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THREE-DIMENSIONAL ASSESSMENT OF THE MAXILLA IN TOMOGRAFY OF CLASS III MALOCCLUSION PATIENTS

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ABSTRACT

Objective: The present study aimed to analyze the three-dimensional pattern of the maxilla in patients diagnosed with Class III malocclusion who underwent orthognathic surgery. **Materials and Methods**: This is an observational, retrospective study based on the analysis of tomographic records obtained between 2019 and 2024. Cone-beam computed tomography (CBCT) scans acquired prior to surgical intervention and available on the Proplan CMF platform were included, involving patients with a confirmed diagnosis of Class III malocclusion. Tomographic measurements were performed to identify possible morphological variations of the maxilla associated with the malocclusion. **Results:** The results showed that the maxillae of male patients generally exhibited larger dimensions when compared to those of female patients. Furthermore, despite the dimensional differences between sexes, each group demonstrated a relatively homogeneous internal morphological pattern, with minimal discrepancies in the measurements analyzed. These findings suggest that sexual dimorphism significantly influences the size of the maxilla in patients with Class III malocclusion but does not substantially affect the shape pattern within each group. **Conclusions:** It is concluded that understanding these anatomical variations is essential for the individualized planning of orthognathic surgeries, contributing to improved functional and aesthetic outcomes. Further studies with larger sample sizes are recommended to validate and expand upon the observed data.

Keywords: Angle Class III Malocclusion. Cone-Beam Computed Tomography. Malocclusion. Orthognathic Surgery. Oral and Maxillofacial Surgeons.

INTRODUCTION

In 1899, Angle was the first to classify malocclusions into Class I, Class II, and Class III based on the relationship of the first molars to the occlusal line. Thus, a Class III maxillary relationship means that the mandible is positioned anteriorly to the maxilla. This pattern is typically associated with a Class III molar relationship but can occasionally present as a Class I molar relationship when dental compensation overcomes the skeletal imbalance. Therefore, Class III malocclusions are not limited to the anterior positioning of the lower first molars, as described by Angle, but instead result from a combination of dentoalveolar, skeletal, and vertical growth alterations (Ghodasra, Brizuela, 2023).

Early treatment for this condition is considered the best alternative since delaying it can lead to functional, aesthetic, and psychological changes (Ngan, 2006; Viazis, 1995; Burns et al, 2010). Class III malocclusion may result from isolated mandibular prognathism, maxillary hypoplasia with retrognathism, or a combination of both. Early diagnosis ensures proper treatment planning (Baccetti, Tollaro., 1998; Cozza, Marino, Mucedero, 2004).

In addition to this anatomical heterogeneity, studies have shown that heredity and environmental factors can play a substantial role in the etiology of this malocclusion (Neela et al, 2007). For growing patients, it is still possible to implement orthopedic approaches such as the use of a mandibular cervical headgear to help redirect mandibular growth and improve skeletal relationships (Pithon, Bernardes, 2021).

Each part of the craniofacial complex has its own growth pattern and rate of maturation. Therefore, to achieve a harmonious and balanced face, synchronized growth is required among the bones of the craniofacial complex, especially in similarly oriented dimensions (Hentz, Nogueira, 2023; Lewis, Roche, Wagner, 1985).

The vertical and horizontal growth of the mandible varies according to the direction of condylar growth. As for the maxilla, its downward displacement and extension within the facial pattern are determined by sutural growth, accompanied by simultaneous periosteal growth of the alveolar arches in a three-dimensional manner (Enlow, 1966). Normal continuous growth begins in the prenatal period and continues after birth, potentially influenced by genetics and environmental factors. These factors affect neuromuscular tissue, bone, cartilage, and teeth (Bjork, 1955).

There are already studies in the literature that described the anatomical characteristics and dimensional patterns of the mandible in patients with Class III malocclusion, particularly highlighting increased mandibular length and prognathism (Zandi et al, 2021).

