MANDIBLE PHENOTYPE IN CLASS III SKELETAL MALOCCLUSION

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Palavras-chave: Maloclusão Classe III de Angle. Morfologia da mandíbula. Análise morfométrica.

RESUMO

Objetivo: avaliar as características fenotípicas da mandíbula na maloclusão de Classe III em radiografias cefalométricas laterais (LCR) e anteroposteriores (APR). **Materiais e Métodos**: trata-se de um estudo retrospectivo observacional com amostra de conveniência. Indivíduos com maloclusão de Classe III foram avaliados em 80 LCR (31 mulheres e 49 homens) e 70 APR (25 mulheres e 45 homens). No grupo controle, os indivíduos com oclusão excelente foram analisados em 20 LCR e 20 APR (10 de cada sexo). As medidas lineares e angulares das amostras foram tabuladas e submetidas ao teste estatístico de Shapiro-Wilk. Uma vez conhecida sua distribuição assimétrica, foi selecionado o teste U de Mann-Whitney para comparação entre grupos e sexos, além do teste do coeficiente de correlação de Pearson. **Resultados**: o comprimento do corpo mandibular, altura do ramo, altura da sínfise mandibular e processos alveolares, distância intercondilar, intergônio e comprimento total da mandíbula foram características estruturais envolvidas na constituição da desordem esquelética estudada. Além disso, a localização espacial da mandíbula em relação à maxila e à base do crânio mostrou forte influência na configuração dessa desordem craniofacial, evidenciada pela protrusão da mandíbula, fenótipo evidente da participação desse osso na maloclusão esquelética de Classe III. **Conclusão**: ficou evidente o envolvimento das características estruturais e espaciais da mandíbula em relação à maxila e à base do crânio na constituição da má oclusão esquelética de Classe III.

Keywords: Angle class III malocclusion. Jaw morphology. Morphometric analysis.

ABSTRACT

Objective: to evaluate the phenotypic characteristics of the mandible in Class III malocclusion in lateral cephalometric radiographs (LCR) and anteroposterior radiographs (APR). **Materials and Methods**: this is a retrospective observational study with a convenience sample. Individuals with Class III malocclusion were evaluated in 80 LCR (31 females and 49 males) and 70 APR (25 females and 45 males). In the control group, individuals with excellent occlusion were analyzed in 20 LCR and 20 APR (10 of each sex). The linear and angular measurements of the samples were tabled and submitted to the Shapiro-Wilk statistical test. Once their asymmetric distribution was known, the Mann-Whitney U test was selected for comparison between groups and sexes, in addition to Pearson's correlation coefficient test. **Results**: the length of the mandibular body, height of the ramus, height of the mandibular symphysis and alveolar processes, intercondylar distance, intergonion, and total length of the mandible were structural characteristics involved in the constitution of the skeletal disorder studied. Moreover, the spatial location of the mandible in relation to the maxilla and the base of the skull showed a strong influence on the configuration of this craniofacial disorder, evidenced by the protrusion of the mandible, an evident phenotype of the participation of this bone in Class III skeletal malocclusion. **Conclusion**: the involvement of structural and spatial characteristics of the mandible in relation to the maxilla and the cranial base in the constitution of Class III skeletal malocclusion was evident.

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INTRODUCTION

The mandible is the largest bone of the human face and plays a fundamental role in the constitution of facial physiognomy.[1] It is often considered the main responsible for the development of Class III malocclusion, whose skeletal configuration consists of varied phenotypic characteristics. Individuals may be affected by this craniofacial disorder, compromising facial aesthetics and deteriorating the quality of life.[2]

According to the contemporary literature, Class III skeletal malocclusion has a strong associated genetic component and is influenced by environmental factors, resulting in multifactorial etiology.[3-5] The characteristic phenotype of affected participants presents excessive mandible growth (a more advanced positioning in the anteroposterior direction in relation to the maxilla), hypodevelopment of the maxilla, or a combination of both.[3,4] Other studies go further by showing the existence of mandibular morphological determinants, as peculiar structural regions of the mandibular bone that are more prone to alterations and that may justify the profile observed in an affected subject.[6,7]

Given the above, this study seeks to understand mandible involvement in the configuration of Class III skeletal malocclusion, evaluating which structural characteristics of the mandibular bone express the Class III malocclusion phenotype, and what characteristics of the spatial relationship of the mandible with the maxilla and skull base influence the configuration of Class III malocclusion. This phenotypic analysis will be performed using lateral and anteroposterior cephalometric radiographs.

MATERIALS AND METHODS

This study was approved by the Research Ethics Committee of Clementino Fraga Filho University Hospital, at the Federal University of Rio de Janeiro (UFRJ) (protocol number 4.276.785).

Subject

This is a retrospective study with a convenience sample. This study was conducted with lateral cephalometric radiographs (LCR) of 80 individuals (31 females and 49 males) affected by Class III malocclusion (ANB≤0 or Wits≤-4) and anteroposterior radiographs (APR) of 70 individuals (25 females and 45 males) affected by Class III malocclusion. The control group comprised radiographs of individuals with excellent occlusion from the Department of Pediatric Dentistry and Orthodontics at the Federal University of Rio de Janeiro (UFRJ), totaling 20 LCR and 20 APR (10 females and 10 males).[1] The image inclusion criteria were as follows: individuals with normal overall health status, affected by Class III skeletal malocclusion, and with LCR and/or APR in their medical records. The exclusion criteria were individuals with any type of syndrome, cleft lip and palate, facial trauma, or submitted to previous orthodontic treatment. Steiner's analysis was chosen as the basis for determining the linear and angular values in the cephalometric tracing in lateral norm (Figure 1), while analysis of Rickets was used as the basis for the linear and angular values in frontal (Figure 2) norm. Using Dolphin Imaging *software*® version 11.5 (Dolphin Imaging, Chatsworth, California, USA), cephalometric tracings were performed by the same operator, under the same luminosity conditions (Table 1).

