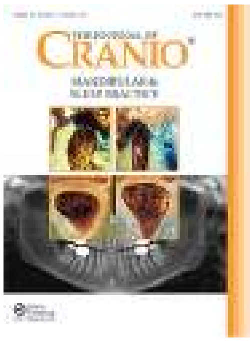

CRANIO®

The Journal of Craniomandibular & Sleep Practice

ISSN: 0886-9634 (Print) 2151-0903 (Online) Journal homepage: http://www.tandfonline.com/loi/ycra20

Comparative analysis of jaw morphology and temporomandibular disorders: A three-dimension imaging study

Anna Colonna DDS, Daniele Manfredini DDS, PhD, MSc, Luca Lombardo DDS, Luca Muscatello MD, Rosario Marchese-Ragona MD, Niki Arveda DDS & Giuseppe Siciliani MD

To cite this article: Anna Colonna DDS, Daniele Manfredini DDS, PhD, MSc, Luca Lombardo DDS, Luca Muscatello MD, Rosario Marchese-Ragona MD, Niki Arveda DDS & Giuseppe Siciliani MD (2018): Comparative analysis of jaw morphology and temporomandibular disorders: A three-dimension imaging study, CRANIO®, DOI: 10.1080/08869634.2018.1507094

To link to this article: https://doi.org/10.1080/08869634.2018.1507094

Published online: 14 Aug 2018.

Submit your article to this journal

View Crossmark data

Full Terms & Conditions of access and use can be found at
http://www.tandfonline.com/action/journalInformation?journalCode=ycra20

CRANIO®: THE JOURNAL OF CRANIOMANDIBULAR & SLEEP PRACTICE
https://doi.org/10.1080/08869634.2018.1507094

RADIOLOGY

Check for updates

Comparative analysis of jaw morphology and temporomandibular disorders: A three-dimension imaging study

Anna Colonna DDS [a], Daniele Manfredini DDS, PhD, MSc [a], Luca Lombardo DDS[a], Luca Muscatello MD[b], Rosario Marchese-Ragona MD[c], Niki Arveda DDS[a] and Giuseppe Siciliani MD[a]

[a]Postgraduate School of Orthodontics, University of Ferrara, Ferrara, Italy; [b]Section of ENT Pathology, NOA Hospital, Massa-Carrara, Italy; [c]Section of ENT Pathology, Department of Neuroscience, University of Padova, Padova, Italy

ABSTRACT

Objective: To investigate the association between volumetric measurements of craniofacial morphology and temporomandibular disorders (TMDs).

Methods: Computerized tomography (CT) scans of 20 individuals aged 18 to 40 with (TMD group) or without TMJ pain (control group) were gathered based on a case-control design. Three-dimensional reconstructions were performed to evaluate the gonial angle, condylar volume, and the distance between the posterior edge of the condyle and the sigmoid notch.

Results: The gonial angle was significantly larger (8% difference) in the TMD group with respect to controls, whereas the condylar volume was significantly higher in the control group (15.2% difference). No significant difference was found in the linear distance.

Conclusion: There is an association between the presence of TMJ pain and some features of craniofacial morphology. Individuals with TMJ pain have a lower condylar volume and a tendency towards hyperdivergent growth.

KEYWORDS
Temporomandibular disorders; facial morphology; 3D imaging study

Introduction

Temporomandibular disorders (TMDs) are a heterogeneous group of conditions affecting the temporomandibular joint (TMJ), masticatory muscles, and/or associated structures [1]. They are the main cause of non-odontogenic orofacial pain [2] and have a multifactorial etiology, involving anatomical, neurological, endocrine, psychosocial, and cognitive-behavioral factors [3]. Over the years, the importance of dental occlusion as the target for diagnosis and treatment has progressively diminished in favor of more centrally-oriented strategies for pain diagnosis and management [4,5].

However, some severe malocclusion traits, e.g., large overjet, that may mirror peculiar skeletal features have been occasionally associated with the presence of TMDs [6,7]. Thus, facial morphology, rather than dental occlusion, can be associated with TMDs. For instance, a recent review has concluded that hyperdivergent jaw growth pattern and Class II skeletal profile are associated with a higher frequency of TMJ disc displacement and degenerative disorders [8]. The same review also pointed out that the available knowledge on the topic is based on linear and angular, i.e., bi-dimensional, measurements to assess joint morphology [8].

Within these premises, the aim of this study was to investigate some parameters of jaw and condylar morphology in individuals with and without clinical TMD symptoms, e.g., TMJ pain. The study hypothesis was that, based on the skeletal Class II-TMD association, subjects with TMJ disorders have a lower condylar volume, unrelated with the presence of degenerative joint disease. To test the hypothesis, three-dimensional (3D) condylar measurements were performed.

