

Study of the Condilar Morphology in Cone-beam Computed Tomography Images and its Association with Biological Sex in Humans - Pilot study

Mayara Priscilla Teixeira Ribeiro¹, Victor Jacometti², Sergio Lucio Pereira de Castro Lopes³, Ricardo Henrique Alves da Silva⁴

¹Department of Stomatology, Public Health and Forensic Odontology, School of Dentistry of Ribeirão Preto, University of São Paulo, Ribeirão Preto, SP, Brazil

²Department of Pathology and Forensic Medicine, Ribeirão Preto Medical School, University of São Paulo, Ribeirão Preto, SP, Brazil,

³São Paulo State University (Unesp) - Institute of Science and Technology - São José dos Campos - Department of Biosciences and Oral Diagnosis - São José dos Campos, SP, Brazil

⁴Department of Stomatology, Public Health and Forensic Odontology, School of Dentistry of Ribeirão Preto, University of São Paulo, Ribeirão Preto, SP, Brazil

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ABSTRACT

Introduction: human identification is an important study area in deaths from violent causes of various types. Assessing anthropological and anthropometric characteristics, sex can be estimated using bone remnants, including the skull. As part of the skull, the mandible is widely useful for making such an estimate as it has very evident qualitative and quantitative sexual characteristics. The aim of this study was to analyze a possible association of the different shapes of the mandibular condyles with biological sex in a Brazilian sample in a preliminary way.

Methods: using the study by Yale et. al. (1966) as a reference, the morphologies of the condyles of 39 patients, divided into three age groups, were analyzed in cone beam computed tomography exams and classified in different formats according to the views in the coronal and axial sections. Image evaluation was performed using the OnDemand 3D software. Statistical analysis was performed using descriptive statistics in relation to condylar types in the total sample and by sex (absolute and relative frequency).

Results: it was observed that type B was the most found in both sexes in the coronal section, and in the axial section, it was type 1 in the anterior view and type 2 in the posterior view, on the right and left sides, in males and females.

Conclusion: it was concluded that there was no evident difference in this classification between the sexes, suggesting that the shape of the mandibular condyles doesn't have a strong relationship with sexual dimorphism in a Brazilian sample.

Keywords: Forensic Dentistry; Mandibular Condyle Morphology; Sexual Dimorphism; Cone-beam Computed Tomography.

Introduction

Forensic Anthropology, which is considered a secondary method of human identification, plays an important role and can aid significantly this process, since it allows the estimation of general information such as sex, estimated age, height and ancestry of an unknown individual^{1,2} - essential parameters to the biological profile construction.³ This establishment of the anthropological profile makes it possible to reduce the number of suspects and facilitates identification through a primary method. It should be noted that estimating the sex parameter accurately is essential to estimate age, stature and ancestry, once these characteristics show notable differences between males and females, in terms of aging and growth patterns, and in relation to the morphology of the individual⁴. Hence, biological sex can be estimated by an evaluation of metric and morphological characteristics of the bone remnants⁵. When the bones are fragmented or the skeleton is incomplete, although

the accuracy of sex estimation can be affected, the remains still have indispensable role, especially the skull². Frequently, the skull is the only structure that is found for examination⁶, being the second best bony structure for sex estimation, after the pelvis, reaching high accuracies (~92%)^{7,8}. By analyzing the mandible alone, several criteria, whether qualitative or quantitative, can be used for sex estimation with a high level of accuracy. In the study by Pereira et. al.⁹, a sample of 103 mandibles had several measurements studied to assess gender and age, achieving an accuracy of 90% in sex estimation. Also, a study by Dong et al.¹⁰, a sample of 203 cone beam computed tomography (CBCT) exams, 11 mandibular measurements were analyzed to analyze sexual dimorphism, among them, width between the condyles, width between the mental foramina, mandibular angle and maximum body length, obtaining an accuracy of up to 81.8%. In addition to the various quantitative characteristics, it's also important to remember that the qualitative