These findings have contributed significantly to the understanding of mandibular growth deviations associated with this malocclusion. However, despite the data regarding the mandible, there is still a lack of comprehensive studies focused on the dimensional analysis of the maxilla in Class III patients. This gap hinders a complete skeletal understanding of the malocclusion and may limit the precision of diagnostic and therapeutic planning, especially in borderline or heterogeneous cases.

Patients with some dysfunction in normal facial growth who develop a Class III facial pattern may undergo orthognathic surgery depending on the severity of the case. Two-dimensional (2D) radiographs and manual surgical models are essential parts of preoperative orthognathic surgery planning. However, this approach has its limitations, especially in patients with major deformities or facial asymmetries (Ho, 2017).

Two-dimensional cephalometric radiographs cannot provide complete information about a three-dimensional structure such as the face (Xia, Gateno, Teichgraeber, 2009). Currently, virtual-assisted planning is an accurate method for orthognathic surgery of the maxilla and mandible through cone-beam computed tomography (CBCT) and intraoral scanning using scanners (Alkhayer et al, 2020).

In this context, this study aimed to evaluate maxillary dimensions in patients with Class III malocclusion using measurements obtained from preoperative CBCT scans for orthognathic surgery, with the objective of assessing the existence of a morphological pattern.

MATERIALS AND METHODS

An observational, retrospective study was conducted analyzing the CBCT scans of patients diagnosed with Class III malocclusion prior to orthognathic surgery. Data were obtained from Proplan CMF software between 2019 and 2024 in Piracicaba, São Paulo. Patient records included age, gender, and surgery details. A total of 30 patients were analyzed using a proprietary cephalometric protocol with standardized measurements.

PRE-ESTABLISHED MEASUREMENTS

The measurements on the tomography were performed using the head in an oriented position.

- **Septal deviation**
- **Vertical measurements:**

  Reference: Vertical glabella (bony glabella)

A) Bilateral Lateral View:

1 – Measurement from the mesiobuccal cusp of tooth 16 to the infraorbital line (the infraorbital line is traced at the level of the infraorbital foramen, not corresponding to the Frankfurt plane).

2 – Measurement from the mesiobuccal cusp of tooth 26 to the infraorbital line (the infraorbital line is traced at the level of the infraorbital foramen, not corresponding to the Frankfurt plane).

B) Frontal View

1 – Measurement from the incisal edges of teeth 11 and 21 to the infraorbital line (the infraorbital line is traced at the level of the infraorbital foramen, not corresponding to the Frankfurt plane).

2 – Measurement from the anterior nasal spine (ANS) to the infraorbital line (the infraorbital line is traced at the level of the infraorbital foramen, not corresponding to the Frankfurt plane).

3 – Measurement from the anterior nasal spine (ANS) to the lowest point of the nasal bones.

- **Transverse Measurements:**

C) Transverse Frontal View:

1 – Measurement of the piriform aperture from the widest point on the right to the widest point on the left.

D) Occlusal View:

1 – Measurement from the mesiobuccal cusp of tooth 16 to the mesiobuccal cusp of tooth 26.

2 – Measure from the incisal edge of tooth 13 to the incisal edge of tooth 23.

E) Axial view:

1 – At the level of the posterior nasal spine, the measurement was taken from the most concave point of the lateral wall of the right maxillary sinus to the most concave point of the lateral wall of the left maxillary sinus.

Horizontal measurements:

F) Profile view:

1- Measurement from the anterior nasal spine to the vertical glabella (bony glabella).
2- Measurement from Point A to the vertical glabella (bony glabella).

3- Measurement from the labial surface of the upper incisor to the vertical glabella (bony glabella).

4- At the level of the anterior nasal spine, measurement was taken from the most posterior part of the lateral plate of the pterygoid process of the sphenoid bone to the vertical glabella (bony glabella).