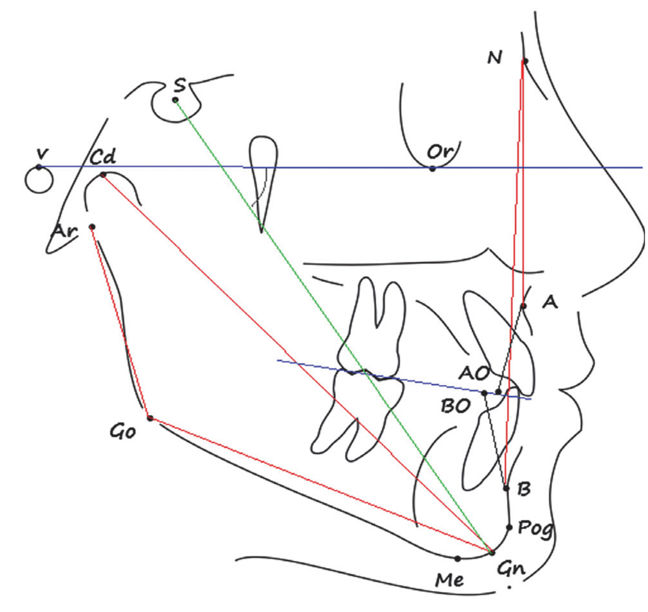

***Figure 1**: Lateral Cephalogram with reference points and lines to derive linear and angular measurements.*

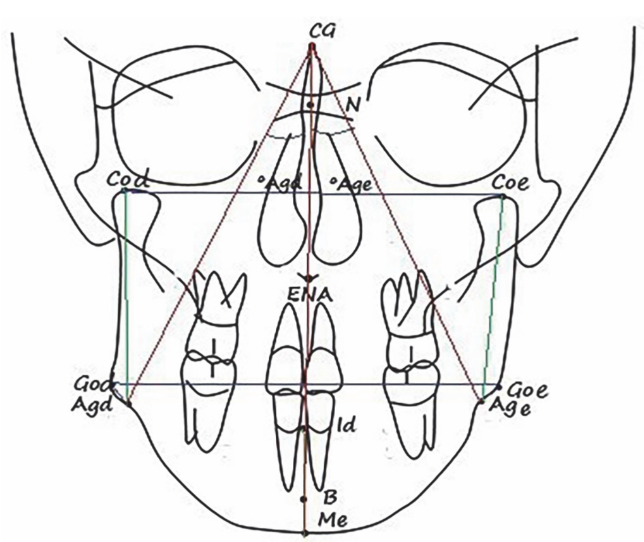

***Figure 2**: Cephalogram with reference points and planes to derive linear and angular measurements on Postero-Anterior Radiography.*

***Table 1**: Anatomical points, lines, planes, and reference angles for analysis of measurements in lateral cephalometric radiographs and postero-anterior radiographs.*

LCR landmarks	Definition	APR landmarks	Definition
N or Nasio	Anteriormost point of the frontonasal suture.	Nasio	Anteriormost point of the frontonasal suture.
A	Deepest point of the anterior contour of the pre-maxilla.	ENA	Point on the lower margin of the nasal opening; it marks the anterior nasal spine.
B	Deepest point of the anterior contour of the alveolar process of the mandibular symphysis.	Id or Infradental	The most anterosuperior point of the alveolar process of the mandible, into the cement and enamel union of the lower central incisors.
AO	Point found at the intersection of the projection of point A on the occlusal plane.	Me or Mental	Lowest point on the anterior contour of the mandible symphysis.
BO	Point found at the intersection of the projection of point B on the occlusal plane.	Co or Condyle	Highest posterior point of the jaw head. Cod – right side and Coe – left side.
Cd or Co	Uppermost point of the left jaw head	Go or Gonion	Lowest posterior point of the angle of the mandible. God – gonion on the right side and Goe – gonion on the left side.
Ar	Point located at the intersection of the posterior contour of the left head of the mandible with the occipital bone.	Ag ou Antigonion	Deepest point of antigonion notch, Agd – right side and Age – left side.
Go or Gonion	Midpoint between the posteriormost and lowest point on the mandibular angle, left side.	CG ou **Galli Crest**	Highest point of the Galli Crest.
Me or Mental	Lowest point of the contour of the mandibular symphysis.	-	-
Gn or Gnatio	Midpoint in the distance between Me and Pog points.	-	-
Pog or Pogonion	Outermost point of the mandibular symphysis contour.	-	-
S or Saddle	Point located at the geometric center of the Turkish saddle	-	-
V or Porio (Mechanical)	Uppermost projection point of the ear positioners.	-	-
Or or Orbital	Lowest point of the left orbit.	-	-

***Table 1**: Anatomical points, lines, planes, and reference angles for analysis of measurements in lateral cephalometric radiographs and postero-anterior radiographs.*

