RSBO

ISSN:
Electronic version: 1984-5685
RSBO. 2022 Jan-Jun;19(1):18-28

Original Research Article

Condylar process and temporomandibular disorders in orthognathic patients: cross-sectional study

Maria Fernanda Pivetta Petinati[1]
Paola Fernanda Cotait de Lucas Corso[1]
Juliana Feltrin de Souza[2]
Nelson Luis Barbosa Rebellato[1]
Rafaela Scariot[1]
Delson João da Costa[1]

Corresponding author:
Rafaela Scariot
Avenida Prefeito Lothario Meissner, n. 632
CEP 80210-170 – Curitiba – PR – Brasil
E-mail: rafaela_scariot@yahoo.com.br

[1] School of Health Sciences, Oral and Maxilofacial Surgery Department, Federal University of Paraná – Curitiba – PR – Brazil.
[2] School of Health Sciences, Department of Pediatric Dentistry, Federal University of Paraná – Curitiba – PR – Brazil.

Received for publication: September 14, 2021. Accepted for publication: November 12, 2021.

Keywords: temporomandibular joint disorders; maxillofacial abnormalities; cone-beam computed tomography.

Abstract

Introduction: The temporomandibular joint seems to respond to functional demands as it is continually subjected to remodeling, which affects volume and shape. Altered functioning can lead to TMJ overload, resulting in temporomandibular disorders. **Objective**: This study evaluates condylar anatomical changes and temporomandibular dysfunctions in orthognathic patients. **Material and methods:** This cross-sectional study was evaluated 174 Patients were between 18 and 57 years old representing facial patterns I (n = 51), II (n = 59), and III (n = 64). Morphology, morphometry and volumetry of 348 condylar processes were analyzed using cone beam computed tomography. Diagnosis of TMD was evaluated using Research Diagnostic Criteria for TMD (RDC/TMD). *P* values <0.05 were considered significant. **Results:** Patients with facial pattern II had more morphological changes than I (p <0.05). For morphometric analysis, the width of the condylar processes among patients with pattern II was shorter than I and III (p <0.001). Height of the condylar processes in patients with pattern III was greater than I and II (p <0.001). Volume of the left condylar process in patients with pattern II was lower than I (p = 0.02). Muscle disorders and other joint conditions were more common in women than men (p <0.05). Patients with pattern II had more muscular disorders and other joint conditions than I (p <0.05). Patients with pattern III showed more muscle disorders and disc displacement than I (p <0.05). **Conclusion:** Orthognathic patients have condylar anatomical changes that may facilitating temporomandibular disorders when compared to non-orthognathic patients. Condylar process morphology and morphometry can make it possible to define an anatomical pattern to contribute to decision-making regarding the treatment or not of a given temporomandibular disorders.

Introduction

The temporomandibular joint (TMJ) seems to respond to functional demands from childhood to adulthood, as it is continually subjected to remodeling, which affects volume and shape [1, 16]. Size and shape of the temporomandibular joint (TMJ) in Orthognathic patients with class II and III malocclusion showed major variations [4]. The mandibular condyle may undergo different functional loading in patients with different facial patterns [11]. Altered functioning can lead to TMJ overload, resulting in temporomandibular disorders (TMD) [11].

TMDs are frequently associated with degenerative changes in the bone structures of the TMJ [5]. According to Krisjane *et al.* [11], bone changes in TMJ are more commonly seen in class II and class III patients. Thus, from a clinical point of view, the functional loads applied to the TMJ may influence its morphology, since the shape and functions of the TMJ are closely linked [16].

Some dentofacial deformities may increase the risk of TMD [14]. The association between measurements and shape of the mandibular condyle on cone bean computed tomography (CBCT) has become increasingly important for assessing TMD-related clinical signs. Therefore, the objective of this study was to analyze whether condylar anatomical changes in orthognathic patients favor temporomandibular disorders.

Material and methods

Study design and sample

A cross-sectional observational study was conducted patients with facial pattern I, II or III. All patients had undergone CBCT due to preoperative planning of orthognathic surgery between 2016 and 2018 at the clinic for Bucomaxilofacial Surgery and Traumatology University Federal of Paraná, Brazil. This study was approved by the local Research Ethics Committee (CAAE: 69725317.5.0000.0102). Written informed consent was obtained in compliance with the World Medical Association Declaration of Helsinki, Ethical Principles for Medical Research Involving Human Subjects. Nine patients were excluded who had a previous surgical treatment in TMJ and the maxillofacial region, patients in clinical treatment for TMD or who used medications (anti-inflammatories, analgesics, and muscle relaxants), patients with a history of previous facial surgeries, trauma, pathology or syndromes involving structures related to the maxillomandibular complex. The convenience sampling consisted of patients with facial patterns I (n = 51), II (n = 59), and III (n = 64), totaling 174 patients or 348 condylar processes.