G) Sagittal view:

1 – Measurement from the most posterior point of the posterior nasal spine to the vertical glabella (bony glabella).
2 – Measurement from the most anterior part of the second cervical vertebra to the posterior nasal spine.
3 – Measurement from the most anterior part of the second cervical vertebra to the anterior nasal spine.
4 – Measurement from the most anterior part of the second cervical vertebra to Point A.
5 – Measurement from the posterior nasal spine to the anterior nasal spine, tip to tip, at an inclined angle.

- **Lip measurement**

Reference: True vertical line (soft glabella) 8 mm anterior to the bony glabella. Profile view: Measurement from the lip to the true vertical line (soft glabella).
In this study, acronyms were used to abbreviate the reference points used in the maxillary measurements: infraorbital line (LI), anterior nasal spine (ANS), posterior nasal spine (PNS), nasal bones (NB), vertical glabella (VG).
Protocol 7,082,758 approved in Campinas, São Paulo, September 17, 2024.

RESULTS

When evaluating the profile of the study participants, distributed by sex and presence of septal deviation, 18 participants (60.0%) were female and 12 (40.0%) were male. Regarding septal deviation, 11 participants (36.7%) had deviation to the right side, 11 (36.7%) had deviation to the left side, and 8 (26.7%) had no deviation. Table 1 presents the tomographic measurements in millimeters, grouped into categories of vertical, transverse, horizontal measurements, and those related to the lip.

Table 1: Tomographic measurements in millimeters, grouped by vertical, transverse, horizontal, and lip dimensions.

Measurements	
Vertical	
Mesiobuccal cusp of tooth 16 to the infraorbital line	
Mean (±SD)	46,1 (±4,1)
Median (Q1 – Q3)	47,0 (43,5 – 48,4)
Mesiobuccal cusp of tooth 26 to the infraorbital line	
Mean (±SD)	45,8 (±3,8)
Median (Q1 – Q3)	46,3 (43,4 – 47,8)
Incisal edge of tooth 11 to the infraorbital line	
Mean (±SD)	48,3 (±4,7)
Median (Q1 – Q3)	49,1 (46,1 – 51,2)
Incisal edge of tooth 21 to the infraorbital line	
Mean (±SD)	48,2 (±4,9)
Median (Q1 – Q3)	49,2 (45,7 – 50,8)
Anterior nasal spine to the infraorbital line	
Mean (±SD)	21,8 (±2,5)
Median (Q1 – Q3)	21,8 (20,4 – 23,6)
Anterior nasal spine to the inferior point of the nasal bones	
Mean (±SD)	32,7 (±2,9)
Median (Q1 – Q3)	32,6 (31,1 – 35,0)
Transverse	
Greatest diameter of the piriform aperture	
Mean (±SD)	21,7 (±1,8)

Median (Q1 – Q3)	21,4 (20,4 – 22,9)
Mesiobuccal cusp of tooth 16 to the mesiobuccal cusp of tooth 26	
Mean (±SD)	52,7 (±3,1)
Median (Q1 – Q3)	52,7 (50,7 – 54,3)
Incisal edge of tooth 13 to incisal edge of tooth 23	
Mean (±SD)	35,6 (±1,9)
Mediana (Q1 – Q3)	35,3 (34,5 – 36,9)
Outer wall of the right maxillary sinus to the outer wall of the left maxillary sinus	
Mean (±SD)	61,5 (±5,7)
Median (Q1 – Q3)	60,7 (58,1 – 64,2)
Horizontal	
Anterior nasal spine to the vertical glabella	
Mean (±SD)	3,9 (±3,9)
Median (Q1 – Q3)	3,4 (1,5 – 6,6)
Point A to the vertical glabella	
Mean (±SD)	-0,4 (±3,5)
Median (Q1 – Q3)	0,1 (-3,2 – 2,2)
Upper incisor to the vertical glabela	
Mean (±SD)	6,6 (±5,2)
Median (Q1 – Q3)	7,0 (2,0 – 9,8)
Sphenoid to the vertical glabella	
Mean (±SD)	-57,7 (±5,0)
Median (Q1 – Q3)	-58,6 (-60,2 – -54,0)
Posterior nasal spine to the vertical glabella	
Mean (±SD)	-47,7 (±5,3)
Median (Q1 – Q3)	-47,3 (-51,1 – -44,2)
*S*econd cervical vertebra to the posterior nasal spine	
Mean (±SD)	30,6 (±3,8)
Median (Q1 – Q3)	30,9 (26,7 – 32,8)
Second cervical vertebra to the anterior nasal spine Mean (±SD)	81,4 (±5,0)
Median (Q1 – Q3)	81,2 (78,5 – 85,1)
Second cervical vertebra to Point A	
Mean (±SD)	77,0 (±4,6)
Median (Q1 – Q3)	77,7 (75,1 – 80,4)
Posterior nasal spine to anterior nasal spine	
Mean (±SD)	51,1 (±4,6)
Median (Q1 – Q3)	51,3 (48,4 – 54,0)

