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Original Research

Relationship between Dental Arch Parameters and Mandibular Plane Angle

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ABSTRACT:
Aim: To evaluate the relationship between dental arch parameters of arch forms, widths, crowding, overjet, overbite, the curve of Spee, Bolton analysis, and the vertical facial pattern determined by the steepness of the FMA. **Materials and Methods**: In this cross sectional study, 165 adults diagnostics records (casts and cephalometric radiographs) were included. The anteroposterior relationshipwasclassified according to the ANB cephalometric readings into Class I (0-4°) , II (>4°), III (<0°). The vertical relationship of the subjects was selected to have similar numbers of each mandibular plane angle (FMA) category of low angle (<25°), average (25°– 30°), high angle (>30°). All the dental cast measurements were performed using a digital caliper accurate to 0.1 mm. Arch form measurement was done using Orthoform^{TM} templates according to the best fit method. Intercanine widths and intermolar width were obtained using the digital caliber.Tooth size-arch length discrepancy was assessed with Nance Analysis. Bolton analysis was used to find tooth size ratio calculation. Overjet, overbite, and curve of Spee measurement were done. Eachdental parameter was assessed in relation to the AP and vertical skeletal parameters. **Results:** Of the 165 samples, 58.8% (n=97) were females and 41.2% (n=68) were males.The distribution of low angle (<25°), average (25°-30°), and high angle (>30°) of FMA was 36.4% (n=60), 32.1% (n=53), and 31.5% (n=52), respectively. The distribution of class I (1-5), class II (>5), and class III (<1) of ANB was 54.5% (n=90), 27.9% (n=46), and 17.6% (n=29), respectively.The FMA and arch form showeda statistically significant association in the maxillary arch form only. Inter-molar widths of the maxilla were highest in low angle, followed by average, and least in high angle. In the mandible, the difference between inter-molar and inter-canine widths was highest in average, followed by high angle, and least in low angle. However, both associations were statistically not significant.Finally, there was a statistically significant difference between overbite and FMA or ANB; and between overjet and ANB. **Conclusion:** Among the parameters co-related, the significance was seen betweenANB and overjet or overbite.However, FMA showed significant with maxillary arch form and overbite.

Keywords: Dental arch, overbite, cross sectional sturdy, male, female, maxilla, mandible.

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BACKGROUND

Orthodontic diagnostics form the cornerstone of orthodontic treatment.The term diagnosis is defined as the identification of a disease by careful investigation of its symptoms and history. Malocclusions are the “disease” processes of orthodontics and the central focus of orthodontic diagnoses (Nanda, 2015).A correct diagnosis of malocclusion with related dento-skeletal aspects will help achieve the best and most stable outcomes of orthodontic therapy(Peck, 2017).Evaluating the need for the extraction, stability, retention, and various aspects of the phases of orthodontic treatment aredependentupon the utilization of diagnostic toolsinitially with necessary aids. Conscientious clinicians should try to develop individualized treatment plans with the data availablein planningthe ideal treatment (Manosudprasit et al., 2017; Peck, 2017).Pre-treatment diagnostic records including dental casts, cephalometric and panoramic radiographs of subjects are considered routine practice for orthodontic treatment planning. A skillful orthodontist can extract a multitude of attributesfrom these diagnostic tools. Using these diagnostic records will help in the assessment of the growth and development of the face and related anatomical features (Manosudprasit et al., 2017).

Cephalometric radiograph is a radiograph of the head taken with the x-ray beam perpendicular to the patient's sagittal plane. Itwas introduced in 1931 by Broadbent and Hofrath (Jacobson, 2006). Since then it has has become an essential tool in orthodontic diagnosis and assessment of skeletal problems in a simple and accurate method.Facial growth and development areof great concern to orthodontists. The amount and direction of growth will significantly affect the orthodontic treatment plan and biomechanics(Carlson, 2015). With the introduction of cephalometricradiographicy, the interest in the study of facial patterns advanced. Moreover, facial types can be studied with an emphasis on their association with malocclusions and skeletal relationships(Mangla et al., 2011).

A thorough knowledge of craniofacial growth and development is essential to an orthodontist and can be monitored and assessed with cephalometry. Major growth sites in craniofacial skeleton are sphenooccipital synchondrosis for cranial base, nasal septal cartilage for nasomaxillary complex, and the condylar cartilage for mandible (Suryawanshi et al., 2017). Among these sites the condylar cartilage acts as the greatest growth center in the craniofacial complex. Growth of the mandibular condyle leads to transposition of the mandible as well as it contributes to increase in mandible size. The maxilla becomes larger due to bone opposition at the sutures, whereas entire anterior surface of maxilla is an area of resorption.The position of point A in relation to reference plane of skull base is commonly used to assess the degree of maxillary prognathism.The maxilla grows forward and downward in two ways i.e. growth at the sutures and by a push from behind which is created by cranial base growth with mandibular point B used to assess mandibular position(Suryawanshi et al., 2017).The divergence between maxillary point A and mandibular point B with the cranial base or other structures establishes the anteroposterior (AP) relationship.

Facial vertical growth patterns play a vital role in achieving facial balance(Ahmed et al., 2016). Variations in vertical growth are common and haveorthodontic implications. A long or a short face may be due to an abnormal proportion of the hard or soft tissues that form the face. Growth excess in the vertical dimension may result inassociated oralchanges such asalterations in the gingival smile, incompetent lips, and a long face(Vaden and Pearson, 2002). On the other hand, a deficiency in vertical growth may lead to an inadequate display of incisors, overclosure of lips, and a short face(Obwegeser, 2007).Both facial types are considered not pleasing aesthetically andneed to be treated with the help of appropriate orthodontic tools. A thorough assessment and an accurate diagnostic evaluation of such discrepancies in the vertical facial pattern merittreatment success(Thiesen et al., 2015).

Using cephalometric points and subsequent measurements, verticalskeletal growth can be assessed. Various authors have proposed innumerable linear and angular analyses using different reference points to assess skeletal growth(Yu et al., 2020). Commonly used angular analyses include landmarks and angles such as Sella-Nasion to Gonion-Gnathion plane angle (SN.GoGn), Sella-Nasion to Mandibular Plane (SN.MP), Frankfurt to Mandibular plane Angle (FMA), Maxillary/Mandibular plane Angle (MMA), and the Y-axis (Ahmed et al., 2016).Historically, Downs in 1952 used the Frankfort horizontal (FH) plane as the reference line on lateral cephalograms to assess the mandibular diversion pattern through Y-axis and the Frankfort mandibular plane angle (FMA)(Downs, 1952).Steiner in 1953 postulated Sella-Nasion to mandibular plane angle (SN-MP) to assess vertical growth pattern using the anterior cranial base as the reference plane(Steiner, 1953). Schwartz using the palatal plane, proposed the maxillary/mandibular planes angle (MMA) to assess the intermaxillary relationship in the vertical dimension(Schwartz, 1961). Jarabak's ratio and facial height ratio (LAFH.TAFH) arealso used to assess the facial vertical growth of an individual. Additional linear and angular parameters may be helpful to assess vertical facial growth(Owens et al., 2002). Although studies using theparameters mentioned showvarious shortcomings, these measurementsare often used alone or in combination. It is also to be noted that the cephalometric norms established by the previous studies may not serve adequately for other population groups, suggesting that cephalometric parameters may vary for different groups of individuals. (Al-Jasser, 2005). Although FMA and SN.MPare both valid measures for vertical evaluation, Tashkandi et al, found significant differences in their classification of divergency in a Saudi population with higher levels of hyperdivergency with SN.MP compared to FMA (Tashkandi et al, 2021).