Data collection

During initial evaluation of the patients, demographic data such as sex, age and ethnicity were collected. Facial pattern classification was performed by observation assessing each patient face in the frontal and profile views. Patients were classified as I, II or III, inter-examiner (examiner M.F.P.P.: kappa = 0.913; examiner D. J. C.: kappa = 0.889) and intra-examiner (kappa = 0.887). Facial pattern was identified by facial balance in which malocclusion, when present, was only dental and not associated with any skeletal discrepancy. Facial patterns II and III are characterized, respectively, by mandibular retrognathism and mandibular prognathism [11]. Borderline cases were evaluated by the gold standard examiner (D. J. C.), maxillofacial surgeon with over 20 years of experience.

Three dimensional scans were acquired using the i-CAT Cone Beam 3D Imaging System (3D Imaging System, Hatfield, PA, USA). Volumes were reconstructed with 0.2 mm isometric voxel. The tube voltage was 120 kVp and the tube current 37.07 mA. Exposure time was 26.9 seconds. Segmentation of the head of the mandible was based on 2D Digital Imaging and Communications in Medicine (DICOM), created using CT data set and the software ITK-Snap (http: /www.itksnap.org). The sample of this study were seated during the exam and were oriented to have their heads positioned with the Frankfurt horizontal plane parallel to the floor.

The description for morphological classification was defined as normal for contour of the cortical bone intact and without alterations signals (figure 1). Morphological analysis of the condylar process was performed by two examiners (P.F.L.C. and M.F.P.P). Inter-examiner (examiner 1: kappa = 0.909; examiner 2: kappa = 0.892) and intra-examiner (kappa = 0.886) calibrations were performed. During morphological analysis of the tomographic images, all names contained in the DICOM files were blinded. The examiners analyzed sagittal (lateral) and coronal (frontal) sections of each condylar process separately throughout its length.

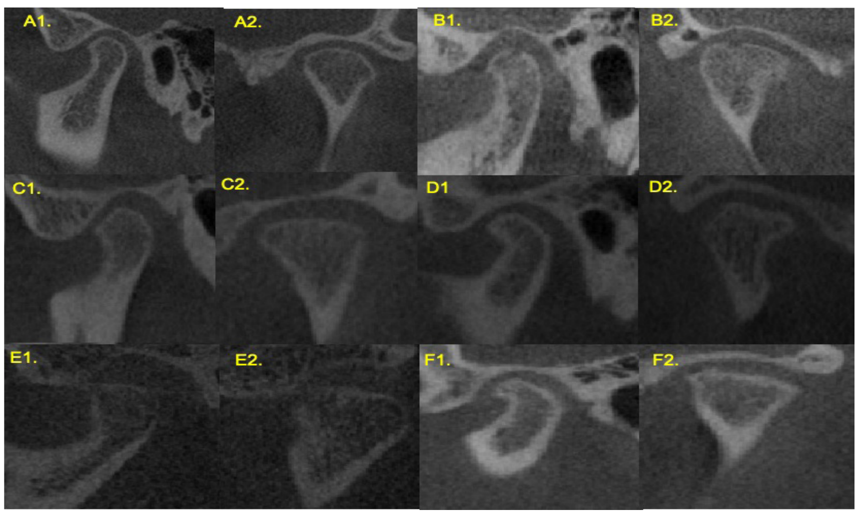

Figure 1 – Morphological classification. (A1 and A2) erosion for area of decreased density of the cortical bone and the adjacent subcortical bone (B1 and B2), flattening for flat bone contour deviating from the convex form (C1 and C2), osteophytes for marginal bone outgrowths on the condylar process (D1 and D2), deformation for other major alterations that do not fit in to another classification (E1 and E2) and combination for more than one classification of change in the same condylar process (F1 and F2) [5]

Morphometric and volumetric analyses were conducted using intra-examiner calibration (M.F.P.P.) through an analysis of 60 Cone Beam Computed Tomography (CBCT) examinations of the condylar process. Three analyses were performed for each measurement (volume, length, height, and width) at different times, within a 15-day interval (ICC = 0.937).

The points for morphometric and volumetric measures are in the figure 2. The points for morphometric measures were length, width, and height. Length was defined as the linear distance between the most anterior region of the head of the mandible (ACm), and the most posterior (PCm). Width was defined as the lateromedial linear distance of the head of the mandible (LCm-MCm). Height (h) was defined as the linear distance between superior region of the mandibular condyle (SCm) and the deepest point of the sigmoid notch (InM). For the volumetric analysis it was used for the delimitation of the condylar process some points as reference. For the lower delimitation we used the lowest point of the mandibular notch (InM) and the point of the most anterior region of the articular eminence (AEa). To delimit the upper portion, the point of choice was the upper mandibular condyle (SCm), while for the posterior region it was the posterior point of the mandibular condyle. The lateromedial limit was the medial point (MCm) and the lateral point of the mandibular condyle (LCm).