LCR lines and planes	Definition	APR lines and planes	Definition
NA	Joins points N and A.	CG-Me	Trace crest Galli-mental. Expresses the growth of the Middle and lower thirds of the face, in millimeters.
NB	Plotted between points N and B.	CG-Ag	Plane drawn between Galli crest and right and left anti-gonion points.
Frankfort Horizontal Plane	Joins mechanical portions and orbital points.	Cod-Coe	Intercondylar distance between Cod-Coe points, in millimeters.
Y Axis	Plan drawn between points S and Gn.	God-Goe	Intergonion distance between God-Goe points, in millimeters
Ar-Go Line	Height of the mandibular ramus, in millimeters.	Co-Ag	Measurements of the height of the mandibular ramus, in millimeters, right and left sides.
Go-Gn Plane	Length of the mandibular body, in millimeters.	Id-Me	Measurement of the height of the mandibular symphysis region and alveolar process, in millimeters.
Cd-Gn Line	Total length of the jaw, in millimeters.	-	-
Wits	Distance, in millimeters, between AO and BO points. Determines the intermaxillary relationship.	-	-
Angles measurements in LCR	**Definition**	**Angles measurements in APR**	**Definition**
ANB Angle	Intersection of NA and NB, determines the relationship between maxila and mandible, in degrees.	CG-Me-Agd	Angle formed by the intersection of CG-Me and CG-Agd planes.
Y Axis Angle	Intersection of the Y Axis with the Frankfurt Horizontal Plane, in degrees. Expresses the direction of mandibular growth.	CG-Me-Age	Angle formed by the intersection of CG-Me and CG-Age planes.

Statistical analysis

Data distribution and homogeneity of variances were evaluated in Graph Pad Prism 8.4.3 software using the Shapiro-Wilk test. According to the normality distribution of the samples, the non-parametric Mann-Whitney test was also performed, in addition to the Pearson correlation coefficient test in order to complement the descriptive analysis of the samples.

Post hoc estimates of the power of the analyzes were carried out assuming a significance level of 5% and using the effect sizes obtained for each comparison performed and the sample sizes for each group. These estimates were carried out using the G*Power 3.1 software.

RESULTS

Normal distribution was found for data from all LCR measures of the control group (excellent occlusion) and non-normal distribution for data from all LCR measures in the group with Class III skeletal malocclusion, except for Axis Y angle measures. Regarding APR sample data, the Shapiro-Wilk test showed normal distribution in the control group, except for cg-agd linear measures (mm). In the malocclusion group, five measures had normal distribution, and five had non-normal distribution. Considering the frequent result of non-normal distributions in the data, the Mann-Whitney nonparametric test was performed, aiming to highlight the structural and spatial characteristics of the mandible in Class III skeletal malocclusion, by distinguishing lateral and anteroposterior cephalometric measures in individuals with malocclusion and excellent occlusion. The same test was applied to verify differences between sexes in the groups. The *p*-value was also calculated to identify the significance level of the events surveyed. Medians and interquartile ranges were calculated, and measures were chosen based on discrepant values to describe the variability of the sample. The standard deviation of collected data was also calculated, demonstrating their variability. To complement the descriptive analysis of the samples, Pearson's correlation coefficient test was performed between cephalometric and anteroposterior measures Id-Me x ANB, Go-Gn x ANB, Go-Gn x Y Axis, Y and X AXIS, Ar-Go x Go-Gn, to measure the degree of correlation between such measures and their directions.

Considering the cited analysis, we observed a statistically significant difference in linear Go-Gn measures (mm), with *p*-value=0.0236*, indicating the greater length of the mandibular body in individuals affected by Class III skeletal malocclusion (median value 75.6(71.85-80.25)). Negative values of linear Wits measures (mm) were also identified in Class III skeletal malocclusion, in relation to the control group (*p*-value= 0.0001*). Angular ANB measures (º), with statistically significant differences (*p*-value= 0.0001*), were lower in individuals with malocclusion, configuring the anteriormost positioning of the mandible in relation to the maxilla. Moreover, the comparison of angular Axis Y measures (º) in the total sample showed a statistically significant difference (*p* -value=0.0030*), expressing displacement of mandible growth in the anterior direction in affected individuals (Table 2).

It was also possible to observe a significant difference between affected and unaffected men and women in linear Wits measures (mm) (*p*-value= 0.0001*) – the group with Class III skeletal malocclusion had higher negative values (median value M= [-1.5(-3.9 - 0.75)] and F= [-2.1(-3.8 - 0.8)]) than the control group (median value M= 3.8(2.5-4.6) and F= 3.1(1.3-4.4)). There was also a statistically significant difference in angular ANB values between the sexes (*p*-value M and F= 0.001*). Angular values were lower in the affected group (median value M= [-1.2(-3.35 – 0.65)] and F= [-1.4(-3.1 – 0.7]) indicating a more anterior positioning of the mandible in relation to the maxilla. However, the comparison of angular Y Axis measures (º) expressed a statistically significant difference between men affected by Class III malocclusion and those not affected (*p*-value M= 0.0098*), resulting in expressive anterior displacement of mandible growth in affected males (Table 3).

Table 4 shows a statistically significant difference in linear Id-Me measures (mm) between the control and the group with Class III skeletal malocclusion (*p*-value= 0.0387*). It shows that the heights of the mandibular symphysis and the alveolar process are smaller in individuals with Class III malocclusion (median value= 30.25(27.3 – 33.4) when they detect individuals in the control group (median value= 33.3 (29.3 – 36.25).

The comparison of linear CG-Me measures (mm) identified a divergence in the height of the middle and lower thirds of the face (*p*-value= 0.0035*) – women with malocclusion have a shorter face (median value F= 118.6(112.3 – 128.65) than those with excellent occlusion (median value F=133.6(124.4 – 141.6). Linear CG-Ag measures (mm) on the right and left sides also showed a statistically significant difference (*p*-value CG-Agd= 0.0034* and CG-Age= 0.0051*), with a greater distance between the craniometric points in women with malocclusion (median value CG-Agd= 109(102.15 – 114.15) and CG-Age= 109.2(102.55 – 114.6) (table 5).

Linear Cod-Coe measures (mm) revealed a statistically significant difference between women with and without Class III malocclusion (*p*-value= 0.0097*), identifying a shorter intercondylar distance in those affected with it. Another significant statistical value was found in linear God-Goe measures (mm) between women with malocclusion and the control (*p*-value= 0.0038*), revealing a shorter distance between the Gonium points, in millimeters, in affected women (table 5).