The dental arch form is another important feature of the dentition and understanding its descriptive characteristics is essential for orthodontic treatment. Dental arches are dynamic and change due to treatment interventions as well as normal growth and development(Sangwan et al., 2011). Adequate knowledge of the factors affecting the shape and dimension of the dental arch helps plan the treatment of malocclusion to achieve more successful results concerning esthetics, function, and stability(Shahroudi and Etezadi, 2013). Several arch forms have been describedin the literature.Chuck in 1932 classified arch forms as tapered, square and ovoid, which create the basic arch forms (Chuck, 1932). Anotherclassification is the Ricketts pentamorphic arch forms which considered factors such as arch correlation, size, and length. They have been divided into narrow ovoid, ovoid, narrow tapered, tapered, and normal forms(Ricketts, 1979).The importance of dental arch form related to skeletal form is so prevalent that there are numerousreported studies in the literature from the 1970s to the present decade. However, still there is controversy due to variable results seen with reported studies(Alkadhi et al., 2018).

Other dental arch dimensions of special interest to dentists and orthodontistsarechanges in the arch width, length, and height.Thus, an understanding of dental arch dimensions is crucial. Dental arches have been investigated using different measurements and reference points, including but not limited to, inter-canine, inter-premolar, and intermolar widths, either between cusps or fossae, anterior palatal and mandibular lengths, molar vertical distance, total palatal, and mandibular lengths, and palatal depth(Ling and Wong, 2009).Anterior teethcrowding, the curve of Spee, and tooth size-arch discrepancy are other dental factors thatimpacted by the skeletal form(Kato and Arai, 2021; Ronay et al., 2008).

Overjet is defined as horizontal overlap of the incisors. Normally the incisors are in contact, with the upper incisors ahead of the lower by only the thickness of their incisal edges (i.e., overjet of 2 to 3 mm is the normal relationship). If the lower incisors are in front of the upper incisors, the condition is called reverse overjet or anterior crossbite. Overbite is defined as the vertical overlap of the incisors. Normally, the lower incisal edges contact the lingual surface of the upper incisors at or above the cingulum (i.e., normally there is a 1- to 2-mm overbite). In open bite, there is no vertical overlap, and the vertical separation of the incisors is measured to quantify its severity(Proffit, 2018).Curve of Spee commonly refers to the arc of a curved plane that is tangent to the incisal edges and the buccal cusp tips of the mandibular dentition viewed in the sagittal plane.Bolton analysis was formulated to measure certain ratios of the dimensions of upper and lower teeth (anterior and overall) that must exist in harmony for proper interdigitations of upper and lower teeth. The devised ratio for the anterior segment was 77.2±0.22 and for the overall segment was 91.3±0.26 (Bolton, 1962).

AIMS AND OBJECTIVES

Althoughseveral studies have reported on dental and skeletal characteristics, therestill appears to be a research gap comparingall dentoskeletal characteristics of subjects compared to thevertical skeletal relationship.Thus, the present study aims toinvestigate the conclusive relationship between dental arch parameters of arch forms, widths, crowding, overjet, overbite, the curve of Spee, Bolton analysis,tothe vertical facial pattern determined by the steepness of the FMA. Why FMA chosen although it is difficutl to find compare to SN, unless many studies used it and it is for the purpose of comparison.

MATERIALS AND METHODS

ETHICAL APPROVAL

This study was approved by the ethical committee and permission was obtained to use the dental casts and the cephalometric radiographs by the Institutional Review Board (IRB) of Riyadh Elm University (REU). IRB number "FPGRP/2021/567/415/408".

STUDY DESIGN

This is a cross sectional study to assess the relationship between dental arch parameters and mandibular plane angle.Two hundred and fifty untreated adults were included in this study. Eighty five casts were excluded according to the exclusion criteria with a total of one hundred and sixty five included into the final analysis.Sample size was calculated using the G-Power sample power calculator 3.1.9.7 (Universitat- Kiel, Kiel, Germany). Using 5% as margin of error, 95% confidence interval, and power of 80%, a total sample size of 165 was determinedand were randomly selected from current orthodontic patients at the Department of Orthodontics at Riyadh Elm University, Riyadh, Saudi Arabia.

INCLUSION AND EXCLUSION CRITERIA

INCLUSION CRITERIA

- A full dentition except for 3rd molars.
- Pretreatment lateral cephalograms.
- High quality maxillary and mandibular dental casts (smooth, accurate, durable, symmetrical, pleasing to the eye, and remain in occlusion when placed on the distal corners, heels, and sides of the models).

EXCLUSION CRITERIA

- Previous orthodontic treatment.
- Edentulous spaces.
- History of trauma.
- Extensive restorations or prosthetics that do not resemple the original anatomy of the tooth.
- Anterior or posterior crossbites.
- Significant cuspal wear. (Score 2 or more according to Smith and Knight tooth wear index (Smith BG and Knight JK, 1984).
- Severe crowding (>9 mm) or spacing (>9 mm).

CEPHALOMETRIC MEASUREMENTS

ANB

The subjects were classified according to the cephalometric readings into Class I, II, III and using ANB (A point, nasion, B point) to determine anteroposterior relationship. The skeletal classification was defined by using the values of the sagittal intermaxillary angle (SNA – SNB = ANB), according to the cephalometric standard for skeletal type as recommended by Steiner (Steiner, 1953):

- ANB angle with values between 0 and 4 = Class I.

- ANB angle with values >4 = Class II.
- ANB angle with values <0 = Class III.

FMA

Vertical relationship was based on the mandibular plane angle (FMA) into low angle <25°, average 25°– 30°, high angle >30° . FMA was measured by the angular intersection of the Frankfort horizontal plane and the mandibular plane), (Tweed,1946).