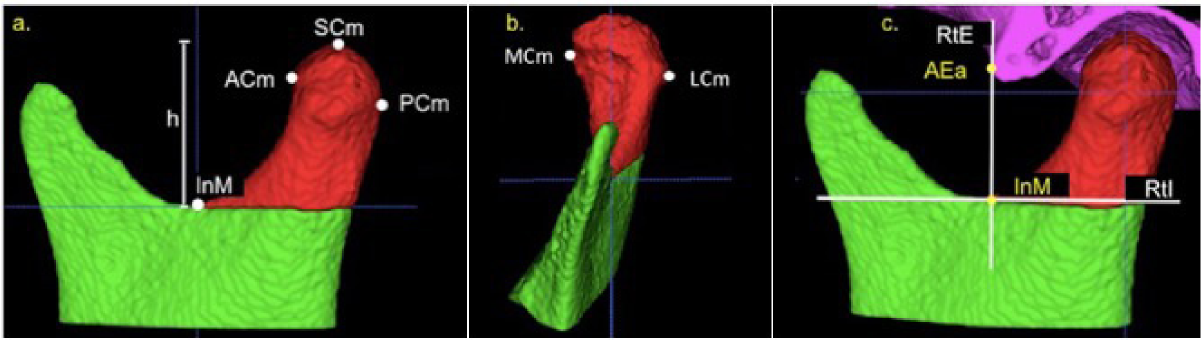

Figure 2 – Points for morphometric and volumetric measures. A) Sagittal view; B) Coronal view

Diagnostic evaluation of TMD was done using only the RDC/TMD [8]. This examination allows TMD diagnoses to be divided into three major groups, Group I (muscular diagnoses), Group II (articular disc displacements) and Group III (inflammatory joint diagnoses). For the purpose of statistical analyses, diagnoses were grouped into three main divisions: I, II and III.

For the diagnosis of muscle disorders, the patient should have reported pain and positive palpation of at least 3 points of the masticatory muscles. For the diagnosis of disc displacement, the patient should present snapping or opening limitation during the clinical examination. To classify the presence of other joint conditions, arthralgia, osteoarthritis or osteoarthrosis, the patient should report joint pain, and also present pain on palpation in the TMJ or joint noises during the examination.

Statistical analysis

The data collected were analyzed using descriptive and inferential statistics. Kappa test and the intra-class correlation coefficient were used to evaluate the reliability of the data according to classification of the variables. Evaluations of dichotomous dependent variables and independent variables were calculated using univariate Poisson regression. Age was dichotomized based on median values. The normality condition for numerical variables was evaluated by the Kolmogorov-Smirnov test. Comparison between facial patterns and morphometry were analyzed using the one-way ANOVA test, followed by the Tukey test. Kruskal-Wallis and Mann-Whitney U tests were used to compare facial patterns and volumetry. Univariate Poisson regression was used to evaluate between TMD diagnostic and sample characteristic (sex, age, ethnicity and patterns). Multivariate Poisson regression was performed for the variables that presented $p<0.2$ in the univariate Poisson regression. Values of $p<0.05$ indicated statistical significance. Data were analyzed using the IBM Statistical Package for the Social Sciences (IBM SPSS® Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.).

Results

This study was performed by analyzing mandibular condyles of 174 patients of orthognathic surgery patients. The analysis investigated CBCT images of 111 female and 63 male patients. The total median age was 26 (18-57) years. Caucasians dominated in all three facial patterns (70%).

Table I shows morphological changes in the condylar process according to epidemiological data and facial patterns (I, II or III). Caucasians had more right-sided morphological changes than non-Caucasians (RP: 2.25; 95% CI = 1.09 - 4.65; p = 0.02). Among the 38 Caucasians with morphological alterations on the right side, 16 were diagnosed with erosion, 13 flattening, 2 deformations, and 7 a combination of flattening and erosion. Patients with facial pattern II presented more morphological alterations than facial pattern I, for both right (RP = 2.75; 95% CI = 1.35 - 5.52; p = 0.005) and left (RP = 3.85; 95% CI = 1.85 - 8.02; p <0.001). Among the 22 patients with facial pattern II and morphological alterations to the right side, 6 were diagnosed with erosion, 6 flattening, 2 deformation, and 8 a combination of flattening and erosion. Among the 27 patients with facial pattern II and morphological changes to the left side, 6 presented with erosion, 5 flattening, 3 deformation, and 13 combinations (12 flattening and erosion, 1 flattening and osteophyte). Patients with facial pattern III had more morphological changes in the left condylar process than patients with facial pattern I (RP = 2.38; 95% CI = 1.08 - 5.24; p = 0.031). Among these patients, 14 presented with erosion, 1 flattening, 1 deformation and 1 a combination of flattening and erosion.