The height of the mandibular ramus, recognized by the linear Co-Ag measure, on the right and left sides, was smaller in women affected by Class III malocclusion (mediam value Co-Agd= 67.2 (63.4–70.6) and Co-Age= 67.6(64.3-70.95)) than in those with excellent occlusion (mediam value Co-Agd= 77.55(71.5-79.4) and Co-Age= 77.45(73.5-79.8)). There was also a statistically significant difference between affected and unaffected women concerning linear Id-Me measures (*p*-value= 0.0302*), showing a smaller height (median value in Class III group= 28.5(27.25-31.15) and Excellent occlusion group= 32.5(29.6-34.5)) of the mandibular symphysis region and alveolar process in women with malocclusion (table 5).

A strong positive correlation was found between Go-Gn (mm) and Y-axis measures (mm), establishing a direct proportion between them. This correlation was found in both the group with Class III malocclusion (r= 0.8501*) and the control group (r= 0.8975*). The same behavior was found between males and females of both groups (table 6).

The correlation between linear Ar-Go (mm) and Go-Gn measures (mm) was positive and moderate in the total sample (Excellent occlusion r= 0.6856* and Class III r= 0.5710*). There was also a moderate correlation in the same measures between men with (r= 0.6732*) and without malocclusion (r= 0.6988*). Only women with excellent occlusion showed a strong positive correlation (r= 0.8335*), while women with Class III malocclusion showed a weak positive correlation (table 6).

A strong positive correlation was found between linear Go-Gn (mm) and Cd-Gn measures (Excellent occlusion r= 0.9339* and Class III r=0.8972*), which were directly proportional. This result was present in correlating males (r= 0.9392*) and females (r= 0.9365*) with excellent occlusion and with Class III malocclusion (M r= 0.9357* and F r= 0.8185*), reinforcing the role of total or partial mandibular size in the configuration of malocclusion (table 6).

In table 6, a weak negative correlation was found between linear Go-Gn (mm) and angular ANB measures (º) in individuals with excellent occlusion (r= -0.3559), with Class III malocclusion (r= -0.1704), and men (r= -0.1520) and women (r= -0.2080) with malocclusion. Women with excellent occlusion had a weak positive correlation (r= 0.02058), while men in the same group had a strong negative correlation (r= -0.7046#), demonstrating that the longer the mandibular body, the smaller the degree of the ANB angle (i.e., the more anterior the mandible in relation to the maxilla).

Men with excellent occlusion also had a strong negative correlation between linear Y Axis measures (mm) and angular ANB measures (r= -0.7479#), indicating that in this group, the greater the distance between points S and Gn, the smaller the ANB angle (º) (i.e., the more anterior the mandible is positioned in relation to the maxilla) (table 6).

The other values presented in Table 6 do not indicate significant relevance to the study and therefore will not be commented separately.

Table 2: *Descriptive analysis and comparison between the group of individuals with excellent occlusion and individuals with Class III skeletal malocclusion on lateral cephalometric radiographs (LCR), considering the total sample.*

Measures	Min.	Max.	Median	Mean	Standard Deviation	Min.	Max.	Median	Mean	Standard Deviation	*p*-value
N-A (mm)	46.3	68.9	58.8 (55.45-62.65)	58.84	±5.4	40.2	78.7	56.85(54,05-60.3)	57.73	±6	0.2287
V-Or (mm)	54.1	83.3	95.95(92,15-99.1)	69.9	±7.9	44.1	87.6	95.55(90,25-102.6)	70.96	±7.3	0.9506
N-B (mm)	75.7	112.5	95.95(92,15-99.1)	95.21	±8.6	69.5	136	95.55(90,25-102.6)	96.22	±10.6	0.9506
Y axis (mm)	96.2	149.5	129.24(117.9-133.5)	126.48	±12.6	93.2	190.8	128.2(120.25-136.8)	129.38	±13.7	0.6673
Ar-Go (mm)	43.9	75.9	53.65 (50.95-60)	55.03	±7.8	38	76.7	51.7(48.4-55.5)	52.39	±6.5	0.0876
Go-Gn (mm)	52.3	83	71.85(69-75.85)	71.97	±6.6	54.4	108.4	75.6(71.85-80.25)	75.90	±7.6	**0.0236***
Cd-Gn (mm)	83.9	134.3	116.35(110.9-121.05)	115.06	±11.1	94.1	174.7	119.8(113.15-125.25)	120.19	±11.9	0.1386
Wits (mm)	0.8	6.8	3.4(1.8-4.5)	3.39	±1.7	-21.9	-6.5	(-3.7(-1.8-8.3))	-2.29	±4.4	**0.0001***
ANB (º)	0	5.7	2.25(1.55-3.3)	2.45	±1.4	-16.2	-5.2	1.3(3.15-0.65)	-1.67	±3.4	**0.0001***
Y axis (º)	54.3	72.4	62.5(59.65-66.4)	63.07	±4.8	39.6	72.7	58.7(55.15-62.5)	58,81	±5.5	**0.0030***

Table 3: Descriptive analysis and comparison between the group of individuals with excellent occlusion and individuals with Class III skeletal malocclusion on lateral cephalometric radiographs (LCR), considering the distinction between sexes.