Figure 6. Cephalometric tracing to determine the angle (ANB). (Falkine et al., 2014)

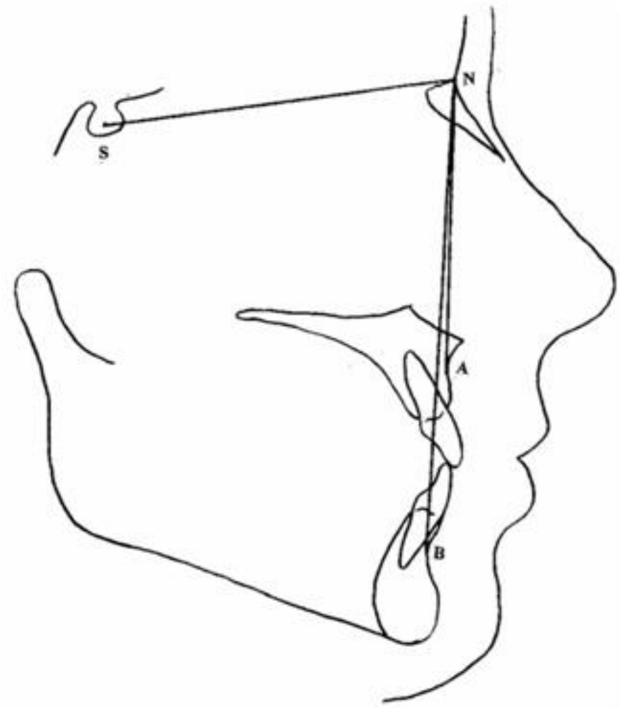
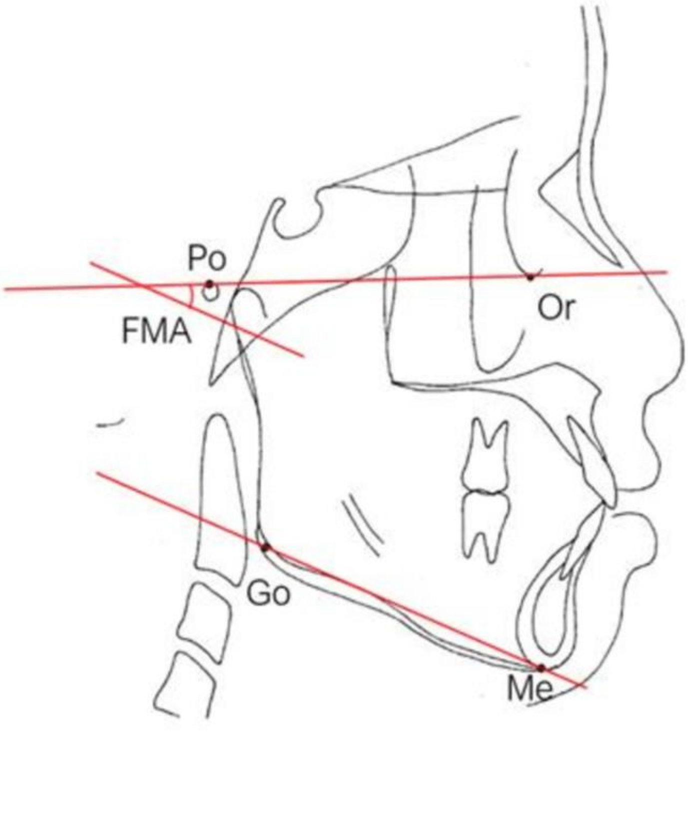


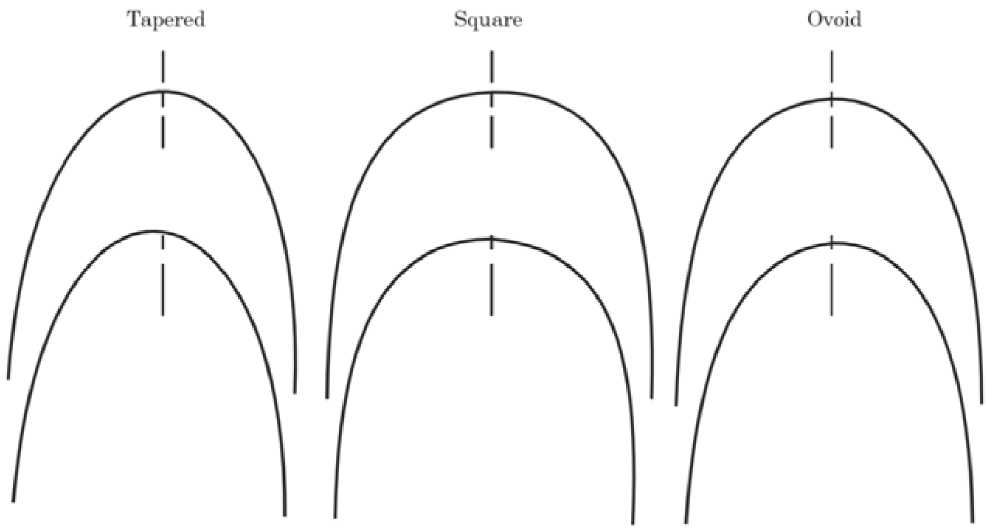
Figure 7. FMA tracing in the cephalometry (Falkine et al., 2014)



DENTAL CAST MEASUREMENTS
All the dental cast measurements were performed using a digital caliper from PRODENT USA accurate to 0.1 mm. The following maxillary and mandibular dimensions were measured.
Figure 8.PRODENT USA digital caliper

ARCH FORM
Arch form measurement was done using OrthoformTM templates by 3M Unitek. Intercanine widths from the cusp tips of left canine to the right canine and intermolar width from the mesiobuccal cusp tip of left first molar to the right first molar were obtained on each dental cast with the help of Boley gauge and then transferred to the photocopied images of the dental casts with the help of pencil dots.Three types of arch forms were established to categorize the sample; tapered, square and ovoid(Chuck,1932). For this purpose. The templates were overlaid on the orthodotic casts of the upper and lower arches being mindful of the midline and considering the pencil dots on the canines and molars. Arch forms were chosen according to the bestfit method (Mushtaq,2011).

Figure 9. Types of Arch Forms™ (Orthoform templates by 3M Unitek)



INTERCANINE AND INTERMOLAR WIDTHS WERE MEASURED TO DETERMINE ARCH WIDTHS

- The measurement was done using digital caliper between the below mentioned points:
- Intercanine distance is the distance between the canines' tips.
- Inter-first molar distance is the distance between the first molars central fossae (Moyers, 1988).

TOOTH SIZE-ARCH LENGTH DISCREPANCY SPACING OR CROWDING
Space analysis (Hays Nance analysis) reveals the relationship between tooth size and dental arch length for proper alignment of the teeth in the absence of irregularities or diastemas. This is a basic mathematical equation comparing the required and available space (Erdemir et al., 2016).
In each arch, the mesiodistal widths of each tooth mesial to the first permanent molar wassummed to determine the “space required”. To determine the “space available”, the actual arch length wasmeasured using a digital caliper. This wasaccomplished by measuring arch perimeter from the mesial of one first molar to the other over the contact points of posterior teeth and incisal edge of anteriors. This wasachieved by dividing the dental arch into segements that can be measured as straight

line approximations of the arch. The difference between the space available and the space required describes the space relationship. Depending on the obtained values the casts are divided into crowding or spacing (Proffit, 2018).