Table I – Crude prevalence ratio of morphological changes according to sample characteristics

Characteristics		Right side: With changes n (%)	Right side: Without changes n (%)	Right side: p Value	Right side: Crude PR [CI95%]	Left side: With changes n (%)	Left side: Without changes n (%)	Left side: p Value	Left side: Crude PR [CI95%]
Sex	Male	20 (44.4)	38 (35.8)	Reference	–	20 (39.2)	38 (38.0)	Reference	–
	Female	25 (55.6)	68 (64.2)	0.317	0.780 [0.47 – 1.27]	31 (60.8)	62 (62.0)	0.884	0.967 [0.61 – 1.52]
Age	≤26 years	24 (53.3)	67 (63.2)	Reference	–	29 (56.9)	62 (62.0)	Reference	–
	> 26 years	21 (46.7)	39 (36.8)	0.254	1.327 [0.81 – 2.15]	22 (43.1)	38 (38.0)	0.540	1.151 [0.73 - 1.80]
Ethnicity	Caucasian	38 (84.4)	68 (64.2)	0.02*	2.25 [1.09 – 4.65]	37 (72.5)	69 (69.0)	0.715	0.540 [0.66 -1.81]
	Non-caucasian	7 (15.6)	37 (34.9)	Reference	–	14 (27.5)	30 (30.0)	Reference	–
Pattern I		8 (17.8)	42 (39.6)	Reference	–	7 (13.7)	43 (43.0)	Reference	–
Pattern II		22 (48.9)	28 (26.4)	0.005*	2.75 [1.35 – 5.52]	27 (52.9)	23 (23.0)	<0.001*	3.85 [1.85 – 8.02]
Pattern III		15 (33.3)	36 (34.0)	0.118	1.83 [0.85 -3.94]	17 (33.3)	34 (34.0)	0.031*	2.38 [1.08 – 5.24]

Prevalence ratio of morphological changes according to sample characteristics
P value for Univariate Poisson Regression
* Significance level of 0.05.
PR – Prevalence Ratio
CI – Confidence Interval

The comparison of facial patterns with morphometric and volumetric measures can be observed in table II. The width of the condylar process of patients with facial pattern II was shorter than patients with facial pattern I and III ($p < 0.001$). The height of the condylar process of the patients with facial pattern III was greater than patients with pattern I and II ($p < 0.001$). The left condylar process volume of patients with facial pattern III was lower than patients with pattern I ($p = 0.02$).

Table II – Comparison of the morphometric and volumetric measures of the mandibular condyle according to the facial patterns

	Pattern I	Pattern II	Pattern III	p Value
Length (mm2) Right side Mean ± SD	13.15 ± 1.53	13.31 ± 1.89	12.87 ± 2.03	0.473†
Length (mm2) Left side Mean ± SD	12.77 ± 1.94	12.86 ± 1.87	12.47 ± 1.99	0.559†
Width (mm2) Right side Mean ± SD	a 18.62 ± 2.55	b 16.80 ± 2.95	a 19.63 ± 2.74	<0.001* †
Width (mm2) Left side Mean ± SD	a 19.02 ± 2.57	b 17.01 ± 3.22	a 19.12 ± 2.61	<0.001* †
Height (mm2) Right side Mean ± SD	a 16.23 ± 2.49	a 14.90 ± 2.78	b 18.08 ± 3.30	<0.001* †
Height (mm2) Left side Mean ± SD	a 15.62 ± 3.25	a 14.88 ± 2.51	b 17.89 ± 3.01	<0.001* †
Volume (mm3) Right side Medium (min-max)	618.90 (261.80-1246.15)	580.20 (288.55-1539.05)	511.60 (283.85-1301.70)	0.120
Volume (mm3) Left side Medium (min-max)	a 675.75 (235.25-1733.10)	ab 575.35 (169.85-1468.55)	b 530.10 (178.25-1444.0)	0.02*

Kruskal-Wallis test and Mann-Whitney U test for nonparametric data
* Significance level of 0.05
† One-way ANOVA test followed by Tukey's post-test for parametric data
SD = Standard Deviation
Equal letters – no significant difference between groups
Different letters – there is significant difference between groups