ones have great relevance, considering that sexual dimorphism in the mandible is well represented by the difference in size and shape between the sexes, with the first being larger and the latter more robust in males, in most cases^{11,12}. One of the ways to study the characteristics present in the mandible that can be used for sex estimation is to analyze the shape of the condyles, with or without radiographic or tomographic images. In 1966, Yale *et al.*¹³ carried out a study on 1560 skulls, classifying the morphology of the superior, anterior and posterior parts of the condyles in five different categories in posterior view and in three categories in superior view. Using this study as a reference, Arayapisit *et al.*¹⁴ examined the condylar morphology in 3000 panoramic radiographs and in 178 CBCT images of patients who also had panoramic radiographs, counting the incidence of the five categories between the sexes, as well as the age and tooth loss of the individuals, concluding that there was a significant relationship between the occurrence of the morphological categories of the mandibular condyles and the three mentioned factors (sex, age and tooth loss). For the analysis of the mandibular characteristics already mentioned, many reasons have contributed to the increase in the use of computed tomography (CT) exams, both in researches and in cases of human identification. In the case of CBCT, its use is advantageous mainly due to the low radiation dose required compared to regular CT, the absence of image overlap, the possibility of image reconstruction in several views, the precision of the measurements of the structures and also the fact that the images obtained are in three dimensions (3D)^{15,16}, allowing freedom of planning and case study. Furthermore, there are no size or shape distortions in the images produced, which makes the 3D reproduction of the patient/victim's skull accurate and reliable¹⁷, eliminating the limitations imposed by two-dimensional images¹⁸. Developing and improving studies of different bone elements that can help in human identification is of paramount importance¹⁹, since they are able to offer more possibilities for the analysis of the varied remains of a victim that can be found in situations of violent deaths or disasters. In addition to this, knowing that the characteristics of skeletons differ among existing populations in the world also makes it essential to produce studies of attributes such as sex, age, ancestry and stature in different people^{20,21}. Considering the importance of sex estimation for Forensic Anthropology study and for human identification, and the increasing use of computed tomography exams, based on the morphological classification proposed by Yale *et al.*¹³ (1966), the present pilot study aimed to evaluate the association of the different shape categories of the condyles, in the coronal and axial sections, in anterior and posterior views and in a superior view, with the biological sex in a Brazilian sample, through analysis of images from cone beam computed tomography scans.

Materials and Methods

Ethical aspects: The project was submitted to the Ethics Committee for Research with Human Beings, in order to fulfill all the requirements of Resolution 466/12, and was approved under the CAAE number: 44963521.0.0000.5419.

Sampling: A number of 140 digital CBCT scans were obtained through the collection of the Radiology and Imaging discipline of the Institute of Science and Technology – São Paulo State University “Júlio de Mesquita Filho” (UNESP), São José dos Campos campus, of female and male individuals, distributed in 75 exams of female patients and 65 exams of male patients. The sample was obtained retrospectively.

Sample selection criteria: All individuals who were of Brazilian origin, aged over 17 years and under 75 years on the date of the CBCT exam, and whose exam images allowed both dental arches and condyles to be visualized and analyzed in full were included in the sample. According to the findings of Okeson²², Lira, Fontenele²³ and Nguyen *et al.*²⁴, imaging exams of individuals who had total upper and/or lower dental absences, and/or who had partial dental absences of at least two posterior teeth were excluded from the sample, since these clinical conditions could constitute confounding factors in the analysis of condylar morphology. During the design of this study, the dental absence of third molars were not considered, due to the high incidence of agenesis of these elements, which reached 46.7% in the study by Singh *et al.*²⁵ and which had a world average rate of 22.63% in the work of Carter, Worthington²⁶.

Sample analysis: The CBCT exams were analyzed by a single evaluator in a dimly lit environment, using the OnDemand 3D software (Cybermed, South Korea), in the axial section window, to verify the shape of the anterior and posterior slopes of the condyles. Standardization was performed using the “rotate” tool. Predetermined brightness and contrast were used, with a 2X intensity filter for all exams. CBCTs were analyzed in the MPR window (multiplanar reconstruction). In the sagittal view, the plane of the hard palate parallel to the horizontal plane was adjusted. This was done with the plane rotation tool, taking into account the guidelines of the images. In the axial slices, the shapes of the anterior and posterior slopes were analyzed and, in the coronal slices, the superior slope for their respective classifications. Based on the bilateral classification of the mandibular condyles according to shape in anterior, posterior and superior views, proposed in the study by Yale *et al.*¹³, in 1966, the morphology of the superior surface of the condyles, in anterior and posterior views (coronal section), was classified into five different types (see Appendix A): Type A: flattened; Type B: convex; Type C: angled superiorly; Type D: rounded; Type E: surface with anomalous morphology, not corresponding to any of the previous types. In superior view (axial

section), the shape of the anterior and posterior surfaces of the condyle was classified into three types (see Appendix B): Type 1 (T1): concave; Type 2 (T2): convex; Type 3 (T3): flat. Using the information obtained, the morphological types of the condyles of the mandible were studied and classified bilaterally in each exam, in order to verify their greater or lesser occurrence between the sexes. The initial sample of 140 male and female tests was divided into five groups according to age, namely: Group 1: from 17 to 30 years old; Group 2: from 31 to 40 years old; Group 3: from 41 to 50 years old; Group 4: from 51 to 60 years old; Group 5: over 60 years old. After performing the analysis of all CBCT images, applying the sample selection criteria previously described, the sample was reduced to n=39, with 20 males and 19 females. As there were no representatives aged between 51 and 60 and over 60 years old, the division by age group included only the first three groups mentioned above. The overall mean age was 28.84 years, with a standard deviation of 7.54. In males, the mean age was 28.45 years, with a standard deviation of 7.49. In females, the mean was 29.26 years, with a standard deviation of 7.77.