Materials and methods

A case-control study was designed, and participants included two groups of individuals belonging to either a study ("TMD") or a control group. The study group comprised 11 patients seeking TMD treatment at the School of Dentistry of the University of Ferrara, Ferrara, Italy; the control group included 11 age- and sex-matched TMD-free subjects seeking care at the Otorhinolaryngology Department of the University of Padova, Padova, Italy.

CONTACT Anna Colonna annachiara.colonna@gmail.com Postgraduate School of Orthodontics, University of Ferrara, Via Borsari 46, Ferrara 44100, Italy

Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/ycra.

© 2018 Informa UK Limited, trading as Taylor & Francis Group

TMD patients were recruited retrospectively based on the presence of TMJ pain and the availability of a computerized tomography (CT) that was previously prescribed by other colleagues. The control group was selected among patients without TMD symptoms who had undergone maxillofacial CT for ENT (ear, nose, throat) reasons. Potential participants were excluded if aged older than 40 or younger than 18 years or if they had congenital craniofacial syndromes, generalized arthrosis disease, a history of previous TMJ surgery, and/or significant trauma.

Images were assessed by a maxillofacial radiologist, who evaluated the TMJ status and excluded any signs of disease.

The study protocol was reviewed and approved by the Institutional Review Board of the Postgraduate School of Orthodontics, University of Ferrara, Ferrara, Italy. Informed written consent was signed by all participants.

Multiple software was used to elaborate CT scans and compare some parameters of jaw and condylar morphology between the two study groups:

- An open-source Digital Imaging and Communication in Medicine management program (Osirix, Pixmeo SARL, Switzerland) was used to transfer and anonymize the clinical datasets.
- 3D rendering of each skull was obtained from digital volumetric tomography using the 3D Slicer open-source software platform [9], which allows segmentation of files. The mandible and joint area were isolated and exported in STL format (Figures 1–3).
- Rhinoceros software (Robert McNeel & Associates, Seattle, WA, USA) was then used to create a geometric model of each mandible from the STL mesh. To isolate each hemi-mandible, the virtual model was orientated using the posterior portion of the condyle as a reference point, which was fundamental for measuring the outcome parameters (Figure 4).

For each hemi-mandible, a set of angular, linear, and volumetric assessment was performed:

- Angular measurement (degrees): Gonial angle (Ar-Go-Gn), identified by the tangent to the posterior margin of the ascending ramus (Ar-Go line) and the lower margin (Go-Gn line) of the mandibular body (Figure 5).
- Linear measurement (mm): Distance between the posterior edge of the condyle and the center of the mandibular notch (Figure 6). The angular and linear measurements were performed with the Rhinoceros software.
- Volumetric measurement (mm^3): Volume of the condyle, for the assessment of which, two slices were created, viz., a line going from the gonion to the mandibular notch and its perpendicular (Figure 7). Geometric models were built from these slices, and the portions of interest were assessed (Figures 8 and 9).

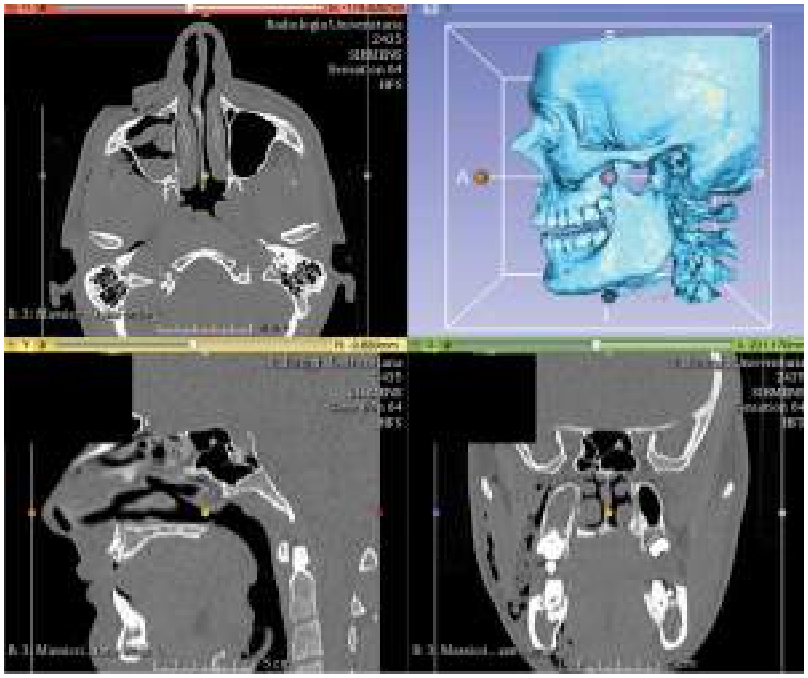

Figure 1. Segmentation process performed using 3D Slicer software.