As shown in table III, muscle disorders (RP = 2.27; 95% CI = 1.17 - 4.40; p = 0.015), disc displacement (RP = 2.18; 95% CI = 1.01 - 4.73; p = 0.047) and other joint conditions (RP = 4.35; 95% CI = 1.36 - 13.91; p = 0.013) occurred more commonly in women than men. TMD was not associated with age or ethnicity (p > 0.05). Muscle disorders (RP = 9.07; 95% CI = 2.23 - 36.84; p = 0.002) and other joint conditions (RP = 4.03; 95% CI = 1.22 - 13.25; p = 0.022) occurred more frequently in patients with facial pattern II than patients with pattern I. Among the patients with facial pattern II and diagnosed with muscular disorders, 16 had myofascial pain (Ia) and 5 myofascial pain with mouth-opening limitation (Ib). Among patients with other joint conditions, 11 had arthralgia (IIIa) and 3 osteoarthrosis (IIIc). Patients with facial pattern II presented a borderline difference for disc displacement than pattern I (p = 0.055). Patients with facial pattern III had more muscle disorders (RP = 8.76; 95% CI = 2.16 - 35.54; p = 0.002) and disc displacement (RP = 3.38; 95% CI = 1.21 - 9.44; p = 0.020) than patients with facial pattern I. Among the facial pattern III patients with muscular disorders, 15 had myofascial pain (Ia) and myofascial pain with mouth-opening limitation (Ib). Among the facial pattern III patients with disc displacement, 14 had disc displacement with reduction (IIa) and 3-disc displacement without reduction and with mouth-opening limitation (IIb).

Table III – Prevalence ratio of TMD diagnostic groups according to sample characteristics

Group I Muscular disorders					
Characteristics		**With n (%)**	**Without n (%)**	**p Value**	**Crude PR [$CI_{95\%}$]**
	Female	36 (80.0)	75 (58.1)	0.015*	2.27 [1.17-4.40]
Age	≤26 years	21 (46.7)	80 (60.2)	0.074	0.632 [0.38-1.04]
	> 26 years	24 (53.3)	49 (38.0)	Reference	–
Ethnicity	Caucasian	36 (80.0)	85 (66.4)	0.105	1.71 [0.89-3.30]
	Non-caucasian	9 (20)	43 (33.6)	Reference	–
Pattern I		2 (4.4)	49 (38.0)	Reference	–
Pattern II		21 (46.7)	38 (29.5)	0.002*	9.07 [2.23-36.84]
Pattern III		22 (48.9)	42 (32.6)	0.002*	8.76 [2.16-35.54]
Morphology	With changes	19 (55.9)	69 (59.0)	0.747	1.10 [0.60-1.99]
	Without changes	15 (44.1)	48 (41.0)	Reference	–
Group II Disc displacements					
Characteristics		**With n (%)**	**Without n (%)**	**p Value**	**Crude PR [$CI_{95\%}$]**
Sex	Male	7 (20.6)	56 (40.0)	Reference	–
	Female	27 (79.4)	84 (60.0)	0.047*	2.18 [1.01-4.73]
Age	≤26 years	22 (64.7)	79 (56.4)	0.385	1.32 [0.70-2.50]
	> 26 years	12 (35.3)	61 (43.6)	Reference	-
Ethnicity	Caucasian	26 (78.8)	95 (67.9)	0.233	1.59 [0.74-3.44]
	Non-caucasian	7 (21.2)	45 (32.1)	Reference	–
Pattern I		4 (11.8)	47 (36.6)	Reference	–
Pattern II		13 (38.2)	46 (32.9)	0.055	2.80 [0.97-8.07]
Pattern III		17 (50.0)	47 (33.6)	0.020*	3.38 [1.21-9.44]
Morphology	With changes	16 (69.6)	72 (56.3)	0.243	0.61 [0.26-1.39]
	Without changes	7 (30.4)	56 (43.8)	Reference	–
Group III Other joint conditions					
Characteristics		**With n (%)**	**Without n (%)**	**p Value**	**Crude PR [$CI_{95\%}$]**
Sex	Male	3 (11.5)	60 (40.5)	Reference	–
	Female	23 (88.5)	88 (59.5)	0.013*	4.35 [1.36-13.91]

To be continued...