Statistical analysis: To perform the analysis of the CBCT images, the intra-rater agreement was assessed by the Kappa's coefficient, repeating the assessments in 20% of the sample two weeks after the first examination. Descriptive statistics were used in relation to condylar types in the total sample and by sex (absolute and relative frequency). Furthermore, the Kappa's coefficient result was 0,87, indicating an excellent agreement.

Results

Analysis by sex: In male individuals, regarding the superior morphological classification in anterior and posterior views (coronal section), in the right condyle there were 10 individuals (50.00%) with type B classification, and, in the left condyle, there were 12 individuals (60.00%) who also presented type B predominantly, as shown in figure 1. In females, which can be seen in figure 2, it was possible to verify that,

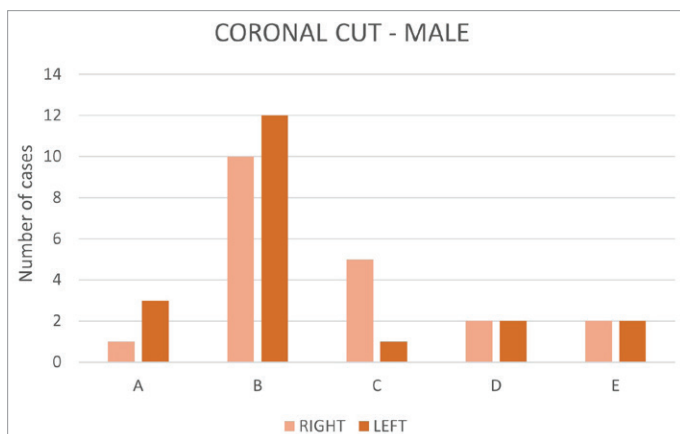


Figure 1. Distribution of types of classification of condylar morphology in anterior and posterior views (coronal section) in males.

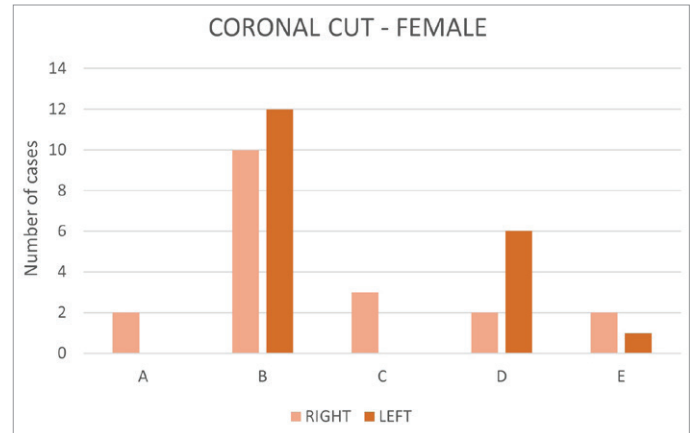


Figure 2. Distribution of types of classification of condylar morphology in anterior and posterior views (coronal section) in females.

as in males, most of the condyle types were classified as type B, with 10 images (52.63%) of the condyle on the right side and 12 images (63.15%) of the condyle on the left side within this type. An important point to be highlighted in figure 2 is in relation to the classification of the superior condylar morphology in anterior and posterior views in females, which, unlike what could be observed in males (Figure 1), didn't present condyles on the left side belonging to types A and C. As mentioned, in males there were, respectively, three and one cases classified within these two types on the left side, representing 15.00% and 5.00% of the sample, in this order. In addition to this point, it's also valid to highlight the difference in figures 1 and 2 between the sexes in the classification of the type D condyle on the left side, which occurred in six cases (31.57%) in the female and only in two (10.00%) in the male. Based on the results obtained in the condylar morphological classifications of the anterior and posterior surfaces in upper right and left views (axial section), there was no evident difference between the classifications of the right and left sides in males, as can be seen in figures 3 and 4. Regarding anterior and posterior condylar morphological classifications in superior view in females, as observed in figures 5 and 6, a first point noted between the right and left sides is related to