Lip	
Lip to the true vertical line	
Mean (±SD)	3,3 (±5,3)
Median (Q1 – Q3)	3,2 (-1,2 – 7,1)
SD = standard deviation. Q1 = first quartile. Q3 = third quartile.	

Fount: The authors.

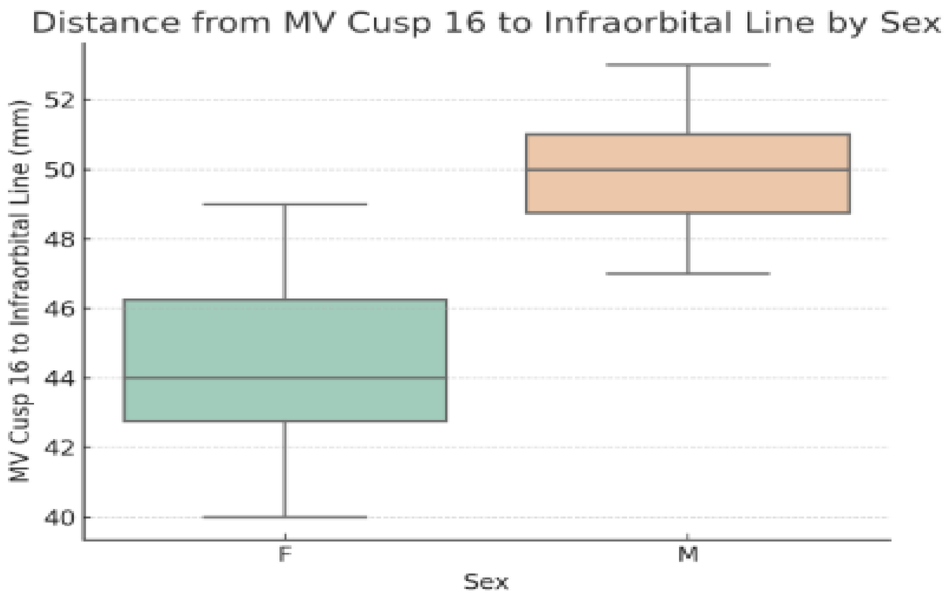
When comparing the tomographic measurements in millimeters between sex groups, statistically significant differences ($p < 0.05$) were observed. The distance from the mesiobuccal cusp of tooth 16 to the infraorbital line showed a mean of 44.4 mm (± 4.1 mm) for the female group and 48.6 mm (± 2.5 mm) for the male group, with p = 0.002 (t = -3.4372), indicating a difference between sexes. On the opposite side, from the mesiobuccal cusp of tooth 26 to the infraorbital line, the mean was 44.5 mm (± 4.0 mm) for females and 47.8 mm (± 2.6 mm) for males, with p = 0.009 (t = -2.7913), also a statistically significant difference.