Continuation of table III

Characteristics		Group III Other joint conditions With n (%)	Without n (%)	p Value	Crude PR [$CI_{95\%}$]
Age	≤26 years	17 (65.4)	84 (56.8)	0.416	1.36 [0.64-2.89]
	> 26 years	9 (34.6)	64 (43.2)	Reference	–
Ethnicity	Caucasian	19 (76.0)	102 (68.9)	0.482	1.36 [0.57-3.21]
	Non-caucasian	6 (24.0)	46 (31.1)	Reference	–
Pattern I		3 (11.5)	48 (32.4)	Reference	–
Pattern II		14 (53.8)	45 (30.4)	0.022*	4.03 [1.22-13.25]
Pattern III		9 (34.6)	55 (37.2)	0.173	2.39 [0.68-8.37]
Morphology	With changes	13 (56.5)	75 (58.6)	0.853	1.07 [0.50-2.29]
	Without changes	10 (43.5)	53 (41.4)	Reference	–

Univariate Poisson regression
* Significance level of 0.05
RP – Prevalence Ratio
† – Arthralgia, osteoarthritis, and osteoarthritis were included for this category

In table IV, we analyzed the data using Poisson regression models for the TMD diagnostic groups that presented p <0.20 in the univariate Poisson regression. Women had more muscular disorders (RP = 2.04; 95% CI = 1.08 -3.85; p = 0.028) and other joint conditions (RP = 3.95; 95% CI = 1.24 - 12.54; p = 0.02) than men. Patients with facial pattern II had more muscular disorders (RP = 8.38; 95% CI = 2.07 - 33.88; p = 0.003) and other joint conditions than the patients with facial pattern I (RP = 3.54; 95% CI = 1.10 - 11.36; p = 0.034). Patients with facial pattern III showed more muscle disorders (RP = 8.37; 95% CI = 2.07 - 33.75; p = 0.003) and disc displacement (RP = 3.23; 95% CI = 1.16 - 9.00; p = 0.025) than pattern I.

Table IV – Multivariate Poisson regression for TMD diagnostic groups according to sample characteristics

		Group I Muscular disorders		Group II Disc displacements		Group III Other joint conditions †	
Characteristics		**p Value**	**PR adjusted [CI95%]**	**p Value**	**PR adjusted [CI95%]**	**p Value**	**PR adjusted [CI95%]**
Sex	Male	Reference	–	Reference	–	Reference	–
	Female	0.028	2.04 [1.08-3.85]	0.06	2.06 [0.97-4.37]	0.02*	3.95 [1.24-12.54]
Pattern I		Reference	–	Reference	–	Reference	–
Pattern II		0.003*	8.38 [2.07-33.88]	0.07	2.59 [0.91-7.38]	0.034*	3.54 [1.10-11.36]
Pattern III		0.003*	8.37 [2.07-33.75]	0.025*	3.23 [1.16-9.00]	0.214	2.21 [0.63-7.75]

Multivariate Poisson regression
* Significance level of 0.05
PR – Prevalence Ratio
† – Arthralgia, osteoarthritis, and osteoarthritis were included for this category
p <0.20 were included in the multivariate regression

Discussion

Patients with facial pattern II and III presented more bone changes than patients with facial pattern I. Our study is in line with previously published studies with the findings from Krisjane *et al.* [11], in which morphological alterations were shown to vary with skeletal types. This same author reported that morphological alterations were detected in 3% of class I, 43% of class II and 20 % of class III [11]. This finding may be explained by the balance between adaptive capacity and stresses placed on the joints. When there is a facial imbalance, remodeling may occur. Our results showed that for facial patterns II and III, the most frequent morphological alterations were erosion, followed by combinations (flattening and erosion, flattening and osteophyte, and flattening and deformation). Studies have reported on the distribution of bone alterations in the condylar process and its combinations [2, 5]. These studies present a prevalence of different types of bone changes. The reason for differences among these studies may be due to the difficulty in identifying bone alterations [8], which occurs via a gradual remodeling process.

In this study, the width of the condylar process of patients with facial pattern II was shorter than I and III. The height of the condylar process of patients with facial pattern III was greater than I and II. These findings show that a difference was maintained in the averages of width and height between class II and III. In particular, class II presented values lower than class III, a finding supported by the literature [8, 12]. Despite the length of the mandibular condyle being one of the most reliable measures to be analyzed by CBCT [18], the length of the condylar process did not show an association in our study. In fact, the head of the mandible of patients with facial patterns I, II and III displayed similar lengths. These measures are not commonly analyzed in imaging clinics yet. However, they may help in the diagnosis of TMD in the future and should become more prevalent [22].

Several studies in the literature have evaluated the volume of the mandibular condyle and the condylar process in facial deformities using CBCT images [17, 22]. No association was found between the volume of the right condylar process and facial patterns. On the left side, the condylar process volume is lower in patients with facial pattern III than I. An association between facial pattern and mandibular condyle volume on the left side only is unknown, and may be related to anatomical variations. However, differences between the measurements of facial patterns II and III, as observed in the morphometric analysis, were not maintained. In contrast to our study, Saccucci *et al.* [17] reported that Caucasian children with class III skeletal type had a significantly higher condylar process volume than their class I and II counterparts; whereas class II patients had a lower condylar process volume than class I and III patients. We attempted to interpret this data in light of the fact that asymmetry is normal for all structures of the human body.