Measures	Sex	N	Min.	Max.	Median	Mean	Standard Deviation	N	Min.	Max.	Median	Mean	Standard Deviation	*p*-value
-A (mm)	**M**	10	46.3	68.9	59.7(56.6-63.7)		±6.5	49	46.6	78.7	57.9(55.9-62.6)	59.53	±6.2	0.4697
	F	10	51	63.3	57.65(54.7-62.3)	57.74	±4.1	31	40.2	62.7	54.6(52.5-58.8)	54.68	±4.7	0.1001
V-Or (mm)	**M**	10	54.1	83.3	69.9(64.8-71.9)		±7.8	49	44.1	87.6	73.3(65-9-76.3)	71.56	±7.9	0.2601
	F	10	60.1	81.5	69.75(63-81)	70.76	±8.3	31	49.4	79.1	69.9(66.1-75.7)	69.84	±6.2	0.9227
N-B (mm)	**M**	10	75.7	112.5	95.95(94.4-97.4)		±9.3	49	82.5	136	97.4(92.7-105.25)	100.01	±10.1	0.5736
	F	10	82.3	105.1	95.4(86.1-99.6)	94.13	±8.2	31	69.5	113.8	92(84.2-97)	90.22	±9.3	0.3180
Y Axis (mm)	**M**	10	96.2	149.5	129.3(127-133)		±13.5	49	104,3	190.8	132.4(123.45-138.2)	133.32	±14.1	0.5011
	F	10	107.2	142.3	129.45(112.2-134)	124.71	±12.2	31	93.2	144.1	122.5(116.3-130.8)	122.46	±10.6	0.8506
Ar-Go (mm)	**M**	10	43.9	75.9	56.65(53.5-64.8)		±8.8	49	44.8	87.6	52.4(48.4-58)	53.86	±6.9	0.0726
	F	10	43	62.8	52.45(48.6-53.9)	52.1	±5.4	31	38	61	50.2(47.4-52.2)	49.76	±5	0.3564
Go-Gn (mm)	**M**	10	52.3	83	71.85(70.4-76.2)		±8.1	49	62.6	108.4	76.9(72.2-81.45)	77.28	±7.6	0.0929
	F	10	64.8	80.1	72.45(67.6-74.7)	71.72	±5.2	31	54.4	87.6	73.6(68.4-79.8)	73.32	±7.2	0.2437
Cd-Gn (mm)	**M**	10	83.9	134.3	118(114.3-121.8)		±12.9	49	99.4	174.7	120.8(115.05-128.35)	123.26	±12.4	0.2352
	F	10	101.7	128.7	113.6(104.4-117.9)	113.73	±9.4	31	94.1	139.6	116.3(108.4-120.7)	114.69	±9.5	0.5444
Wits (mm)	**M**	10	1	6.8	3.8(2.5-4.6)		±1.6	49	-21.9	6.1	(-1.5(-3.9 - 0.75))	-2.06	±4.6	**0.0001***
	F	10	0.8	6.6	3.1(1.3-4.4)	3,04	±1.8	31	-11.3	6.5	[-2.1(-3.8 - 0.8)]	-2.30	±4	**0.0001***
ANB (º)	**M**	10	0.6	5.6	2.25(2.1-2.8)		±1.3	49	-16.2	4.6	(-1.2(-3.35 - 0.65))	-1.42	±3.4	**0.0001***
	F	10	0	5.7	2.3(1.1-3.3)	2.39	±1.6	31	-9.4	5.2	(-1.4(-3.1 - 0.7))	-1.82	±3.3	**0.0001***
Y Axis (º)	**M**	10	59.4	72.4	63.75(60.3-67.1)		±4.2	49	45.9	68.1	59.2(56.1-63.65)	59.67	±4.8	**0.0098***
	F	10	54.3	70.4	61(57.6-65.7)	62.14	±5.4	31	39.6	72.7	58(54-61.1)	57.51	±6.4	0.0716

Table 4: Descriptive analysis and comparison between the group of individuals with excellent occlusion and individuals with Class III skeletal malocclusion on anteroposterior radiographs (APR), considering the total sample.

Measures	Min.	Max.	Median	Mean	Standard Deviation	Min.	Max.	Median	Mean	Standard Deviation	*p*-value
CG-Me (mm)	99.3	152.5	133.6(124.95-138.7)	131,93	±11.7	95.7	156.2	125.1(118.6-134.8)	126.91	±13.2	0.0590
CG-Agd (mm)	92,2	150.6	117.35(115.9-122.85)	118.0	±11	86.7	133.4	112.05(106-123.7)	113.66	±11.3	0.1170
CG-Age (mm)	91.7	149.9	116.9(113.95-112.4)	117.85	±11.9	86.2	135.4	111.3(104.6-121.2)	112.9	±11.4	0.0660
Cod-Coe (mm)	94	133.5	106.1(98.75-112.7)	107.08	±10.1	78	135.1	102.75(95.5-114.5)	105.56	±12	0.4652
God-Goe (mm)	83.7	122.2	99(91.75-104.5)	98.81	±9.4	71.1	126.2	96(88.4-105.1)	97.25	±11.3	5.263
Co-Agd (mm)	55.9	92.3	76(70.55-79.65)	74.62	±8.2	52.8	92.9	70.25(65.1-79.5)	71.83	±9.8	0.1471
Co-Age (mm)	55.2	97.5	75.4(71-79.8)	75.19	±9.4	52.3	93.7	69.75(66.4-78.7)	72.23	±9.6	0.1193
Id-Me (mm)	21.4	38.9	33.3(29.3-36.25)	32.5	±4.5	17.9	38.8	30.25(27.3-33.4)	30.14	±4.2	**0.0387***
Cg-Me-Agd (º)	16.8	24.9	20.85(20.15-22.15)	21.03	±1.8	17.3	26.1	21.6(20.3-23.2)	21.77	±1.9	0.1443
Cg-Me-Age (º)	18.3	24.9	21.8(19.4-22.95)	21.43	±2.1	17.4	27.7	22.05(21.3-23.2)	22.23	±1.8	0.1746

Table 5: *Descriptive analysis and comparison between the group of individuals with excellent occlusion and individuals with Class III skeletal malocclusion on anteroposterior radiographs (APR), considering the distinctions between sexes.*