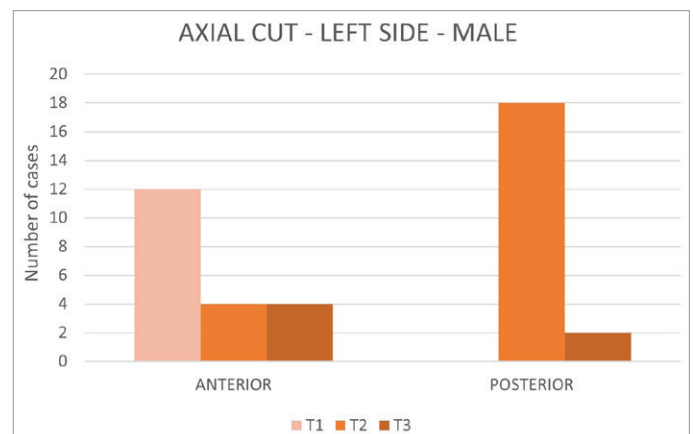


Figure 3. Distribution of types of anterior and posterior condylar morphological classifications in superior view (axial section) of the left condyle in males.

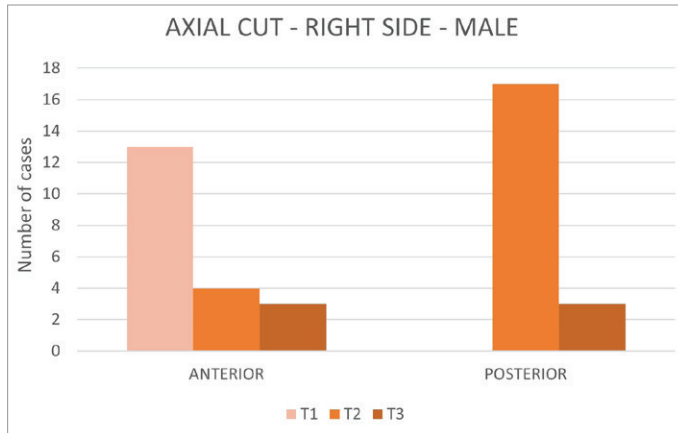


Figure 4. Distribution of types of anterior and posterior condylar morphological classifications in superior view (axial section) of the right condyle in males.

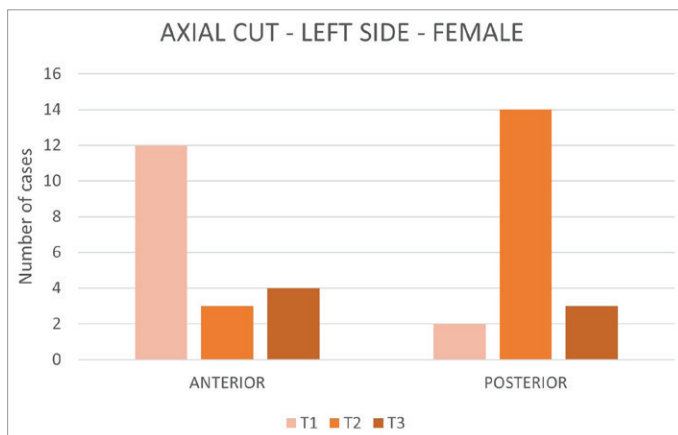


Figure 5. Distribution of types of anterior and posterior condylar morphological classifications in superior view (axial section) of the left condyle in females.

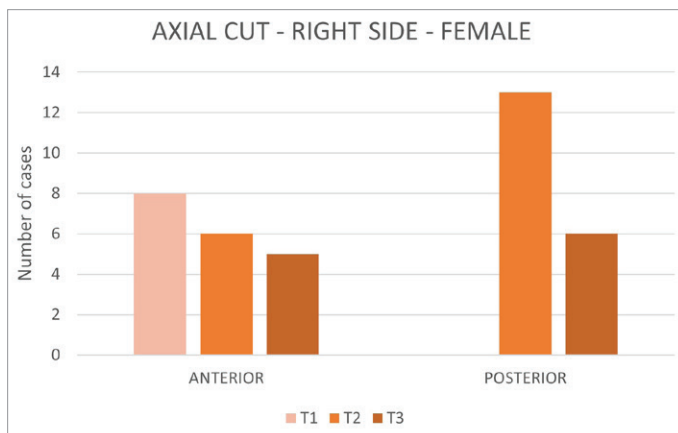


Figure 6. Distribution of types of anterior and posterior condylar morphological classifications in superior view (axial section) of the right condyle in females.