Figure 10. Nance Space Analysis
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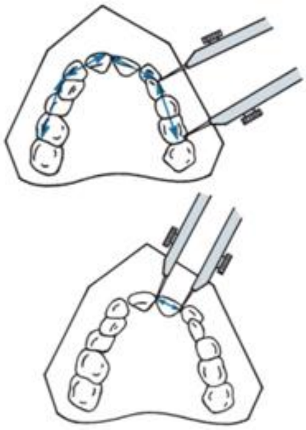


TOOTH SIZE RATIO CALCULATION: BOLTON ANALYSIS

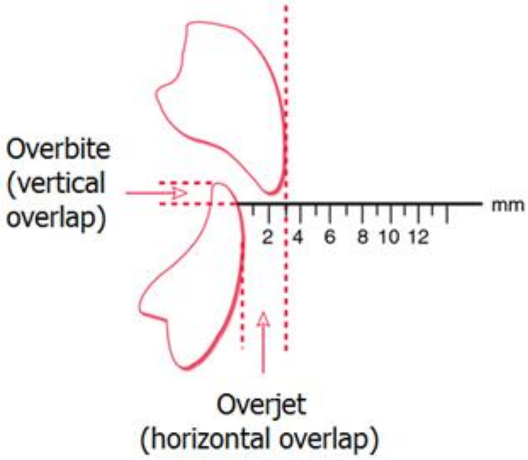
Bolton analysis determines the ratio of the mesiodistal widths of the maxillary teeth versus mandibular teeth. First, mesiodistal widths of the permanent teeth are measured and summed for calculation of the overall ratio using the following formula (Bolton, 1962; Erdemir et al., 2016). Overall ratio = (sum of mesiodistal widths of the 12 mandibular teeth/sum of mesiodistal widths of the 12 maxillary teeth) × 100. If this ratio is greater than 91.3 %, there is an excess of mandibular tooth material. If the ratio is smaller than 91.3 %, the excess is in the maxilla. The anterior ratio is also calculated using mesiodistal widths of the maxillary and mandibular incisors and canines by the same formula to reveal any discrepancy in the anterior region. If the ratio is greater than 77.2 %, the mandibular anterior teeth are relatively wide compared to the maxillary anterior teeth. If the ratio is smaller than 77.2 %, the maxillary anterior teeth are relatively wide (Bolton,1962).

OVERJET AND OVERBITE MEASUREMENT

Measurement of overjet and overbite was done using digital caliper.

- **Overjet:** is defined as horizontal overlap of the incisors. Normally the incisors are in contact, with the upper incisors ahead of the lower by only the thickness of their incisal edges. Normal 2-3 mm; decreased less than 2 mm; increased more than 3 mm. It was measured directly on the dental casts in contact.
- **Overbite:** is defined as the vertical overlap of the incisors. Normally, the lower incisal edges contact the lingual surface of the upper incisors at or above the cingulum. A mark was placed on the lowers where the upper covered then it was measured. Normal 10-20%, 1-2 mm; decreased less than 10%, <1 mm; increased more than 20%, 2 mm. It was measured directly on the dental casts in contact (Proffit, 2018).

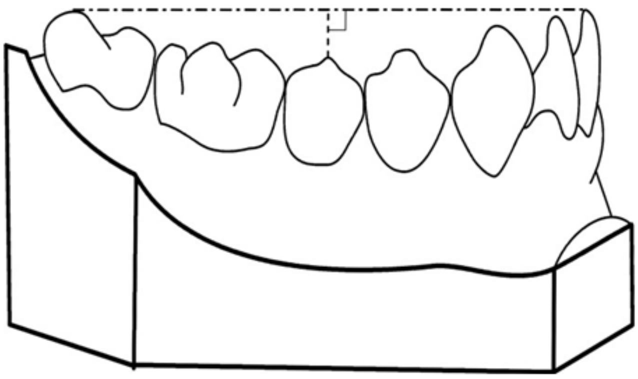
Figure 11. Overjet and Overbite measurement (thefreedictionary.com).



CURVE OF SPEE

This wasmeasured by the sum of the perpendicular distances from cusp tips of canines, premolars, and mesiobuccal cusp tip of the first molar to the occlusal plane (the line connecting distobuccal cusp of first molar and incisor) from the right side only. This was traced on the cast and categorized into normal up to 2mm and deep more than 2mm(Spee FG, 1980), (Shannon, 2004).

Figure 12: Curve of Speemeasurement (Marshall et al., 2008).



STATISTICAL ANALYSIS

Descriptive statistics including the Mean and SD were calculated for all measurements. Frequency and percentage was used for categorical variables. One-way Analysis of Variance (ANOVA) andPearson's correlation coefficient was used used to determine the relation between FMA and each dental arch parameter. Tukey post hoc tests were then performed to disclose the significant mean difference within the groups. All data were analyzed using SPSS version 21 (Armonk, NY: IBM Corp., USA). A p-value of <0.05 was considered statistically significant.

RESULTS

DESCRPTIVE ANALYSIS OF THE SAMPLE

Intra-examiner measurements showed a high correlation with Pearson's correlation coefficient values (*r*) of 0.70–0.90 for all angular and linear measurements which is an acceptable value. Of the 165 samples included in the final analysis, 58.8% (n=97) were females and 41.2% (n=68) were males.The average age was 20.4 years with a range of 13-47 years of age. The overall mean ANB of the entire sample was found to be 3.28º± 2.78ºand the FMA was 27º± 5º.The distribution according to ANB anglulation was54.5% class I (n=90), 27.9% class II (n=46), , and 17.6% class III (n=29). The vertical distribution waslow angle36.4% (n=60),, average32.1% (n=53), and high angle 31.5% (n=52) as shown in Table 1 below.

Table 1. Descriptive analysis of ANB and FMA classification of sample

		Frequency	Percent
ANB	Class I (1-5)	90	54.5
	Class II (>5)	46	27.9
	Class III (<1)	29	17.6
FMA	Low angle (<25°)	60	36.4
	Average (25°-30°)	53	32.1
	High angle (>30°)	52	31.5

GENDER ANALYSIS

Only mandibularintermolar width showed a statistically significant difference between males and females (p<0.05) (Table 2). No statistically significant association was found between FMA, ANB, maxillaryarch form, mandibulararch form, curve of Spee, and gender (p>0.05) (Table 3).

