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COMPARISON BETWEEN DENTAL AND BASAL ARCH FORMS IN SUBJECTS WITH DIFFERENT VERTICAL SKELETAL PATTERNS USING CONE BEAM COMPUTED TOMOGRAPHY: A RETROSPECTIVE STUDY

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ABSTRACT

Introduction: This research investigates the important relationship between the dental arch and basal bone in the orthodontic treatment planning process, aiming to evaluate how these arches interact in persons with varying vertical skeletal configurations through the use of Cone Beam Computed Tomography (CBCT). **Aim:** The primary objective is to analyze the association between dental and basal arch shapes in individuals characterized by various vertical skeletal patterns, employing CBCT technology. **Methodology:** 70 CBCT images was retrieved from the Oral Radiology Department's archives at the Faculty of Dentistry, University of Suez Canal. These images were categorized into three distinct groups based on their SN-MP and gonial angles. The study measured four linear dimensions and two arch form ratios. Group comparisons were conducted employing the One-way ANOVA test, with further validation through Tukey's post hoc analysis. Additionally, the Pearson correlation coefficient was utilized to explore the relationship between dental and basal arch dimensions within each group. **Results:** The analysis revealed no notable differences in arch dimensions across the three studied groups, with the exception of the dental intermolar depth between the normodivergent and hypodivergent categories. In the normodivergent group, a strong correlation was identified between the dental and basal inter-canine and inter-molar widths, unlike the moderate or absent correlations observed in the hyperdivergent and hypodivergent groups. **Conclusion:** This investigation underscores a significant positive association between dental and basal arches in normodivergent individuals, in contrast to the moderate or nonexistent correlations in hyperdivergent and hypodivergent subjects. This result may assist clinicians in tailoring treatments for patients with normal, elevated, or reduced skeletal angles.

INTRODUCTION

Diagnosis and treatment plans for orthodontics are significantly impacted by the interaction between dental and basal forms. Periodontal complications and relapse may happen when teeth are moved more than the basal bone can hold them [(1)].

The interaction of the circumoral musculature with the alveolar bone beneath the teeth determines the shape of the dental arch in humans. The skeleton shape of individuals, surrounding soft tissues structures, and environmental variables all affect how their dental arch will look[(2)]. Traditionally, the evaluation of basal bone has relied on the analysis of plaster casts, employing techniques such as identifying the root's apical third or determining a specific measurement from the gingival margin to the mucogingival junction [(3)].

However, due to their precision, virtual models are now thought to be a workable substitute for plaster models as they have the advantage of measuring tooth size-arch length discrepancy accurately, quickly, and easily, and because virtual images can be sent to any location in the world for prompt consultation or referral. [4].

By emerging cone beam computed tomography (CBCT) and due to its potential for more sophisticated diagnoses and 3D treatment planning, CBCT has been a fast-developing imaging modality in orthodontics. New landmarks were developed using developing CBCT to investigate basal bone and dental arch variables through images[5,6].

Therefore, the purpose of this research was to examine the correlation between dental and basal arch shapes across patients with various vertical skeletal configurations utilizing CBCT.

MATERIALS AND METHODS

I.1 Study design

This investigation constituted a retrospective cross-sectional analysis aimed at contrasting the dental and basal arch shapes among individuals exhibiting diverse vertical skeletal profiles (Normodivergent, Hypodivergent, and Hyperdivergent growth patterns). It was executed at the Faculty of Dentistry, Suez Canal University, following the Ethical Research Committee's sanction of the study protocol on September 6, 2022, under the reference number 533/2022.

I.2 Sample Size Calculation

According to analyses of a previous research, a sample size calculation was undertaken via G*power48 (version 3.1.9.2, Franze Faul, Kiel University, Germany). The statistical software was based on the pre-established parameters[7].

A minimum total sample size of 63 samples were sufficient at power (1-β=0.80) of 80% at a significance probability level of $p<0.05$. The actual sample size attained has been augmented by around 10% to assure that could make up for any missing data and margin of error. A total sample size of 70 samples were selected for the study.