Measures	Sex	N	Min.	Max.	Median	Mean	Standard Deviation	N	Min.	Max	Median	Mean	Standard Deviation	*p*-value
CG-Me (mm)	**M**	10	99.3	152.5	134.1(128.1-138.2)	130.93	±14.3	45	103.7	156.2	128(122.1-141)	130.79	±12.7	0.6711
	F	10	120.5	145.4	133.6(124.4-141.6)	132.94	±9	25	95.7	139.4	118.6(112.3-128.65)	119.87	±11.2	**0.0035***
CG-Agd (mm)	**M**	10	92,2	150.6	117.05(113.8-122.9)	117.99	±15	45	93	133.4	114(108.05-127.7)	116.57	±11.1	0.9230
	F	10	105.4	126	117.75(116.3-120.9)	118.01	±5.5	25	87.7	129.6	109(102.15-114.15)	108.29	±10	**0.0034***
CG-Age (mm)	**M**	10	91.7	149.9	116.65(112.6-122.7)	117.4	±15.3	45	91.7	135.4	113(106.55-126.9)	115.78	±11.2	0.7269
	F	10	102	129.8	117.4(114.7-122.1)	118.03	±8	25	86.2	127.3	109.2(102.55-114.6)	107.6	±10	**0.0051***
Cod-Coe (mm)	**M**	10	94.7	133.5	101.75(97.1-108-9)	105.55	±12.1	45	88.6	135.1	107.2(99.2-119.25)	109.27	±12.1	0.3679
	F	10	94	119.7	110.25(105.6-113.3)	108.61	±8	25	78	122.2	98.3(93.8-103.2)	99.23	±9.3	**0.0097***
God-Goe (mm)	**M**	10	83.7	122.2	94.45(88.4-104-6)	97.16	±11.6	45	82.9	126.2	99.7(92.9-109.2)	101.47	±10.9	0.2775
	F	10	86.8	109.8	110.25(105.6-113.3)	100.46	±6.9	25	71.1	105	89.1(85.65-93-7)	89.83	±8.2	**0.0038***
Co-Agd (mm)	**M**	10	55.9	92.3	74.15(70.3-80)	74.17	±10	45	55.3	90.3	72.3(65.6-83.95)	74.21	±9.8	0.9102
	F	10	60.6	82.7	77.55(71.5-79.4)	75.08	±6.5	25	52.8	92.9	67.2(63.4-70.6)	67.87	±8.7	**0.0092***
Co-Age (mm)	**M**	10	55.2	97.5	72.7(69.1-79.7)	74.66	±11.8	45	54.2	93.7	71.3(67.3-82.9)	74.76	±9.6	0.8847
	F	10	59.2	82.9	77.45(73.5-79.8)	75.73	±6.8	25	52.3	89.3	67.6(64.3-70.95)	28.86	±8.2	**0.0043***
Id-Me (mm)	**M**	10	21.4	38.5	33.95(29-36.5)	32.58	±5.4	45	21.2	38.8	31.2(28.1-34.25)	30.74	±4.2	0.3074
	F	10	26.5	38.9	32.5(29.6-34.5)	32.42	±3.8	25	17.9	35.5	28.5(27.25-31.15)	28.86	±3.7	**0.0302***
Cg-Me-Agd (º)	**M**	10	16.8	23	20.5(18.8-21.4)	20.35	±1.8	45	17.3	26.1	21.8(20.5-23.2)	21.98	±1.9	**0.0170***
	F	10	19.5	24.9	21.55(20.5-23.1)	21.72	±1.7	25	18.5	26.1	20.9(20.2-22.35)	21.43	±1.8	0.6727
Cg-Me-Age (º)	**M**	10	18.6	23.7	21.8(20.4-22.2)	21.35	±1.6	45	17.4	27.7	22.3(21.55-23.8)	22.54	±2	0.0759
	F	10	18.3	24.9	21.25(19.3-23.9)	21.51	±2.6	25	19.4	24.8	21.7(20.85-22.55)	21.62	±1.2	0.8505

***Table 6**: Descriptive analysis of the association between selected measures, performed with Pearson's correlation coefficient test.*

Coefficient Test and Pearson's Correlation				
Group	**Correlated Measures**	**r**	**Confidence Interv al (95%)**	***p*-value**
Patients with excellent occlusion	Go-Gn (mm) x ANB (º)	-0.3559	(-0.6898 - 0.1028)	0.1236
	Go-Gn (mm) x Y Axis (mm)	**0.8975***	(0.7546 - 0.9591)	<0.0001
	Ar-Go (mm) x GoGn (mm)	**0.6856***	(0.3490 - 0.8655)	0.0008
	Go-Gn (mm) x Cd-Gn	**0.9339***	(0.8375 - 0.9739)	<0.0001
	Y Axis (mm) x ANB (º)	-0.2205	(-0.6041 - 0.2460)	0.3501
	Id-Me (mm) x ANB (º)	-0.2128	(-0.5989 - 0.2536)	0.3677
Men with excellent occlusion	Go-Gn (mm) x ANB (º)	-0.7046#	(-0.9242 - (-0.1348))	0.0229
	Go-Gn (mm) x Y Axis (mm)	**0.9000***	(0.6239 - 0.9764)	0.0004
	Ar-Go (mm) x GoGn (mm)	**0.6988***	(0.1234 - 0.9225)	0.0246
	Go-Gn (mm) x Cd-Gn	**0.9392***	(0.7575 - 0.9858)	<0.0001
	Y Axis (mm) x ANB (º)	-0.7479#	(-0.9365 - (-0.2235))	0.0129
	Id-Me (mm) x ANB (º)	-0.5748	(-0.8844 - 0.08586)	0.0822
Women with excellent occlusion Ar	Go-Gn (mm) x ANB (º)	0.02058	(-0.6170 - 0.6419)	0.9550
	Go-Gn (mm) x (mm)	**0.9383***	(0.7541 - 0.9856)	<0.0001
	Ar-Go (mm) x GoGn (mm)	0.8335*	(0.4289 - 0.9595)	0.0027
	Go-Gn (mm) x Cd-Gn	**0.9365***	(0.7479 - 0.9852)	<0.0001
	Y Axis (mm) x ANB (º)	**0.2155**	(-0.4791 - 0.7442)	0.5498
	Id-Me (mm) x ANB (º)	**0.1689**	(-0.5156 - 0.7218)	0.6410