the absence of type 1 classification on the right side in posterior view, while there were two cases (10.52%) framed in this type on the left side in the same view. A second point observed in these figures concerns the difference in the number of exams of the left condyle classified as types 1 and 2 in the anterior view, which were, respectively, 12 (63.15%) and three (15.78%), while in the same view on the right condyle the numbers of these types were eight (42.10%) and six (31.57%). A third and final observation regarding these figures is in relation to the classification of type 3 in posterior

view, whose number of exams that fit this type in the left condyle was three (15.78%) and, in the right condyle, it was double (31.57%). Analyzing the superior view, the predominant type of anterior morphology was type 1 in both sexes. For females, on the right side, there were eight cases (42.10%) and, on the left side, there were 12 cases (63.15%). For males, there were 13 cases (65.00%) on the right side and 12 cases (60.00%) on the left side. Performing the analysis of the type of posterior morphology of the left and right sides, type 2 predominated, also in both sexes. For females, there were 13 cases on the right side (68.42%) and, on the left side, 14 cases (73.68%). For males, there were 17 cases on the right side (85.00%) in this classification, while on the left side there were 18 cases (90.00%).

Analysis by age groups: Group 1 (17 to 30 years old): As can be seen in figures 7 and 8, in males, in the coronal section of the right and left sides, most of the condyles were classified as type B. On the right side, there were five cases (41.66%), and, on the left side, there were eight cases (66.66%). In females, in relation to the coronal section of the right and left sides, the predominance was type B, with seven cases (63.63%) on both sides, also according to figures 7 and 8. In males, regarding the right axial view, as seen in figure 9, in the anterior view there were nine type 1 exams (75.00%), and in the posterior view, as shown

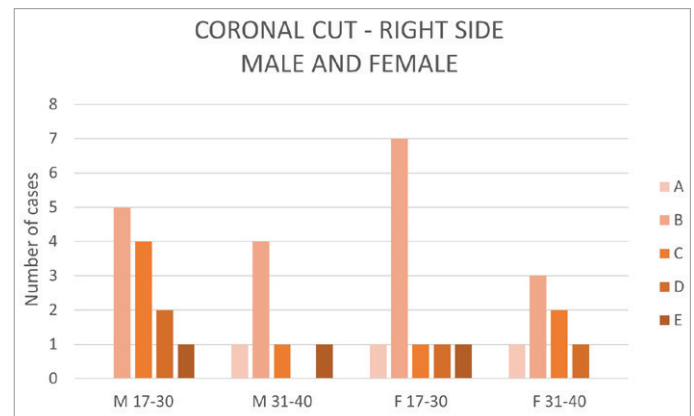


Figure 7. Distribution of condylar morphology types in anterior and posterior views (coronal section) on the right side by age groups in males (M) and females (F).

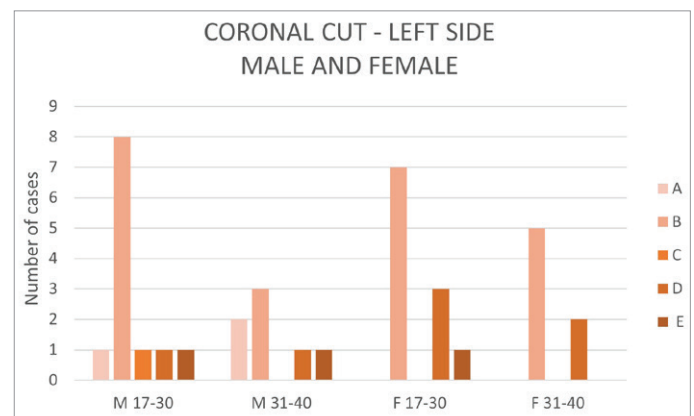


Figure 8. Distribution of condylar morphology types in anterior and posterior views (coronal section) on the left side by age groups in males (M) and females (F).

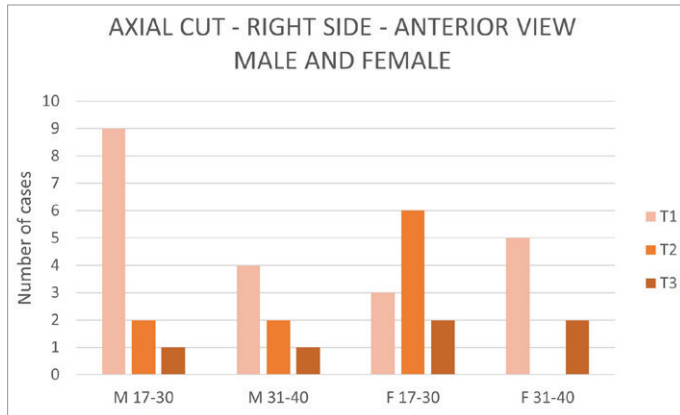


Figure 9. Distribution of types of condylar morphology in top view (axial section), anteriorly, on the right side by age groups in males (M) and females (F).

