to their patients that there might be a limit for expansion of the dental arch with any appliance. Furthermore, we still do not know exactly the limit for each patient.

The purpose of this study was to investigate the relationship between the dental arch form and the supporting bone. We hypothesized that there is a quantifiable relationship between basal and dental arch forms, and that basal-bone landmarks can be used as reliable references for determining biologic arch form in clinical orthodontics.

MATERIAL AND METHODS

The mandibular dental casts of 35 patients (13 male, 22 female) were randomly selected from a sample of 750. The mandible was studied because therapeutic possibilities are more limited than in the maxilla, and the maxillary arch form is strongly associated with the mandibular form.[2,16] The subjects' pretreatment casts were identified as skeletal Class I (ANB angle, 0°-4°) and dental Class I (canine and molar relationship according to Angle classification) with fully developed permanent dentitions from first molar to first molar. The second molars were excluded from analysis because the age of most patients precluded ascertainment of complete eruption of this tooth. The patients had only minimal restorations with no prosthetic crowns and were excluded if they had occlusal wear or gingival defects, or if the mucogingival junction was not identifiable on the model. Mild crowding or spacing (<2 mm) was acceptable, but no subjects requiring extractions for arch-length deficiency were included in the sample. The average age of these patients was 17 years 11 months.

The dental casts were laser scanned with a computer-assisted noncontact high-definition 3-dimensional (3D) scanning system. This system consisted of a laser-scanning unit (Dental Plaster Model Shape Scanning System,[17] Surflacer model VMS-100F, UNISN, Osaka, Japan), a computer-aided-design software program (Dent-Merge, version 5.0; UNISN), and dental cast analyzing software (Surfacer, version 9.0, Imageware, Ann Arbor, Mich). This setup was used for image production and refinement, and landmark identification. A detailed description of the performance characteristics, including measurement accuracy of this data-recording system, was reported elsewhere.[18] The measuring device of the laser-scanning unit consisted of a slit-ray laser projector and 2 sets of charged-coupled device video cameras to capture the reflected images. X, y, and z coordinate data and data to measure the circumference of the object was produced as a result. The scanner was connected to the computer for image processing. The dental casts were projected and scanned by a revolving polygon mirror with a slit-ray laser beam of 670 nm wavelength at 3 mW output. Triangulation was used to determine the location of each point with a measurement error of less than 0.05 mm.The generation of 3D graphics of each dental cast took approximately 80 minutes. About 90,000 sets of coordinates (x, y, z) per model were stored in the computer.

Each mandibular dental cast was scanned at 3 angles in the frontal and sagittal planes (Fig 1, *a*). The image processor converted the raster coordinates and brightness data of the analog video signals' input from the video cameras into digital data. The computer imported the digital data and converted the picture coordinates to 3D spatial coordinates. The data was synthesized, manually corrected for scanning errors, and merged into a single data set for each model with the Dent-Merge software. With cast analyzing software, a 3D model of the entire mandibular dentition and its adjacent structures was constructed (Fig 1, *b* and *c*).

By using the cast analyzing software, 2 reference points (1 on the crown, and 1 at the mucogingival junction) were selected for each tooth from the right to the left first molar for a total of 24 points for each model.

The FA point is defined as the midpoint of the facial

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