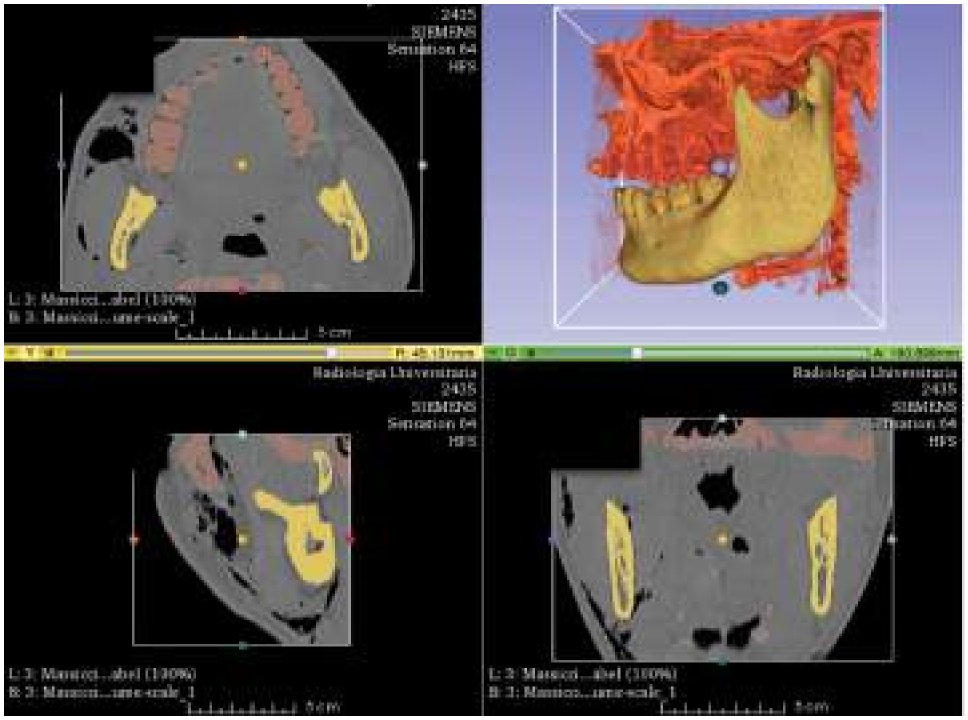

Figure 2. Segmentation process performed using 3D Slicer software.

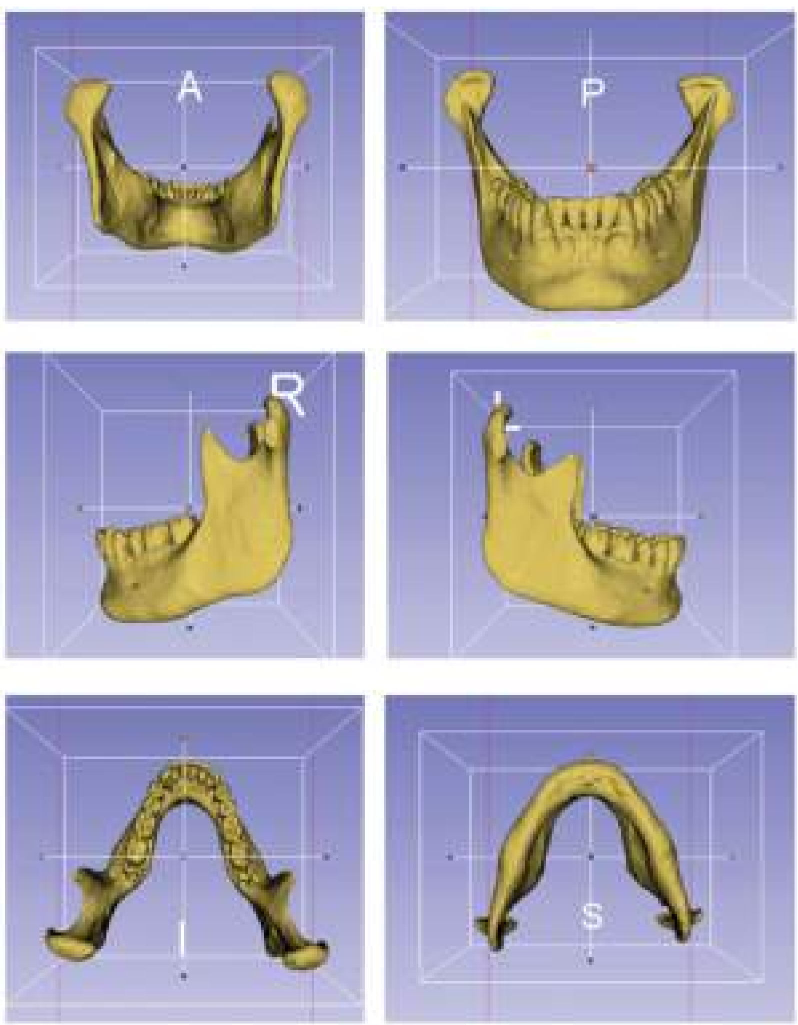

Figure 3. Rendering of the mandibular portion from various views.