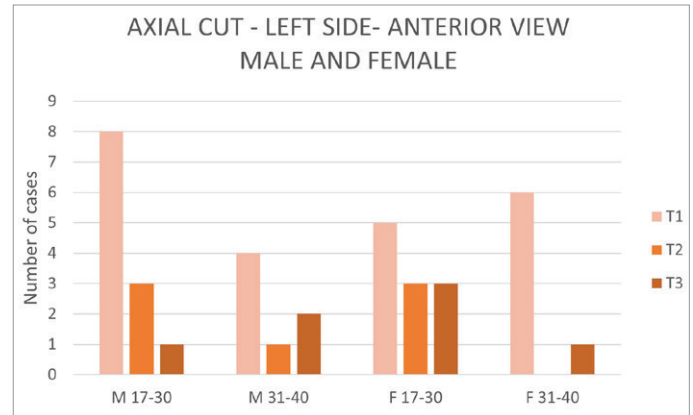


Figure 11. Distribution of types of condylar morphology in top view (axial section), anteriorly, on the left side by age groups in males (M) and females (F).

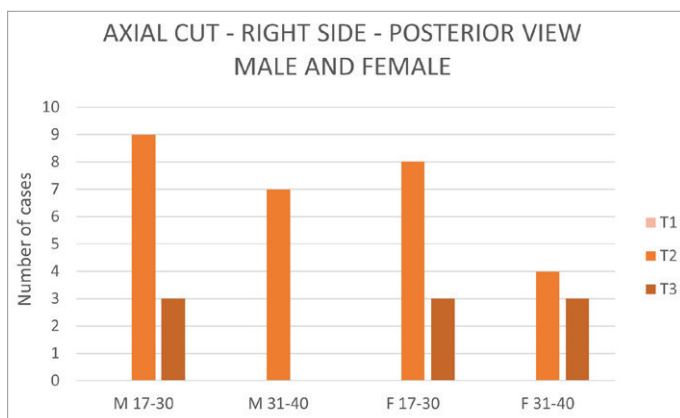


Figure 10. Distribution of condylar morphology types in top view (axial section), posterior part, right side by age groups in males (M) and females (F).

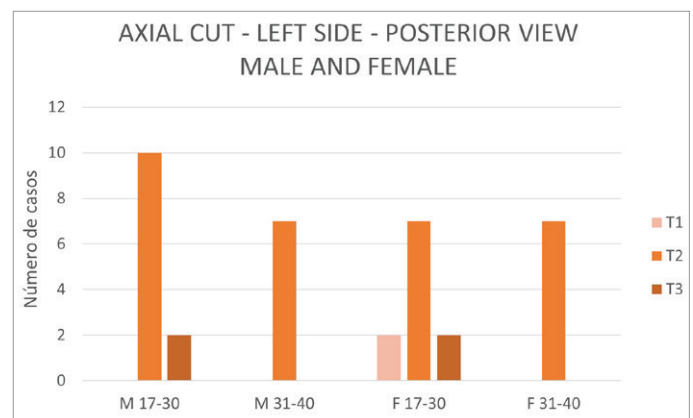


Figure 12. Distribution of types of condylar morphology in top view (axial section), posterior part, left side by age groups in males (M) and females (F).

in figure 10, nine exams were of type 2 (75.00%). In the left axial view, the majority, eight cases (66.66%), were classified as type 1 in the anterior view (figure 11), and, in the posterior view, there were 10 cases (83.33%) classified as type 2, according to figure 12.

As for the female sex, in the case of the right axial section in anterior and posterior views, it was possible to observe that type 2 encompassed the majority of cases, represented, respectively, by six (54.54%) and eight (72.72%) occurrences, as shown in figures 9 and 10. As for the left axial view, in the anterior view there was a majority of type 1, with five cases (45.45%) and, in the posterior view, the majority was of type 2, with seven cases (63.63%), as illustrated in figures 11 and 12. Group 2 (31 to 40 years old): As for males, in the coronal view of the right and left sides, most exams were classified as type B. On the right side, there were four cases (57.14%), and on the left side, there were three cases (42.85%), as illustrated in figures 7 and 8. In females, in the same cut, the predominant type was also B, both on the right side, with three cases (42.85%), and on the left side, with five cases (71.42%), also as observed in the figures 7 and 8. As for the right axial section in males in anterior view, it was possible to verify that most of the exams were classified as type 1, with four cases (57.14%), according to figure 9. In posterior view, all exams were classified