I.3 Sample Characteristics

The criteria for inclusion were specified as follows: (1) Individuals aged between 18 and 28 years; (2) Presence of a complete set of permanent teeth (excluding third molars); (3) Skeletal Class I with ANB angle ranging from 1° to 5°; (4) No history of orthodontic treatment. On the other hand, the exclusion criteria included: (1) Any dental restoration affecting the dimensions, shape, or position of the teeth's clinical crowns; (2) Presence of prosthetic crowns or periodontal conditions; (3) Discrepancies in tooth size or arch length resulting in over 3 mm of crowding or spacing; (4) Facial asymmetry associated with a crossbite.

I.4 Sample grouping

In accordance with their vertical skeletal pattern, the CBCT scans were grouped into 3 groups. Vertical skeletal pattern classification was performed using SN – MP angle and gonial angle according to Sassouni's criterion [8].

Group I: Normodivergent (26 subjects)

SN – MP (32° ±4); Gonial angle (124° ±5)

Group II: Hyperdivergent (22 subjects)

SN – MP (> 37 °); Gonial angle is (> 129 °)

Group III: Hypodivergent (22 subjects)

SN – MP (< 27°); Gonial angle is (> 119 °)

II. CBCT

The study utilized high-definition; full-cranium Cone Beam Computed Tomography (CBCT) scans obtained with the SCANORA 3DX system (SOREDEX, Finland). The scanning parameters were established at 120 kV, 47 mA, with a duration of 23 seconds per cycle, covering a field of view measuring 240 × 165 mm. This configuration yielded a voxel resolution of 0.4 mm. Participants were imaged in centric occlusion, ensuring the Frankfort horizontal plane was aligned parallel to the floor.

Subsequently, the CBCT images were converted to the Digital Imaging and Communications in Medicine (DICOM) format for multi-file handling and then uploaded into the OnDemand 3D software (Cybermed Inc, Korea) for three-dimensional volume rendering.

III. Investigation and measurements

The CBCT images were imported into OnDemand 3D software for analysis. A single operator conducted all the measurements for consistency. The reorientation process began by setting the intersection of the lower central incisors as the origin for the X, Y, and Z coordinates. Subsequently, the images were adjusted such that the Y axis aligned with the lower central incisors in the midsagittal plane on the coronal view, the X axis was aligned with the functional occlusal plane on the axial view, and the Z axis was established perpendicular to the X and Y axes in the coronal plane.

To delineate the dental and basal arch forms in each scan, specific anatomical landmarks were employed: facial axis (FA) points for the dental arch and root center (RC) points for the basal arch, marked from the left to the right second molar as illustrated in Figure 1.

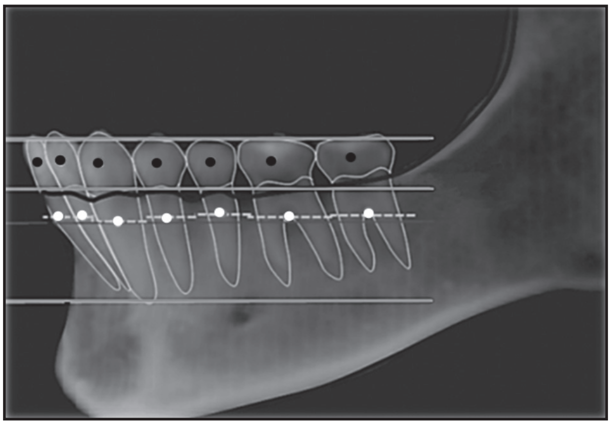

Fig. (1) Illustration of FA points (black points) & RC points (white points).

For Assessment of dental arch, an axial slice for each scan of Mandibular teeth at the level of the **FA** points (a point located on the facial axis of the anatomical crown that divides the gingival and occlusal halves of a tooth) was acquired and the following measurements were obtained (Tab. 1 & Fig. 2.A).