Table 2. Comparison of dental arch parameters by gender

	Gender Mean (SD)		p value
	Male	Female	
Max IMW	44.53 (3.80)	43.88 (3.09)	.230
Max ICW	33.35 (3.18)	32.63 (2.41)	.102
Max SA	-1.40 (4.02)	-1.99 (3.65)	.336
Man IMW	40.87 (4.05)	39.64 (3.62)	.043*
Man ICW	27.14 (3.36)	26.57 (2.43)	.237
Man SA	-1.72 (3.42)	-2.04 (2.70)	.511

OB	2.19 (1.92)	2.07 (2.06)	.702
OJ	3.09 (2.14)	3.18 (2.31)	.795
All Bolton	91.43 (3.11)	91.10 (3.25)	.510
Ant Bolton	77.60 (2.53)	77.02 (2.14)	.119

* Indicates Statistical significance at p<0.05

Table3. Association between FMA, ANB, Max AF, Man AF, COS and gender

		FMA Frequency (Percent)		p value
		Male	**Female**	
FMA	Low angle (<25°)	22 (37.9)	36 (62.1)	.824
	Average (25°-30°)	23 (43.3)	30 (56.6)	
	High angle (>30°)	22 (42.3)	30 (57.7)	
ANB	Class I (1-5)	38 (42.7)	51 (57.3)	.660
	Class II (>5)	16 (35.6)	29 (64.4)	
	Class III (<1)	13 (44.8)	16 (55.2)	
Max AF	Ovoid	33 (44.6)	41 (55.4)	.510
	Tapered	16 (43.2)	21 (56.8)	
	Square	18 (34.6)	34 (65.4)	
Man AF	Ovoid	35 (46.1)	41 (53.9)	.413
	Tapered	10 (41.7)	14 (58.3)	
	Square	22 (34.9)	41 (65.1)	
COS	Normal	36 (36.4)	63 (63.6)	.144
	Deep	31 (48.4)	33 (51.6)	

DESCRIPTIVE ANALYSIS OF MAXILLARY AND MANDIBULAR ARCH FORMS AND CURVE OF SPEE

The distribution of ovoid, tapered, and square of maxillary arch forms was 44.8% (n=74), 22.4% (n=37), and 32.7% (n=54), respectively. Similarly, the distribution of ovoid, tapered, and square of mandibular arch forms was 46.7% (n=77), 14.5% (n=24), and 38.8% (n=64), respectively as seen in Table 4. Distribution of normal and deep curve of Spee was 60.6% (n=100) normal and 39.4% (n=65) deep.

Table 4. Descriptive analysis of Max AF, Man AF and COS

		Frequency	Percent
Max AF	Ovoid	74	44.8
	Tapered	37	22.4
	Square	54	32.7
Man AF	Ovoid	77	46.7
	Tapered	24	14.5
	Square	64	38.8
COS	Normal	100	60.6
	Deep	65	39.4

ASSOCIATION BETWEEN ANB, FMA AND MAXILLARY AND MANDIBULAR ARCH FORMS, AND COS

Pearson Chi-Square test showed no statistically significant association between ANB and maxillaryarch form, mandibulararch form, andcurve of Spee(Table 5).On the other hand, Pearson Chi-Square test showed a statistically significant association between FMA and maxillary arch form (p<0.05). Two-way cross-tabulation showed that low angle were more likely to be square, average were more likely to me ovoid, and high were more likely to be tapered. No statistically significant association was found between FMA and mandibulararch form (p>0.05) and FMA and curve of Spee (p>0.05). (Table 6).

Table5. Association between ANB and Max AF, Man AF, and COS

		ANB Frequency (Percent)			p value
		Class I (1-5)	**Class II (>5)**	**Class III (<1)**	
Max AF	Ovoid	46 (51.1)	19 (41.3)	9 (31.0)	.219
	Tapered	18 (20.0)	13 (28.3)	6 (20.7)	
	Square	26 (28.9)	14 (30.4)	14 (48.3)	
Man AF	Ovoid	44 (48.9)	21 (45.7)	12 (41.4)	.298

	Tapered	12 (13.3)	10 (21.7)	2 (6.9)	
	Square	34 (37.8)	15 (32.6)	15 (51.7)	
COS	Normal	57 (63.3)	25 (54.3)	18 (62.1)	.588
	Deep	33 (36.7)	21 (45.7)	11 (37.9)	

Table6. Association between FMA and Max AF, Man AF, and COS

		FMA Frequency (Percent)			p value
		Low angle (<25°)	**Average (25°-30°)**	**High angle (>30°)**	
Max AF	Ovoid	25 (41.7)	29 (54.7)	20 (38.5)	.028*
	Tapered	8 (13.3)	13 (24.5)	16 (30.8)	
	Square	27 (45.0)	11 (20.8)	16 (30.8)	
Man AF	Ovoid	27 (45.0)	30 (56.6)	20 (38.5)	.400
	Tapered	8 (13.3)	6 (11.3)	10 (19.2)	
	Square	25 (41.7)	17 (32.1)	22 (42.3)	
COS	Normal	31 (51.7)	36 (67.9)	33 (63.5)	.185
	Deep	29 (48.3)	17 (32.1)	19 (36.5)	

* Indicates Statistical significance at p<0.05

DESCRIPTIVE ANALYSIS OF MAXILLARY AND MANDIBULAR INTERMOLAR AND INTERCANINE WIDTHS

Considering the arch widths and forms, the mean (SD) maxillary intermolar width was 44.13 (3.39) with themaxillary intercanine width was 32.93 (2.77), whereas the mandibular intermolar width was found to be 40.14 (3.82) with the mandibular intercanine width was 26.80 (2.84). There was no statistically significant differences between groups according to ANB or FMA as seen in Table 7.

Table 7. Descriptive analysis of maxillary and mandibular intermolar and intercanine widths

	Mean	Standard Deviation	Minimum	Maximum
Max IMW	44.13	3.39	31.00	53.10
Max ICW	32.93	2.77	23.00	39.00
Man IMW	40.14	3.82	25.00	50.94
Man ICW	26.80	2.84	18.74	37.00

Table 8. **Comparison of maxillary and mandibular intermolar and intercanine widths according to ANB and FMA classifications**

	ANB Mean (SD)			p value
	Class I (1-5)	**Class II (>5)**	**Class III (<1)**	
Max IMW	44.20 (3.19)	43.59 (3.25)	44.80 (4.14)	.314
Max ICW	32.76 (2.69)	32.77 (2.60)	33.70 (3.22)	.255
Man IMW	40.08 (3.77)	39.47 (3.79)	41.40 (3.82)	.099
Man ICW	27.01 (3.02)	26.56 (2.66)	26.54 (2.57)	.588
	FMA Mean (SD)			**p value**
	Low angle (<25°)	**Average (25°-30°)**	**High angle (>30°)**	
Max IMW	44.38 (3.15)	44.25 (3.57)	43.73 (3.50)	.571
Max ICW	32.79 (2.88)	33.03 (2.81)	32.99 (2.65)	.887
Man IMW	40.09 (4.20)	39.90 (3.58)	40.46 (3.63)	.743
Man ICW	26.83 (3.16)	26.45 (3.93)	27.12 (2.31)	.473