as type 2, with seven cases, as shown in figure 10. In the left axial section, in males, four cases (57.14%) were type 1 in males in anterior view (figure 11), and, in posterior view, all seven exams were type 2 (figure 12). In females, in the right axial view, in anterior view (figure 9) most of the exams were type 1, with five representatives (71.42%), and, in posterior view, most were type 2 (57.14%), with four representatives, as shown in figure 10. In the left axial view, as shown in figures 11 and 12, respectively, in the anterior view there was a predominance of type 1 cases, with six representatives (85.71%) and, in a posterior view, all the exams (seven cases) were type 2. Group 3 (41 to 50 years old): In the coronal section, in males, on the right and left sides, the type classified was type B. In females, on the right side it was type E and, on the left, type D. In males, the condylar morphology in the right axial view in anterior view was type 3 and, in the posterior view, type 2. In the left axial view in the anterior view, it was type 3 and, in the posterior view, type 2. Finally, in females, in the right axial view in anterior view, the condylar morphology was type 3 and, in posterior view, type 2. On the left side, it was type 1 in anterior view and type 3 in posterior view. As in this group, both in males and females, there was only one exam analyzed, the data were not included in figures 7 to 12.

Discussion

As cited by Al-Koshab *et al.*²⁷, the temporomandibular joint (TMJ) has an intimate relationship with the oral cavity and teeth, as the condyle structure is partially controlled by oral structures and muscles. With this relationship in mind, it is known that a variation in the normality of condylar morphology may occur, on one or both sides, throughout the individual's life, which may be linked to factors such as age, sex, facial type, occlusal strength, functional load and malocclusion²⁸, once the mandible is a dynamic facial bone that adapts to the functional demands during human development²⁹. As the mandible is considered an important sexual dimorphic marker both in size and shape³⁰, the present study sought to analyze a possible association of the morphology of the mandibular condyles with sexual dimorphism in humans. One of the difficulties faced in this search was to find well-defined parameters in the scientific literature regarding the dimension of the influence of the aforementioned variation factors and tooth loss on the morphology of the condyles. Considering that the condyle is susceptible to these changes, controlling possible elements of confusion in the condylar morphological classification was essential. For this reason, the authors evaluated the scientific criteria researched and, as they did not have access to the patients' medical records, since it was a retrospective study, they rigorously considered the sample inclusion factors. Thus, the exclusions of partial tooth loss in the present study were based on different studies. Firstly, in the works of Okeson²² (2013), it's understood that the force transmitted by the muscles to the teeth is greater than the one required when they are in function, which can generate an overload on the support structures of the masticatory system, such as the temporomandibular joints (TMJs), depending on the number of dental elements present in the oral cavity. Thereby, the smaller the number of opposing teeth in contact, the greater the overload of forces exerted on the dental elements present and the imbalance in the transmission of these forces to the joints, and, consequently, the greater the chance of damage to these structures²². Still seeking to verify a possible relationship between occlusal problems and the occurrence of temporomandibular disorders (TMDs), in 2020, Lira, Fontenele²³ carried out a study with 150 individuals with occlusion problems associated or not with posterior tooth loss, with or without painful symptoms, in which it was possible to conclude that the absence of posterior dental elements was associated with all TMD signs and symptoms analyzed. Regarding the determination of a minimum amount of missing dental elements that could interfere with an individual's occlusion and, in this way, cause TMD signs and symptoms, harming the TMJs. Okeson²² and Nguyen *et al.*²⁴ comment that, although there are studies in

the dental literature that cite the existence of a relationship between occlusion problems and the occurrence of TMD, this connection is still controversial. Therefore, it's observed that it's difficult to establish a consensus on a minimum number of missing teeth that could cause problems in the structures of the temporomandibular joints. A point that the study by Sousa *et al.*³¹ highlighted, however, is that the etiology of TMD is multifactorial and that a good dental occlusion keeps the craniomandibular system stable. In terms of possible links between an unstable occlusion due to loss of dental elements and the existence of structural changes in the condyle, the object of interest of the present study, the work of Rodrigues *et al.*³², in which radiographs of 123 individuals were analyzed, aimed to determine whether craniofacial factors and tooth loss are related to changes in the mandibular condyles. As a result of the descriptive analysis of the condyles performed after observation of the panoramic radiographs, the authors were able to conclude that anterior tooth loss didn't interfere with the condylar shape, but posterior tooth loss, especially of premolars and maxillary molars, was more associated with changes in the condyles, and that the absence of posterior dental elements has greater potential to damage the condylar bone structure. In view of the above, a consensus was reached in establishing a minimum tooth loss of two posterior teeth to perform the partial dental exclusions in the sample of this work. This control of confounding variables was carried out with the utmost care, sacrificing a large initial sample number and bringing more reliability to the results presented. As in the study by Yale *et al.*²² in dry skulls, in which most of the condyles (58.3%) were classified as type B in anterior and posterior views, the present study also had most of the condyles classified as type B in relation to the coronal section in both sexes, both on the right and left sides. The results obtained with this study were also similar to those of Ejima *et al.*³³, which found 111 condyles (72%), of 154 exams analyzed in CBCT, with the morphology classified as convex in the coronal section, and Kijima *et al.*³⁴, which found 78 of 191 temporomandibular joints with a convex shape using the classification by Yale *et al.*²⁵ In the study by Yalcin *et al.*³⁵, performed on cone beam computed tomography (CBCT), the condyle morphology in the coronal slice on the right side was convex (type B) in most of the sample (42.1%), similar to that found in this study, which was of 50.00% in males and, in females, 52.63% for the same side. As on the right side, on the left side, in the same section, Yalcin *et al.*³⁵ found the majority of 39.0% with convex morphology, while in this study there were 60.00% in males and 63.15% in females on the left side, also constituting the majority of cases. Differently from what was observed in this work, in the study by Al-Ghurabi *et al.*³⁶, also performed on cone beam computed tomography, most condyles