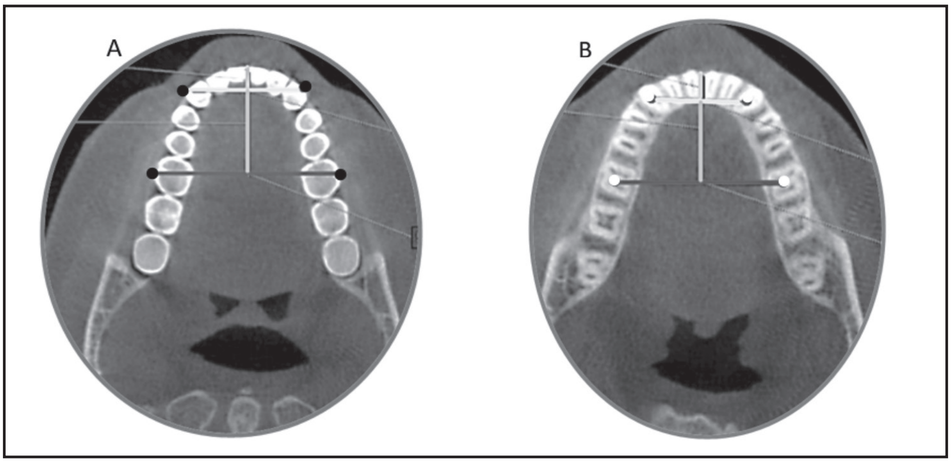

Fig. (2) (A&B) Measurements of arch parameters. A: dental arch B: basal arch

Table (1) *Definition of arch parameters*

Parameter	Definition
Dental inter-canine width	The distance between the left and right mandibular canines' FA points
Dental inter-molar width	The distance between the left and right mandibular 1st molars' FA points
Dental inter-canine depth	The shortest distance from the origin to a line joining the right and left mandibular canines' FA points
Dental inter-molar depth	The shortest distance from the origin to a line joining the right and left mandibular 1st molars' FA points
Dental inter-canine width/ depth ratio	Ratio between dental inter-canine width and depth
Dental inter-molar width/ depth ratio	Ratio between dental inter-molar width and depth
Basal inter-canine width	The distance between the left and right mandibular canines' RC points
Basal inter-molar width	The distance between the left and right mandibular 1st molars' RC points
Basal inter-canine depth	The shortest distance from a line joining the left and right mandibular canines' RC points to the midway point between the left and right mandibular central incisors' RC points
Basal inter-molar depth	The shortest distance from a line joining the left and right mandibular 1st molars' RC points to the midway point between the left and right mandibular central incisors' RC points
Basal inter-canine width/ depth ratio	Ratio between basal inter-canine width and depth
Basal inter-molar width/ depth ratio	Ratio between basal inter-molar width and depth

FA, *Facial axis;* **RC**, *Root center.*

For Assessment of basal arch, an axial slice for each scan of Mandibular teeth at the level of the **RC** points (a point positioned at the intersection of the coronal one-third and apical two-thirds of the root) was acquired and the following measurements were obtained (Tab. 1 & Fig. 2.B).

IV. Statistical analysis

Data was gathered, verified, revised, and arranged in tables and figures using Microsoft Excel 2019. Data were examined using Kolmogorov-Smirnov test to ensure normality. Data analyses were carried out using statistical package for social science (IBM-SPSS ver. 29.0) software. One way ANOVA (analysis of variances) test was done and confirmed by post hoc Tukey multiple comparison test. The Pearson correlation coefficient was used to evaluate the associations among each group's basal and dental indices. All tests were carried at 95% level of confidence with the probability ($P < 0.05$).

RESULTS

Upon comparison, no notable variances were detected in the transverse arch measurements among the three groups. (Tab. 2).

When evaluating antero-posterior arch dimensions among the three groups, no substantial disparities were noted, with the exception of the dental intermolar depth (DIMD) between Group I and Group III (Tab. 3).