Note: Pearson correlation coefficient test. Indicates statistically significant positive correlations. #Indicates statistically significant negative correlations. Interpretation of r-values: r = +1 absolute positive linear correlation; r = -1 absolute negative linear correlation; r = 0 null linear correlation; r between 0.1 to 0.5 Weak positive or negative linear correlation; r between 0.5 to 0.7 Moderate positive or negative linear correlation; r between 0.7 to 0.9 Strong positive or negative linear correlation.*

Table 6: *Descriptive analysis of the association between selected measures, performed with Pearson's correlation coefficient test.*

Coefficient Test and Pearson's Correlation

Group	Correlated Measures	r	Confidence Interv al (95%)	*p*-value
Patients with Class III malocclusion	Go-Gn (mm) x ANB (º)	-0.1704	(-0.3760 - 0.05127)	0.1308
	Go-Gn (mm) x Y Axis (mm)	0.8501*	(0.7752 - 0.9015)	<0.0001
	Ar-Go (mm) x GoGn (mm)	0.5710*	(0.4017 - 0.7026)	<0.0001
	Go-Gn (mm) x Cd-Gn	**0.8972***	(0.8438 - 0.9330)	<0.0001
	Y Axis (mm) x ANB (º)	**-0.1915**	(-0.3947 - 0.02941)	0.0887
	Id-Me (mm) x ANB (º)	**0.09125**	(-0.1469 - 0.3194)	0.4525
Men with Class III malocclusion	Go-Gn (mm) x ANB (º)	-0.1520	(-0.4154 - 0.1350)	0.2971
	Go-Gn (mm) x Y Axis (mm)	0.8700*	(0.7795 - 0.9249)	<0.0001
	Ar-Go (mm) x GoGn (mm)	0.6732*	(0.4835 - 0.8025)	<0.0001
	Go-Gn (mm) x Cd-Gn	**0.9357***	(0.8882 - 0.9634)	<0.0001
	Y Axis (mm) x ANB (º)	**-0.2379**	(-0.4866 - 0.04638)	0.0997
	Id-Me (mm) x ANB (º)	**0.1073**	(-0.1923 - 0.3886)	0.4831
Women with Class III malocclusion	Go-Gn (mm) x ANB (º)	-0.2080	(-0.5237 - 0.1580)	0.2616
	Go-Gn (mm) x Y Axis (mm)	0.8123*	(0.6430 - 0.9059)	<0.0001
	Ar-Go (mm) x GoGn (mm)	0.2597	(-0.1042 - 0.5623)	0.1582
	Go-Gn (mm) x Cd-Gn	**0.8185***	(0.6538 - 0.9092)	<0.0001
	Y Axis (mm) x ANB (º)	**-0.1261**	(-0.4599 - 0.2389)	0.4989
	Id-Me (mm) x ANB (º)	**0.02976**	(-0.3697 - 0.4200)	0.8877

Note: Pearson correlation coefficient test. Indicates statistically significant positive correlations. #Indicates statistically significant negative correlations. Interpretation of r-values: r = +1 absolute positive linear correlation; r = -1 absolute negative linear correlation; r = 0 null linear correlation; r between 0.1 to 0.5 Weak positive or negative linear correlation; r between 0.5 to 0.7 Moderate positive or negative linear correlation; r between 0.7 to 0.9 Strong positive or negative linear correlation.*

DISCUSSION

The results of the present study show specific characteristics of the mandible phenotype that participate in the composition of Class III malocclusion. However, this is considered a craniofacial disorder of varied skeletal configuration, making it difficult to understand, and complex to solve. Data analysis suggests agreement with the literature, which describes that Class III skeletal malocclusion has multifactorial etiology, being influenced by genetic and environmental factors.[3,8]

The mandible body (GO-GN), the first unit of its ossification and with strong genetic influence,[9] showed to be higher in individuals affected by Class III malocclusion, with a statistically significant difference. This finding is in line with the results of studies on LCR by Singh, McNamara, and Lozanoff,[10] or with the findings of Lee *et al.*,[7] who studied individuals with Class III skeletal malocclusion and facial asymmetry in Conical Beam Computed Tomography (CBCT). Although a statistically significant difference was not found when analyzing linear Go-Gn measures between the sexes in the groups, men and women affected by malocclusion had longer jaw bodies than same-sex individuals in the control group.[7,10]

The mandibular symphysis, resulting from the endochondral ossification of the medial part of Meckel cartilage, may have structural features changed by environmental causes more easily while maintaining genetic characteristics. Individuals with malocclusion had a smaller height of the mandibular symphysis and alveolar processes than those with excellent occlusion, with a statistically significant difference. Thus, in the comparison between sexes, affected men presented a slightly smaller height of the mandibular symphysis and alveolar processes, while affected women had a statistically significant reduction in relation to those in the control group. The results of Singh, McNamara, and Lozanoff,[10] corroborate these findings, as they obtained a lower height of mandibular symphysis in individuals with Class III malocclusion.[10]