Another relevant difference was observed in the measurement of the distance between the second cervical vertebra and the anterior nasal spine, with means of 79.4 mm (± 4.3 mm) in the female group and 84.3 mm (± 4.7 mm) in the male group, with a p-value of 0.009 (t = -2.8553). Additionally, the distance between the posterior nasal spine and the anterior nasal spine had a mean of 49.7 mm (± 4.1 mm) for females and 53.2 mm (± 4.5 mm) for males, with p = 0.040 (t = -2.1814), showing a statistically significant difference between sex groups. For the other measurements that did not show statistical significance, less pronounced differences were observed.

Figures 1, 2, and 3 illustrate comparisons of tomographic measurements for different cephalometric distances showing statistically significant differences between sex groups.

Figure 1 presents a graph of the distance from the mesiobuccal cusp of tooth 16 to the infraorbital line. It can be observed that the male group shows higher mean values than the female group, with a more compact distribution.

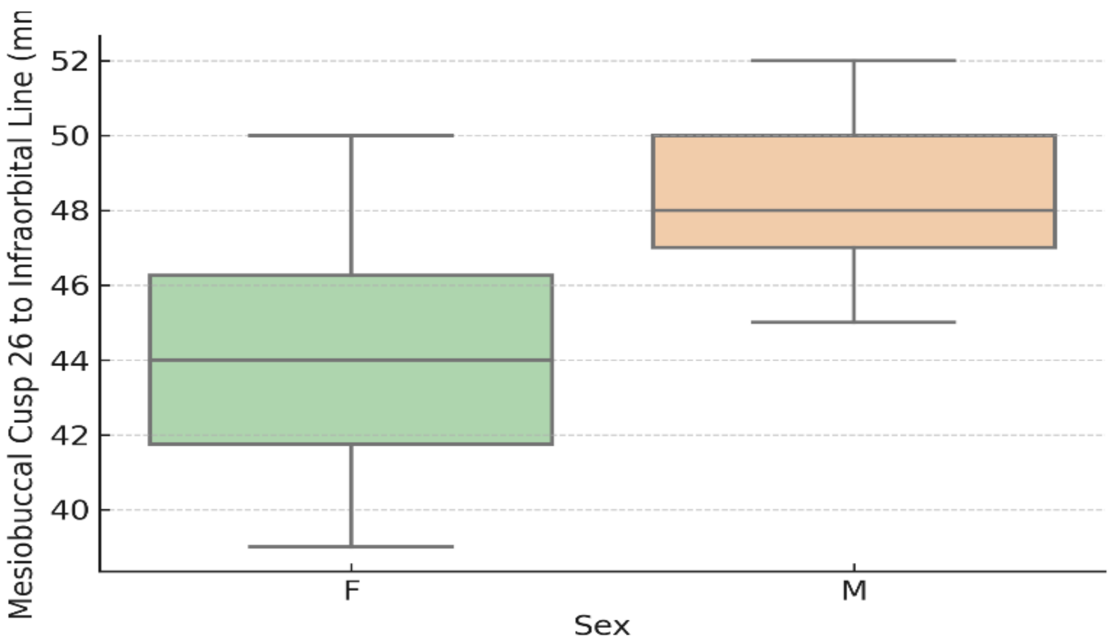
Figure 1: Distance from the mesiobuccal cusp of tooth 16 to the infraorbital line by sex groups.



Fount: The authors.

The measurement of the distance from the mesiobuccal cusp of tooth 26 to the infraorbital line also shows a difference between sex groups, with higher values for men. The values for women exhibit greater dispersion (Figure 2).