Table (2) *Comparison between Transverse arch parameters between the three groups using one-way ANOVA confirmed by post hoc Tukey test.*

Parameters	G I (n=26)	G II (n=22)	G III (n=22)	ANOVA P-value	Tukey P-value		
	Mean ± SD	Mean ± SD	Mean ± SD		G I vs G II	G I vs G III	G II vs G III
DICW	31.19 ± 1.61	31.12 ± 1.92	29.75 ± 2.61	0.102 ns	0.955 ns	0.138 ns	0.165 ns
DIMW	52.44 ± 3.19	52.01 ± 2.24	52.79 ± 3.41	0.762 ns	0.913 ns	0.941 ns	0.742 ns
BICW	23.49 ± 1.22	23.60 ± 1.71	24.74 ± 2.66	0.148 ns	0.987 ns	0.180 ns	0.236 ns
BIMW	45.74 ± 2.43	44.62 ± 1.49	46.11 ± 3.35	0.237 ns	0.434 ns	0.912 ns	0.234 ns

G I: *Normo-divergent* **G II:** *Hyperdivergent* **G III:** *Hypodivergent* **D:** *dental* **B:** *basal*
IC: *intercanine* **IM:** *intermolar* **W:** *width* **ns:** *no significant differences* **P**<0.05

Table (3) *Comparison between anteroposterior arch parameters between the three groups using one-way Anova confirmed by post hoc Tukey test.*

Parameters	G I (n=26)	G II (n=22)	G III (n=22)	ANOVA P-value	Tukey P-value		
	Mean ± SD	Mean ± SD	Mean ± SD		G I vs G II	G I vs G III	G II vs G III
DICDep	5.59 ± 1.21	5.53 ± 1.30	5.26 ± 1.15	0.730 ns	0.989 ns	0.735 ns	0.818 ns
DIMDep	27.70 ± 2.19	27.41 ± 1.37	25.78 ± 2.23	0.018	0.915 ns	0.023	0.061 ns
BICDep	5.58 ± 0.83	5.16 ± 0.82	5.57 ± 1.16	0.377 ns	0.436 ns	0.999 ns	0.458 ns
BIMDep	26.26 ± 1.65	25.06 ± 1.81	25.84 ± 3.21	0. 371 ns	0.320 ns	0.865 ns	0.818 ns

G I: *Normo-divergent* **G II:** *Hyperdivergent* **G III:** *Hypodivergent* **D:** *dental* **B:** *basal*
IC: *intercanine* **IM:** *intermolar* **W:** *width* **Dep:** *depth* **ns:** *no significant differences* **P**<0.05
SD: *standard deviation*

The relationship between the widths of dental and basal inter-canine and inter-molar dimensions was analyzed separately for each of the three groups using the Pearson correlation coefficient (Table 4). In Group I (normodivergent subjects), a significant positive correlation was observed for both inter-canine and inter-molar widths; Group II (hyperdivergent subjects) exhibited a moderate positive correlation for these measurements; and Group III (hypodivergent subjects) demonstrated a moderate positive correlation in inter-molar widths, whereas the inter-canine widths did not present a significant correlation.

Table (4) *Correlation between mandibular dental and basal inter-canine and inter-molar widths*

	Group I		Group II		Group III	
	r	p	r	p	r	p
DICW & BICW	0.82^{s}	<0.01	0.45^{s}	0.024	0.005	0.987
DIMW & BIMW	0.88^{s}	<0.01	0.47^{s}	0.014	0.41^{s}	0.023

Group I: *Normo-divergent* **Group II:** *Hyperdivergent* **Group III**: *Hypodivergent* **D:** *dental*
B: *basal* **IC:** *intercanine* **IM:** *intermolar* **W:** *width* **r:** *coefficient of correlation*
p: *probability* ^{s}**:** *Significant*

DISCUSSION

Understanding the link between the teeth and the underlying investing structure as basal and alveolar bone is important for orthodontic diagnosis and therapeutic purposes since dental arch expansion is limited. Since the non-extraction approach reappeared and gained popularity, a variety of methods have been used to better comprehend and measure the link between teeth and their underlying bone.