had morphology classified as rounded in males and females (45%) in the coronal view, while Shubhasini *et al.*³⁷, of 32 condyles evaluated in CBCT, found 12 (37.5%) with angled morphology, with the convex shape observed in 31.3% of the sample in coronal section, which was the morphological type predominant in both sexes in the present study. Evaluating the relationship between condylar morphology and age of individuals, Tassoker *et al.*³⁸ and Yalcin *et al.*³⁵ found that, in age groups from 56 to 80 years old, the condylar morphology of the flattened and angled type was more predominant than in younger groups from 18 years old. Tassoker *et al.*³⁸ were also able to notice that, among young females and males, convex morphology was the majority in 54.4% and 48.1% of the sample, respectively. In comparison with the present study, it's observed that, in the age group from 17 to 30 years, in both sexes and in the coronal section, on both sides, there was also no great expression of these same morphologies of the flattened and angled type, predominating the convex type in this age group. The study by Al-Ghurabi *et al.*³⁶ also obtained similar results to the present study in relation to condylar morphology and age groups, as the authors reported a higher occurrence of convex condylar shape in the younger age group, between 20 and 29 years. With results agreeing to those of Tassoker *et al.*³⁸, Rodrigues *et al.*³² and Yale *et al.*²², this study found no relationship between condylar morphology and its association with sexual dimorphism

in humans. In contrast, Yalcin *et al.*³⁵ concluded that there was a difference between condylar shape and sex, noting that the occurrence of the flattened shape is more common in men than in women and that the condylar classification of the flattened type in both sexes is uncommon. Apparently, there is no relationship between condylar morphology and sexual dimorphism in the sample analyzed in the present work. However, further studies should be carried out in the future, considering that when the condylar morphological classification of the sample was stratified by age, there were differences between the predominant types, especially in the axial section. On the right side, in anterior view, in group 1, there were more cases classified as type 1 in males and as type 2 in females, while, in group 3, in the same section, side and view, type 3 was predominant in both sexes.

Conclusion

Analyzing the condylar morphology in the CBCT images, it was observed that type B was the most prevalent in both sexes in the coronal view, and, in the axial view, it was type 1 in anterior view and type 2 in posterior view, on both sides, in males and females. Therefore, it was possible to conclude that there was no evident association with this classification between the sexes, suggesting that the shape of the mandibular condyles does not have a strong relationship with sexual dimorphism in this Brazilian sample.

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Mini Curriculum and Author's Contribution

1. Mayara Priscilla Teixeira Ribeiro – DDS. Contribution: Effective scientific and intellectual participation of the study; technical procedures; data acquisition, data interpretation; preparation and draft of the manuscript. ORCID: 0000-0002-5175-8204
2. Victor Jacometti – DDS; MSc. Contribution: Effective scientific and intellectual participation of the study; study design; technical procedures; data acquisition, data interpretation; statistical analysis; preparation and draft of the manuscript; critical review and final approval. ORCID: 0000-0001-7411-2054
3. Sergio Lucio Pereira de Castro Lopes – DDS; PhD. Contribution: Effective scientific and intellectual participation

of the study; study design; technical procedures; technical support; critical review and final approval. ORCID: 0000-0002-0882-5862

4. Ricardo Henrique Alves da Silva – DDS; PhD. Contribution: Supervising Professor, technical support; critical review and final approval. ORCID: 0000-0002-1532-1670

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Corresponding author
Ricardo Henrique Alves da Silva
E-mail: ricardohenrique@usp.br