* Indicates Statistical significance at p<0.05

Horizontally, groups with similar letters have no statistical significant difference

COMPARISON OF DIFFERENCES IN MAXILLARY AND MANDIBULAR INTERMOLAR AND INTERCANINE WIDTH BY FMA

When considering the differences between the intermolar and intercanine widths, the following was noted. In the maxilla, the difference between intermolar and intercanine widths was highest in low angle, followed by average, and least in high angle. In the mandible, the difference between intermolar andintercanine widths was highest in average, followed by high angle, and least in low angle. However, both associations were statistically not significant (p>0.05) (Table 9)

Table 9.Comparison of difference in max and man IM and IC by FMA

	FMA Mean (SD)			p value
	Low angle (<25°)	Average (25°-30°)	High angle (>30°)	
Max (IM-IC) W	11.59 (2.66)	11.22 (2.33)	10.73 (2.42)	.192
Man (IM-IC) W	13.26 (4.58)	13.45 (2.96)	13.34 (2.93)	.962

COMPARISON OF SPACE ANALYSIS

The mean maxillary and mandibular space analyses were found to be -1.73 (3.81) and -1.89 (3.00), respectively with no statistically significant differences according to anteroposterior or vertical classifications (Table 10). Comparison of space analysis by ANB and FMA showed no statistically significant association.

Table 10. Descriptive analysis of Space analysis

	Mean	Standard Deviation	Minimum	Maximum
Max SA	-1.73	3.81	-13.24	7.44
Man SA	-1.89	3.00	-10.00	8.33

Table 11. Comparison of space analysis by ANB and FMA classifications

	ANB Mean (SD)			p value
	Class I (1-5)	Class II (>5)	Class III (<1)	
Max SA	-1.31 (3.85)	-1.84 (3.61)	-2.85 (3.88)	.160
Man SA	-1.60 (3.42)	-2.19 (2.70)	-2.34 (1.79)	.383
	FMA Mean (SD)			**p value**
	Low angle (<25°)	**Average (25°-30°)**	**High angle (>30°)**	
Max SA	-1.33 (3.84)	-1.18 (2.95)	-2.74 (4.38)	.065
Man SA	-1.86 (2.68)	-1.54 (3.25)	-2.28 (3.08)	.445

* Indicates Statistical significance at p<0.05
Horizontally, groups with similar letters have no statistical significant difference

DESCRIPTIVE ANALYSIS OF OVERBITE AND OVERJET

Looking to the anterior dental relationship, a mean overbiteof 2.15 (2.01) and overjet of 3.13 (2.23) were noted in the overall sample as seen in Table 12.

Table 12. Descriptive analysis of overbite and overjet

	Mean	Standard Deviation	Minimum	Maximum
OB	2.15	2.01	-3.02	9.40
OJ	3.13	2.23	-3.00	12.00

COMPARISON OF OVERJET AND OVERBITE BY ANB AND FMA

One-way analysis of variance showed statistically significant difference between overbite and ANB (p<0.05) and overjet and ANB (p<0.05). Tukey post hoc showed statistically significant difference in overbite between class I and class III (p<0.05), and class II and class III (p<0.05). Furthermore, Tukey post hoc showed statistically significant difference in overjet between class I and class II (p<0.05), class I and class III (p<0.05), and class II and class III (p<0.05).On the other hand, one-way analysis of variance showed statistically significant difference between overbite and FMA (p<0.05). Tukey post hoc showed statistically significant difference in overbite between low angle and average (p<0.05), and low angle and high angle (p<0.05) (Table 13).

Table 13. Comparison of ANB by dental arch parameters

	ANB Mean (SD)			p value
	Class I (1-5)	Class II (>5)	Class III (<1)	
OB	2.36 (1.79)[a]	2.47 (2.01)[a]	0.96 (2.25)	.002*

OJ	2.91 (1.82)	4.45 (2.12)	1.69 (2.47)	.000*
	FMA Mean (SD)			**p value**
	Low angle (<25°)	**Average (25°-30°)**	**High angle (>30°)**	
OB	3.22 (1.84)	1.89 (1.61)[a]	1.16 (1.98)[a]	.000*
OJ	3.07 (1.98)	3.05 (2.32)	3.27 (2.42)	.857

* Indicates Statistical significance at p<0.05
Horizontally, groups with similar letters have no statistical significant difference

DESCRIPTIVE ANALYSIS OF OVERALL AND ANTERIOR BOLTON ANALYSIS

When considering the Bolton tooth ratio analysis, the overall Bolton was found to be 91.24 (3.17), and anterior Boltonwas 77.25 (2.31) with no significant relation to ANB or FMA classification. (Table 14, 15).

Table 14. Descriptive analysis of overall and anterior Bolton analysis

	Mean	Standard Deviation	Minimum	Maximum
All Bolton	91.24	3.17	83.50	99.30
Ant Bolton	77.25	2.31	71.10	88.56

Table 15. Comparison of ANB and FMA by Bolton analysis

	ANB Mean (SD)			**p value**
	Class I (1-5)	**Class II (>5)**	**Class III (<1)**	
All Bolton	91.60 (3.23)	90.59 (2.94)	91.16 (3.27)	.211
Ant Bolton	77.35 (2.59)	77.11 (1.82)	77.15 (2.10)	.827
	FMA Mean (SD)			**p value**
	Low angle (<25°)	**Average (25°-30°)**	**High angle (>30°)**	
All Bolton	91.04 (3.36)	91.36 (3.41)	91.35 (2.72)	.831
Ant Bolton	77.52 (1.98)	77.12 (2.28)	77.06 (2.67)	.504

* Indicates Statistical significance at p<0.05
Horizontally, groups with similar letters have no statistical significant difference

DISCUSSION

The creation of a unique dental arch that is ideal for the patient is one of the fundamental goals of orthodontic treatment. This will aid in the achievement of a stable, functional, and esthetic arch, which is the primary goal and most desirable result of orthodontic treatment (Braun et al., 1998; Sampson et al., 1995). The key to the achievement of these goals is the identification of a suitable arch form to be used in the treatment of each case. It is also known that the preservation of the original arch form and size of orthodontically treated patients plays an important role in assuring long-term stability after orthodontic treatmentand preventing relapse(Dasgupta et al., 2021). Thus, an attempt was made to relate various dental arch parameters to vertical facial morphology.
The studies conducted to date report adifference in the relationship between vertical facial morphology and arch width for different ethnic and racial growth (Lasker, 1957), (Liu, 1977). All studies indicate that normal measurement for one group should not be considered as standard for every other race or ethnic group(Ling and Wong, 2009), (Alkadhi et al., 2018). Considering this conclusion, the present study conducted in the Saudi population is justified..