The mandible was selected in the current study because treatment options are fewer than in the maxilla. When it comes to the mandibular arch, the expansion effects are typically restricted to the alveolar bone and mostly result in tooth inclinations. In contrast, the maxillary expansion is more efficient as the maxilla consists of two halves separated by a suture that can be separated and expand the width of the maxillary arch[9].

Patients selected for this study aged 18 – 28 years to ensure that the growth of the mandible has been almost completed as any residual growth may cause discrepancies in the arch parameters between the subjects. Also, the second mandibular permanent molars were fully erupted and completely developed, meaning that the full height of the clinical crown can be easily recorded.

Gender separation was not addressed in this study because earlier studies[10] found that the arch indexes for males and females showed no difference. The sample characterization for this study excluded any subjects with dental restorations to avoid any alteration of size, form, and position of the clinical crown's midpoint to ensure a correctly selected facial axis (FA) point.

Also, to be ensured that there were no discrepancies in the height of plotted centre of resistance of every tooth, all patients showed no signs of bone loss or periodontal disease, with no history of previous treatment for either condition [11]. Unification of the ANB angle in all subjects to accurately determine the link between dental and basal arches was considered to exclude any dental compensation as possible due to sagittal discrepancy in the mandible.

For the evaluation of the basal arch in CBCT scans, the root center (RC) point was established. This RC point, akin to the WALA point, is located within the basal structure, mirroring the resistance center of each tooth. Thus, employing the RC point as a reference on a virtual model instead of WALA points could yield a more precise depiction of the arch's basal configuration. In addition, using root apex as an anatomical landmark to assess the basal configuration of the teeth may be undependable because of the presence of considerable degree of variation in the location, shape and curvature of the root apex and difficulty to be localized in multirooted teeth[5]. However, the positioning of the basal arch near the teeth increases its clinical value when compared to the anatomic basal bones.

The results indicated that there were no notable statistical variances between the three groups, with the sole exception being the dental intermolar depth (DIMDep) between Group I (normodivergent) and Group III (hypodivergent).

Conversely, **Forster and colleagues**[12] conducted an analysis on the dental arch and its association with vertical facial morphology, utilizing 185 dental models. Their findings revealed that, for most of the metrics assessed, the low angle group demonstrated broader arch widths compared to the high angle group. While in another study, Grippaudo et al[13] investigated dental arch variables on 73 virtual 3D models in skeletal class II patients and reported that low angle subjects had a greater intercanine diameter than groups with medium and high angle.

It seems that this contradictory of the results may be due to the vertical direction of growth is not the only one of the contributing factors or may be due to the difference in the sample size or the methodology of the research. In Group I (normodivergent), there was a significant positive correlation observed between the widths of dental and basal inter-canine and inter-molar, suggesting a closer relationship between the dental arch and the basal bone. This result corroborates the 'apical base' theory[14], positing that the bone structure underlying the dental arch primarily dictates its initial shape, thereby constraining the expansion possibilities of the dental arch.

While in group II (hyperdivergent) and group III (hypodivergent) moderate positive or no correlations indicate that there are differences in teeth inclination to their relative basal bone. According to several authors[15–18], higher vertically dimensioned individuals tend to possess posterior teeth that are more buccally inclined. On the other hand, those with lower vertical dimensions tend to possess more lingually inclined posterior teeth.

Grasping the dimensions, contours, and interactions between dental and basal arches could assist orthodontists in accurately aligning patients' teeth throughout the treatment process and maintaining their arch configurations, leading to outcomes that are both more stable and foreseeable.

CONCLUSION

The findings from this research are outlined as follows:

1. There were no notable disparities in the measurements of arches between the three groups, with the exception of the dental intermolar depth (DIMDep) between normodivergent and hypodivergent participants.
2. In normodivergent individuals, a significant positive correlation was established between the dental and basal arches, whereas in hyperdivergent and hypodivergent individuals, the correlation was either moderate or non-existent.
3. The insights gained from this research regarding the connection between dental structures and the underlying basal bone can guide clinicians in the treatment of patients with various skeletal vertical discrepancies.

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