Several factors and limitations are worth considering in the study of condylar anatomical. First, there is no standard software for choosing tools or methods for isolating the head of the mandible analysis by TCCB. In this present study, the deepest point of the sigmoid notch was used to isolate the head of the mandible. Similarly, the sigmoid notch was used in studies by Goulart *et al.* [7], and Schlueter *et al.* [19]. In the literature, there is still no data on the ideal mandibular condyle size or volume, but these data could be useful in predicting risk factors for certain pathology, such as disc displacement [17]. In addition, morphometric and volumetric measurements may be useful during the postoperative period after orthognathic surgery. These measurements may support the detection of early signs of pathological changes in the head of the mandible and distinguish them from physiological remodeling, thereby allowing the dentist to anticipate clinical changes in the patient's facial pattern [23].

Regarding the positive diagnoses for TMD and the characteristics of the sample, there was an association between sex and facial patterns. Women had more muscle disorders and other joint conditions (arthralgia, osteoarthritis, and osteoarthritis) than men. This finding concurs with other study, which have demonstrated more frequent bone changes in TMJ of women than men [1]. The higher occurrence in females can be explained by the hormonal influences of estrogen and prolactin, which may exacerbate cartilage and bone degradation, and stimulate a series of immune responses in the TMJ [24].

The interest in knowing whether there are structural variations in the TMJ and whether this change is related to a specific type of dentofacial deformity has been discussed for some time [9, 11]. In our study, even though there is ethnic diversity in the sample, there was association between morphological variations in the condylar process and Caucasian ethnicity, There is study that cited the influence of ethnicity on the morphology of the mandibular condyle [10] and others who observed only Caucasian ethnicity, the advantages of our study is the ethnic diversity and larger sample size compared to other studies [13, 22].

Our study showed that the facial patterns II and III have more muscular disorders than pattern I. This can be explained by the distinct angulations of the jaws in different facial patterns. Variations in the occurrence of tension may contribute to more muscular disorders in facial pattern II and III. A study of 47 class III patients, an association of myofascial pain with the facial pattern was noted during preoperative examination [21]. However, most studies on TMD and facial patterns compare patients in the preoperative or postsurgical orthodontic treatment phase with a control group [15, 20, 21], which pose difficulties when comparing their results with the findings in our study.

The literature suggests that facial pattern II patients have higher frequency of disk displacement [14]. Our study showed that patients with facial pattern III had more disc displacement than patients with pattern I. This result suggests that disc displacement may be influenced by factors other than facial pattern. It is important to note that facial pattern I was used as a reference in the regression model, so it is reasonable to assume that the results could differ if facial pattern II was compared to pattern III.

Regarding facial patterns and arthralgia, osteoarthritis and osteoarthrosis, some studies have evaluated the relationship between facial morphology and degenerative TMJ disorders. Despite methodological differences between the studies, all results suggest that there is an association between TMJ conditions and class II skeletal relationships [6, 11, 14]. In this study, facial pattern II presented more diagnosis for other joint conditions of the TMJ than pattern I. This fact is probably due to the effective length of the diminished mandible, generating such joint disorder.

Thus, patients with facial patterns II and III have more condylar anatomical changes and temporomandibular dysfunctions than pattern I, that is, this would represent orthognathic patients have condylar anatomical changes that may facilitating temporomandibular disorders when compared to non-orthognathic patients Morphometric and volumetric analysis of the mandibular condyle can make it possible to define an anatomical pattern to contribute to decision making regarding whether to treat or not a particular temporomandibular disorder.

References

1. Alexiou KE, Stamatakis HC, Tsiklakis K. Evaluation of the severity of temporomandibular joint osteoarthritic changes related to age using cone beam computed tomography. Dentomaxillofacial Radiol 2009;38:141-7.

2. Bae S, Park M-S, Han J-W, Kim Y-J. Correlation between pain and degenerative bony changes on cone-beam computed tomography images of temporomandibular joints. Maxillofac Plast Reconstr Surg 2017;39:1-6.

3. Capelozza L, Lorenzoni DC, Janson G, Henriques JFC. Subjective facial analysis and its correlation with dental relationships. Dental Press J Orthod. 2017;22:87-94.

4. Cohlmia JT, Ghosh J, Sinha PK, Nanda RS, Currier GF. Tomographic assessment of temporomandibular joints in patients with malocclusion. Angle Orthod 1996;66:27-36.