FACIAL PROPORTIONS

In the present study, the samplewasclassified according to the cephalometric reading ANB into Class I (0-4 º), II (> 4 º), III (<0 º) and using ANB. The distribution of the current sample showed 54.5% class I (n=90), 27.9% class II (n=46), , and 17.6% class III (n=29) which conforms to the normal distribution in an orthodontic population. Vertically, it was divided into low, average, and high FMA angle individuals according to the angle measurement of lesser than 25 degrees, between 25 to 30, and more than 30 degrees, respectively. It was found that the proportion of people in each group was 36.4%, 32.1%, and 31.5 % respectively for each FMA angle group which was specifically sought out for comparison to dental parameters.
An increased FMA value indicates excessive vertical growth and a hyperdivergent pattern, while a reduced value indicates a reduced vertical growth pattern and a hypodivergent pattern. This study reported an average FMA of 27º± 5ºwhich, although higher than

the Tweed Caucasian norm of 25º, is somewhat comparable to Pakistani (21.5° ± 5º)(Shaikh and Alvi, 2009), and Nigerian (20.8°- 26.1°)(Ajayi, 2005) norms although less than Kenyan 34.0° ± 5.1°(Kapila, 1989).

DENTAL ARCH FORM

The distribution of ovoid, tapered, and square of maxillary arch forms was 44.8% (n=74), 22.4% (n=37), and 32.7% (n=54), respectively. Similarly, the distribution of ovoid, tapered, and square of mandibular arch forms was 46.7% (n=77), 14.5% (n=24), and 38.8% (n=64), respectively. In the present study, the relationship between only maxillary arch form and FMA showed a significant difference (p=0.028). This relationship was noted with more tapered arch forms in high angle cases, ovoid with average angle cases and square with low angle cases.However, the relationship between mandibular arch form and FMA, maxillary and mandibular arch form and ANB did not show any statistically significant difference.In another study on subjects with class II division I (overjet more than 6mm) or with class III malocclusion (edge to edge or reverse overjet), no clear association was found between dental arch form and facial type (Al-Taee and Al-Joubori, 2014).

There has been controversy on this issue in the literature. Previous studies suggested that individuals with a short face (brachyfacial) tend to have excessively wide arches, while narrow arches are characteristic of dolichofacial types (Aitchison, 1965; Kageyama et al., 2006). Anwar and Fida reported similar findings in their study comparing the arch forms with various vertical facial patterns. They concludedthat wide lower arches were predominant in all face types whereas wide upper arches were predominant in both hypo- and hyper-divergent subjects (Anwar and Fida, 2010). Grippaudo et al. reported a similar finding in that there was an association between the upper dental arch form and the vertical facial pattern.A decrease of the upper arch transversal diameters in high SN-MP angle patients and an increase in low angle SN-MP was noticed. However, the lower arch form was not significantly affected by the mandibular divergence which corresponds to our results (Grippaudo et al., 2013).Paranhos et al., on the other hand,found no association between the facial type (dolichofacial, mesofacial, or brachyfacial) and the dental arch morphology (square, oval, or tapered)which is similar to the present study(Paranhos et al., 2014).

Foster et al. also reported that they found male arch widths to be significantly larger than those of females (Foster et al., 2008).However this study found no significance between genders in arch forms.With the above study results, it can be assumed that multiple epigenetic and environmental factors come into play in the formulation of the ultimate arch form of an individual. Therefore, a particular arch form for a certain face type could not be found. There may be variations according to gender or race that must be taken into consideration.

DENTAL ARCH WIDTH

In the present study, no significant difference was found between the maxillary or mandibular intermolar or inter-canine width to FMA or ANB. The mean (SD) maxillary intermolar width was 44.13 (3.39) with themaxillary intercanine width was 32.93 (2.77), whereas the mandibular intermolar width was found to be 40.14 (3.82) with the mandibular intercanine width was 26.80 (2.84).

Shahroudi and Etezadi report a significant positive correlation between sagittal parameters and arch width measures, between SNA and upper intercanine width, and between lower intercanine width and lower arch length. Upper and lower intercanine width were significantly correlated. However, similar to the present study finding, they too did not find any significant difference between arch width parameters andthe three occlusal classes in an AP direction(Shahroudi and Etezadi, 2013). Aggarwal et al findings supported the viewthat maxillary and mandibular interpremolar dental and alveolar width was highest in hypodivergent individuals and least in hyperdivergent individuals(Aggarwal et al., 2018).

Khan et al. in their study revealed similar findings where they noted an insignificant inverse relationship between intermolar arch widths and SN-MP. They reported that the measurement of arch width does not vary with various skeletal vertical patterns(Khan et al., 2021). Ilyas et al. reported that there was no difference in inter-canine widths, intermolar widths, and anterior angle values calculated on the maxillary and mandibular casts of individuals with different facial forms which was similar to the present study (Ilyas et al., 2017).Khan et al. also reported similar findings to the present study demonstrating no relation between the arch width and various skeletal vertical patterns. However, they have pointed out that, greater arch widths were witnessed in patients belonging to the normal and low angle category and patients having high angle SN.MP was observed to have minimum arch widths (Khan et al., 2021).However, Ning et al. did find a correlation between the maxillary width with vertical and sagittal skeletal patterns and reported that insufficient maxillary width would lead to unfavorable skeletal patterns(Ning et al., 2021). Dasgupta et al. were also of asimilar opinion. They too found a high correlation from inter-canine width to inter-premolar width and a medium correlation for intermolar width to vertical facial patterns.They also found an inverse relationship with SN.MP; as SN.MP increased, the dental arch widths decreased(Dasgupta et al., 2021). Foster et al. also found that as SN.MP angle increased, arch widths decreased (Forster et al., 2008).

When considering gender dimorphism and arch widths, this study found a significant relationship in mandibular intermolar width (p=0.043) with males showing higher values than females. No significance was found with maxillary intermolar or intercanine or mandibular intercanine. Khera et al.found that for both genders, there was a trend that as the vertical facial height increased, arch width, arch perimeter, and overbite decreased, but palatal height and curve of Spee increased. Males had significantly larger arch dimensions than females. They concluded that dental arch dimensions were associated with facial vertical morphology and gender(Khera et al., 2012). In both males and females, there was a trend that as vertical facial height increased, arch width decreased and males had significantly larger arch dimensions than those of females (Khekade et al., 2019)

Another example to show the change in the variation regardingrace and ethnicity, is the study by Prasad et al (2013) who showed that, among the south Indian population, there was a significant decrease in inter arch width as the Sella-Nasion, Mandibular Plane (SN.MP) angle increased.Goyal et al., proved there is a relationship between arch width patient's growth pattern using Jarabak's ratio, as arch width increased, Jarabak's ratio increased(Goyal et al., 2020). In our study, although we did not incorporate the Jarback's ratio, the resulting conclusion with use ofFMA is similar, which is why we can cautiously compare our results.