The height of the mandibular ramus also appeared as a peculiar feature of the Class III phenotype. The total sample had a lower height of the mandibular ramus, right and left, in the affected individuals. When comparing the sexes of the groups with Class III malocclusion and with excellent occlusion, it was found that the lowest height pattern of the mandibular ramus on both sides remained in affected male individuals. Also, affected women had statistically significantly lower height of the mandibular ramus on the right and left sides than those not affected. These findings corroborate those of Mossey,[5] who studied the heredity and influence of genetics on malocclusions. Uribe *et al.*,[3] also found similar results in two of the four groups in their study, composed of individuals with Class III malocclusion, from moderate to severe and with associated mandibular prognathism.[5]

Although there was no statistically significant difference when comparing the groups of affected and unaffected individuals, the intercondylar distance in the group with Class III skeletal malocclusion was smaller. According to the literature, dolichocephalic craniofacial conformation (in which transverse dimensions are smaller than height) concentrates a large number of skeletal Class III malocclusions. Between sexes, affected women had statistically significant shorter intercondylar distances. On the other hand, affected males had a slightly higher intercondylar distance than same-sex individuals with excellent occlusion.[11]

Studying the transverse measures of individuals affected by Class III malocclusion and individuals with Class III pseudo-occlusion, Akan and Veli,[11] found greater intergonial distance in men and women affected by true malocclusion. In the present study, however, the distance between the right and left gonions proved to be slightly smaller in the group with Class III skeletal malocclusion than in those with excellent occlusion, considering the total sample. In the comparison between females of both groups, statistically significant shorter distances were found between the right and left gonions in affected women. Only affected males had a greater intergonial distance than unaffected individuals.[11]

The spatial relationship between the mandible, the maxilla, and the cranial base also characterizes the involvement of this bone in the configuration of Class III skeletal malocclusion in the affected group. When comparing the sexes in both study groups, the same spatial relationship was present in men and women affected by Class III malocclusion. Furthermore, the Nuernberg[12] study analyzed the morphological craniofacial characteristics most frequently inherited in families whose members had Class III skeletal malocclusion, involving various age groups; they found negative ANB angles in all individuals with Class III malocclusion.[12]

CONCLUSION

The structural characteristics of the mandible, such as body length, ramus, symphysis and alveolar processes height, total mandibular length, and intercondylar and gonial angle distance directly influence the phenotypic configuration of the mandible in Class III skeletal malocclusion, causing an anteroposterior protrusion in relation to the maxilla and the cranial base, reinforcing the contribution of this bone in the most evident expression of the phenotype of Class III malocclusion.

REFERENCES

1. Bosman AM, Moisik SR, Dediu D, Waters-Rist A. Talking heads: morphological variation in the human mandible over the last 500 years in the Netherlands. Homo. 2017;68(5):329-42. doi: 10.1016/j.jchb.2017.08.002

2. Singh GD, McNamara JAJR, Lozanoff S. Procrustes, euclidean, and cephalometric analyses of the morphology of the mandible in human Class III malocclusion. Arch Oral Biol. 1998;43(7):535-43. doi: 10.1016/S0003-9969(98)00036-3.

3. Uribe LMM, Vela KC, Kummet C, Dawson DV, Southard TE. Phenotypic diversity in white adults with moderate to severe Class III malocclusion. Am J Orthod and Dentofacial Orthop. 2013;144(1):32-42. doi: 10.1016/j.ajodo.2013.02.019.

4. Bui C, King T, Proffit W, Frazier-Bowers S. Phenotypic characterization of Class III patients: a necessary background for genetic analysis. Angle Orthod. 2006;76(4):564-9. doi: 10.1043/0003-3219(2006)076[0564:pcocip]2.0.co;2.

5. Mossey PA. The heritability of malocclusion: part 2. The influence of genetics in malocclusion. Br J Orthod. 1999;26(3):195-203. doi: 10.1093/ortho/26.3.195.

6. Pan JY, Chou ST, Chang HP, Liu PH. Morphometric analysis of the mandible in subjects with class III malocclusion. Kaohsiung J Med Sci. 2006;22(7):331-8. doi: 10.1016/S1607-551X(09)70319-5.

7. Lee HY, Bayome M, Kim SH, Kim KB, Behrents RG, Kook YA. Mandibular dimensions of subjects with asymmetric skeletal Class III malocclusion and normal occlusion compared with cone-bean computed tomography. Am J Orthod Dentofacial Orthop. 2012;142(2):179-185. doi: 10.1016/j.ajodo.2012.03.024.

8. Nikopensius T, Saag M, Jagomagi T, Annilo T, Kals M, Kivistik PA *et al*. A missense mutation in DUSP6 is associated with Class III malocclusion. J Dent Res. 2013;92(10): 893-8. doi: 10.1177/0022034513502790.

9. Chen YJ, Yao CC, Chang ZC, Lai HH, Yeh KJ, Kok SH. Characterization of facial asymmetry in skeletal class III malocclusion and its complication for treatment. Int J Oral Maxillofac Surg. 2019;48(12):1533-41. doi: 10.1016/j.ijom.2019.06.014.

10. Singh GD, McNamara JAJR, Lozanoff S. Mandibular morphology in subjects with class III malocclusions: finite-element morphometric. Angle Orthod. 1998;68(5):409-18. doi: 10.1043/0003-3219(1998)068<0409:mmiswc>2.3.co;2.

11. Akan B, Veli I. Comparison of dental arch and mandibular-maxillary base widths between true and pseudo-Class III malocclusions. Am J Orthod Dentofacial Orthop. 2017;151(2):317-323. doi: 10.1016/j.ajodo.2016.06.039.

12. Nuernberg CC, Bolognese AM. What features of craniofacial morphology are most often inherited in families that have individuals with a Class III malocclusion? [dissertation]. Department of Pediatric Dentistry and Orthodontics: Faculty of Dentistry, Federal University of Rio de Janeiro; 2015. 112f.