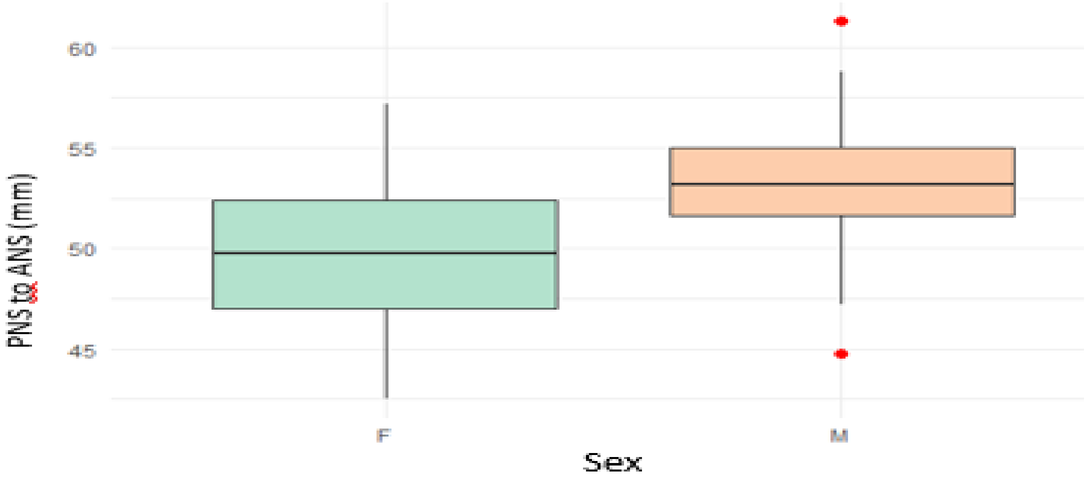
Figure 2: Distance from the mesiobuccal cusp of tooth 26 to the infraorbital line by sex groups.



Fount: The authors.

Figure 3 shows a graph representing the distance between the posterior and anterior nasal spines. The male group presents higher values compared to the female group, with a distribution reflecting moderate variation in both groups.

Figure 3: Distance from the posterior nasal spine to the anterior nasal spine by sex groups.Source: Author's own work (2024).



Fount: The authors.

Table 2 presents the correlation matrix for the horizontal tomographic measurements. Strong and statistically significant positive correlations were identified between the anterior nasal spine (ANS) to vertical glabella (VG) and Point A to VG (r = 0.81, p < 0.001), Point A to VG and incisor to VG (r = 0.74, p < 0.001), ANS to VG and posterior nasal spine (PNS) to VG (r = 0.53, p = 0.003), Point A to VG and PNS to VG (r = 0.65, p < 0.001), and sphenoid to VG and PNS to VG (r = 0.80, p < 0.001).

These findings indicate a tendency for these measurements to increase concomitantly. Moderate correlations were observed among certain variable pairs, whereas weaker correlations were noted in others, such as between the second cervical vertebra (C2) to ANS and PNS to ANS (r = 0.24). Negative correlations were also detected; for example, between C2 to ANS and sphenoid to VG (r = -0.55), suggesting an inverse relationship where an increase in one measurement corresponds to a decrease in the other.

Table 2: Correlation matrix presenting the strength of correlation by Pearson's r and statistical significance for horizontal tomographic measurements.

		ANS to VG	Point A to VG	Incisor to VG	Sphenoid to VG	PNS to VG	C2 to PNS	C2 to ANS	C2 to Point A	PNS to ANS
ANS to VG	R	1								
	p-valor	-								
Point A to VG	R	0,81	1							
	p-valor	< 0,001	-							
incisor to VG	R	0,50	0,74	1						
	p-valor	0,004	<0,001	-						
Sphenoid to VG	R	0,46	0,45	0,18	1					
	p-valor	0,010	0,012	0,334	-					
PNS to VG	R	0,53	0,65	0,50	0,80	1				
	p-valor	0,003	< 0,001	0,005	< 0,001	-				
C2 to PNS	R	0,18	0,09	0,00	-0,19	0,09	1			

	p-value	0,329	0,638	0,982	0,327	0,627	-			
C2 to ANS	R	0,24	0,02	0,03	-0,55	-0,46	0,59	1		
	p-value	0,020	0,905	0,889	0,002	0,010	< 0,001	-		
C2 to Point A	R	0,10	0,12	0,20	-0,50	-0,31	0,61	0,81	1	
	p-value	0,614	0,532	0,282	0,005	0,101	< 0,001	< 0,001	-	
PNS to ANS	R	0,13	-0,15	-0,05	-0,58	-0,69	-0,10	0,65	0,37	1
	p-value	0,495	0,442	0,777	< 0,001	< 0,001	0,600	< 0,001	0,043	-

ANS = Anterior Nasal Spine; VG = Vertical Glabella; PNS = Posterior Nasal Spine; C2 = Second Cervical Vertebra.