SPACE ANALYSIS (CROWDING OR SPACING)

Rasul et al. studied the role of vertical parameters in the development of lower crowding amongst patients and found hyper-divergent cases showed the highest percentage of lower incisor crowding (92.6%) followed by normo and hypo-divergent profiles(Rasul et al.,2012).In our study it was also observed that the highest number of maxillary and mandibular crowding was present in patient with hyperdivergent profile with a mean of(-2.74), (-2.28) mm respectively.

OVERJET AND OVERBITE

There was a statistically significant difference between overbite and ANB (p=0.002) and overjet and ANB (p=0.000). Tukey post hoc showed statistically significant difference in overbite between class I and class III (p<0.05), and class II and class III (p<0.05). Class

II patients showed higher overbite values than Class I patients. Similarly, in previous studies ANB showed a positive significant correlation with the overbite(Islam et al., 2022).

Furthermore, Tukey post hoc showed statistically significant difference in overjet between class I and class II (p<0.05), class I and class III (p<0.05), and class II and class III (p<0.05). As expected, class II patients showed the highest overjet values with class III patients showing the least.Luca also evaluated the correlation between overjet and skeletal parameters. He revealed that overjet was correlated in a statistically significant fashion (*P*<0.001) with ANB (Luca, 2012).

The current study found a significant difference between the overjet and overbite and FMA. One-way analysis of variance showed statistically significant difference between overbite and FMA (p<0.05). Tukey post hoc showed statistically significant difference in overbite between low angle and average (p<0.05), and low angle and high angle (p<0.05).

Islam et al.reported a negative correlation between FMA and overbite.Saltaji et al evaluate the association between vertical facial morphology and overjet in untreated Class II subjects. They found a positive association between the overjet and the tendency toward a hyperdivergent pattern (Saltaji, 2012).

CURVE OF SPEE

In the present study,the distribution of normal and deep COS was 60.6% and 39.4% respectively. No significant relationshipwas found between the COS and FMA or ANB. A study by Gulve reported thatvariation in the depth curve of Spee is related to changes in dental parameters rather than skeletal parameters in all types of skeletal patterns which is similar to the present study(Gulve, 2018). However, previous studies have shown that the mandibular sagittal and vertical position relative to the cranium is related to the curve of Spee(Farella et al., 2002). Furthermore,classicstudies in humans have shownan increased curve of Spee in brachycephalic facial patterns(Björk, 1953; Wylie, 1944) and are associated with short mandibular bodies(Salem et al., 2003).

Batham et al.found a negative correlation between the ANB values and curve of Spee. The curve of Spee was significantly related to the vertical facial pattern. The difference in the findings may be due to the racial pattern, age, and sex of the sample and also the parameters that were chosen for the study(Batham et al., 2013).Tothe contrary ofthe present study findings, Kumari et al.reported a negative correlation between the curve of Spee depth and inclinations of upper and lower incisors and a positive correlation between the curve of Spee depth and severity of lower anterior crowding and Steiner's mandibular plane angle (Kumari et al., 2016). Similarly, in few other previous studies it was seen that the value of ANB was positively correlated with the depth of curve of Spee, as the value of ANB angle increased, the depth of curve of Spee also increased. They concluded that the curve of Spee is related to various dentoskeletal variable(Cheon et al., 2008; Orthlieb, 1997).

Present study results were not in agreement with the study by Rizwan et al.where highly significant differences were found in the value of the curve of

Spee depth among three vertical skeletal patterns. They have also found that moving from hypodivergent to hyperdivergent cases, the curve of Spee depth reduced. In the present study, the grouping of COS wasdeep and normal, while others are divided into flat, normal, and deep(Rizwan et al., 2020). The present study chose only deep and normal because a flat curve of Spee commonly seen in the deciduous dentition was not the intended group of the study. Furthermore, different age groups, gender, and race are considered to havean impact the curve of Spee(Farella et al., 2002).

BOLTON ANALYSIS

In the present study, no significant difference was found between anterior Bolton value, overall Bolton value, and FMA. In regards to the anteroposterior classification, the majority of the literature suggests that Bolton ratios are greatest in Class III subjects. (Othman and Harradine, 2006). On the other hand, a study by Sperry et al. concluded that maxillary tooth ratios were in excess in Class II subjects (Sperry et al., 1977). Neither of these were in agreement with the present study where a relationship could not be positively predicted according to the classification. Anterior Bolton value of 77.52 ± 1.98, 77.12±2.28, and 77.06± 2.67and overall Bolton values of 91.04 ±3.36, 91.36 ±3.41, and 91.35 ±2.72 were found in low angle (<25°), average angle (25°-30°), and high angle (>30°) groups respectively. These findings were similar to the study of Asad et al. and Azeem et al. in that they did not find any correlation between vertical patterns and Bolton ratios(Asad et al., 2008)(Azeem et al., 2017). They concluded that Bolton ratios and vertical facial types are not correlated which is reinforced by the current study (Azeem et al., 2017).

LIMITATIONS

There may be some possible limitations in this study. First and foremost is the the lack of standardization in the methodology of previous studies which makes it difficult to compare the data.Looking at vertical classifications, different authors used Jarabak ratio, SN-MP angle, FMA or other measurements. This complicated the comparison to our data which specifically looked at FMA. Secondly,as mentioned previously, the normal values of one race cannot be fully applied to another. The sample size in this study was collected exclusively from REU patients which could carry sample bias due to the mixture of different races or demographic variables whichmay not reflect the general Saudi population.Finally, dental arch parameters were analyzed manually on orthodontic dental casts rather than 3D scanning. This may impact the accuracy of the results although it is the current gold standard and more cost effective than using 3D scans.

CONCLUSION

The following conclusion can be drawn:

1. Among the parameters co-related, the significance was seen only with the overbite and FMA.
2. Similarly, ANB co-related with the dental parameters again showed significant relation only with overjet and overbite.
3. Comparing the arch form with the FMA showed significance only with the maxillary arch form. However, a similar observation was not found with the ANB.

DEDICATION

I dedicate this work with a lot of warm thanks and appreciation to my dear father and mother for their endless love and sacrifices throughout life and for giving me the support and guidance in every step of this journey. They have always inspired me to aim higher and be a better person and make it easier for me to reach my goals and dreams. I cannot express enough words.

To my family and friends, thank you for believing in me and for supporting me to pursue my studies. Please do not ever doubt my dedication and love for you.

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