5. dos Anjos Pontual ML, Freire JSL, Barbosa JMN, Frazão MAG, dos Anjos Pontual A, Fonseca da Silveira MM. Evaluation of bone changes in the temporomandibular joint using cone beam CT. Dentomaxillofacial Radiol 2012;41:24-9.

6. Estomaguio GA, Yamada K, Ochi K, Hayashi T, Hanada K. Craniofacial morphology and inclination of the posterior slope of the articular eminence in female patients with and without condylar bone change. Cranio. 2005;23:257-63.

7. Goulart DR, Muñoz P, López MGC, de Moraes M, Olate S. Comparative evaluation of condylar volume between patients with unilateral condylar hyperplasia and class III dentofacial deformity. J Oral Maxillofac Surg 2017;75:180-8.

8. Katsavrias EG, Halazonetis DJ. Condyle and fossa shape in class II and class III skeletal patterns: a morphometric tomographic study. Am J Orthod Dentofac Orthop. 2005;128:337-46.

9. Katsavrias EG. Morphology of the temporomandibular joint in subjects with class ii division 2 malocclusions. Am J Orthod Dentofac Orthop. 2006;129:470-8.

10. Kiliç SC, Kiliç N, Sümbüllü MA. Temporomandibular joint osteoarthritis: cone beam computed tomography findings, clinical features, and correlations. Int J Oral Maxillofac Surg. 2015;44:1268-74.

11. Krisjane Z, Urtane I, Krumina G, Neimane L, Ragovska I. The prevalence of TMJ osteoarthritis in asymptomatic patients with dentofacial deformities: a cone-beam CT study. Int J Oral Maxillofac Surg. 2012;41:690-5.

12. Krisjane Z, Urtane I, Krumina G, Zepa K. Three-dimensional evaluation of TMJ parameters in Class II and Class III patients. Stomatologija. 2009;11:32-6.

13. Lentzen M-P, Riekert M, Buller J, Grandoch A, Zirk M, Zoeller JE et al. A volumetric study of mandibular condyles in orthognathic patients by semiautomatic segmentation. Oral Maxillofac Surg. 2021:1-8.

14. Manfredini D, Segù M, Arveda N, Lombardo L, Siciliani G, Rossi A et al. Temporomandibular joint disorders in patients with different facial morphology. A systematic review of the literature. J Oral Maxillofac Surg. 2016;74:29-46.

15. Mladenović I, Dodić S, Stošić S, Petrović D, Čutović T, Kozomara R. TMD in class III patients referred for orthognathic surgery: psychological and dentition-related aspects. J Cranio-Maxillofacial Surg. 2014;42:1604-9.

16. Saccucci M, D'Attilio M, Rodolfino D, Festa F, Polimeni A, Tecco S. Condylar volume and condylar area in class I, class II and class III young adult subjects. Head Face Med. 2012;8:1-8.

17. Saccucci M, Polimeni A, Festa F, Tecco S. Do skeletal cephalometric characteristics correlate with condylar volume, surface and shape? A 3D analysis. Head Face Med. 2012;8:1-8.

18. Scariot R, Gonsar B, Gill N, Furquim F, Corso PFC de L, Trevillato PC et al. Mandibular condylar dimensions: Correlation between 3D tomography and dried skull measurements. Cranio. 2019;37:153-8.

19. Schlueter B, Kim KB, Oliver D, Sortiropoulos G. Cone beam computed tomography 3D reconstruction of the mandibular condyle. Angle Orthod. 2008;78:880-8.

20. Sebastiani AM, Baratto-Filho F, Bonotto D, Kluppel LE, Rebellato NLB, da Costa DJ et al. Influence of orthognathic surgery for symptoms of temporomandibular dysfunction. Oral Surg Oral Med Oral Pathol Oral Radiol. 2016;121:119-25.

21. Sebastiani AM, de Lucas Corso PFC, Bonotto D, de Souza JF, da Costa DJ, Scariot R et al. Does orthognathic surgery improve myofacial pain in individuals with skeletal class III? One-year follow-up. Oral Surg Oral Med Oral Pathol Oral Radiol. 2018;126:322-30.

22. Tecco S, Saccucci M, Nucera R, Polimeni A, Pagnoni M, Cordasco G et al. Condylar volume and surface in Caucasian young adult subjects. BMC Med Imaging. 2010;10:1-10.

23. Xi T, Van Loon B, Fudalej P, Berge S, Swennen G, Maal T. Validation of a novel semi-automated method for three-dimensional surface rendering of condyles using cone beam computed tomography data. Int J Oral Maxillofac Surg. 2013;42:1023-9.

24. Yasuoka T, Nakashima M, Okuda T, Tatematsu N. Effect of estrogen replacement on temporomandibular joint remodeling in ovariectomized rats. J Oral Maxillofac Surg. 2000;58:189-96.