Fount: The authors.

DISCUSSION

Several authors agree that genetic and hormonal factors influence the growth of the craniofacial skeleton (Cruz, Oliveira, 2007). In addition to these internal stimuli, external factors related to orofacial functions play an important role in the morphogenesis of the face and its components. Soft tissues, dental development, respiratory patterns (oral or nasal), and biomechanical constraints significantly influence mandibular growth (Bosma et al, 1990; Captier et al, 2011; Larato, 1970;

Souki et al, 2012). The etiology of Class III malocclusion can be categorized as either genetic or environmental (Jacobson et al, 1974).

Craniofacial characteristics can be attributed to positional discrepancies and dimensional disharmony among various components of the craniofacial skeleton, involving the cranial base, maxilla, and/or mandible (Guyer et al, 1986; Tollaro et al, 1994). In the study conducted by Ellis and McNamara, using a cephalometric sample of 302 adult participants with Class III malocclusion, it was found that 45.5% of the sample exhibited maxillary retrusion (Ellis, McNamara, 1984).

For the analysis of facial patterns, the most commonly used imaging exams in orthodontics and oral and maxillofacial surgery are lateral cephalometric and panoramic radiographs. More recently, the use and accessibility of cone-beam computed tomography (CBCT) have significantly increased. The advantages of CBCT include a lower radiation dose, standardized patient positioning, high-quality images without structural overlap, better cost-effectiveness, and the ability to provide three-dimensional evaluations (Larheim et al, 2015; Ganugapanta et al, 2017).

Studies using 2D images have made substantial contributions to the analysis and diagnosis of patients with dental and facial deformities. Although 2D lateral radiographs are important tools for skeletal analysis, they present several limitations, such as the superimposition of structures and a lack of soft tissue correspondence, which complicates the visualization of anatomical features like the airway (Bag et al 2014).

It has been reported that when comparing 2D and 3D images, the latter provides more reliable and accurate measurements than conventional cephalometry for both hard and soft tissues, as well as for airway volume assessments (Burkhard et al, 2014). In the present study, CBCT was chosen due to its predictability and measurement accuracy.

Class III malocclusion is typically identified early in life and tends to worsen with age (Bag et al 2014). Correcting this condition during childhood and growth phases is beneficial, as untreated young patients are associated with rapid periodontal destruction, accelerated occlusal wear, and temporomandibular joint disorders. Moreover, it increases the risk of progression to a true skeletal Class III malocclusion (Bacetti et al, 1998; White, 1998).

The most common combination of variables identified by Ellis and McNamara included maxillary retrusion, maxillary incisor protrusion, mandibular protrusion, mandibular incisor retrusion, and a long lower facial third (Ellis, McNamara., 1984). In the study by Mouakeh, which included 69 patients in primary or mixed dentition with Class III malocclusion, maxillary retrusion with a normally positioned mandible accounted for 43.5% of the total sample (Mouakeh, 2001).

CONCLUSION

In this study, significant differences were observed primarily between sex groups regarding maxillary dimensions, with the male group presenting larger maxillary measurements compared to the female group. Furthermore, within each sex group, a consistent morphological pattern was observed, with minimal discrepancies among the analyzed measurements.

Despite the limitations of this study, it allowed for the analysis of a substantial volume of data without the need for prospective follow-up. Further studies, particularly those including pre- and postoperative analyses, are necessary to assess the potential existence of a consistent maxillary dimensional pattern in these patients.

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This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CONFLICT OF INTEREST

No conflict of interest.

REGULATORY STATEMENT

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of: Plataforma Brasil. The approval code for this study is: 7.082.758.

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