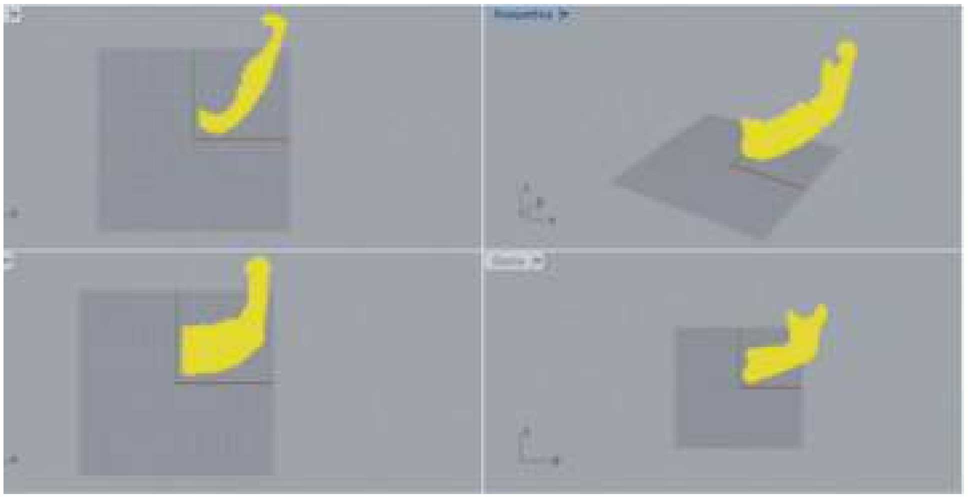

Figure 4. Orientation of the geometric model performed using Rhinoceros software.

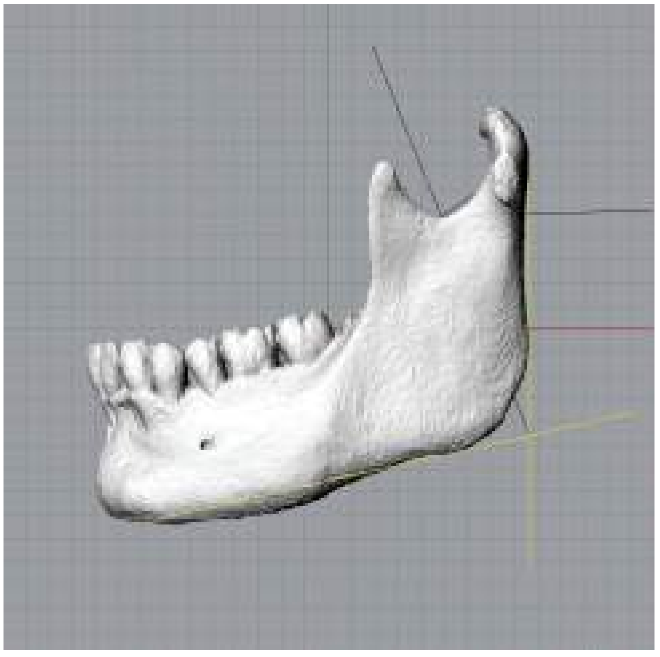

Figure 5. Parameter measurement: Gonial angle.

Statistical analysis

Data were stored on a spreadsheet. Descriptive statistics were reported for each parameter. Differences between the two groups were assessed using Student's *t*-test, with statistical significance set at $p < 0.01$. All statistical procedures were performed with the Excel program (Microsoft Corporation, Redmond, WA, USA).

Results

Two CTs from the TMD group were excluded from further processing and data analysis, due to the presence of minor artifacts.

Therefore, the final sample included 9 TMD patients (5 females, mean age 27.3 ± 6.6 years) and 11 age- and sex-matched controls (6 females, mean age 26.5 ± 6.9 years).

Descriptive statistics for each outcome variable, expressed as minimum, maximum, mean values, and standard deviation, are presented in Table 1.

Differences between the two groups were significant for the variables gonial angle and condyle volume ($p < 0.01$) (Table 1).

In line with the study hypothesis, the condylar volume was significantly higher (15.2% difference) in the control group, with respect to the TMD group (1305.5 ± 315.5 mm^3 vs. 837.7 ± 230.0 mm^3).

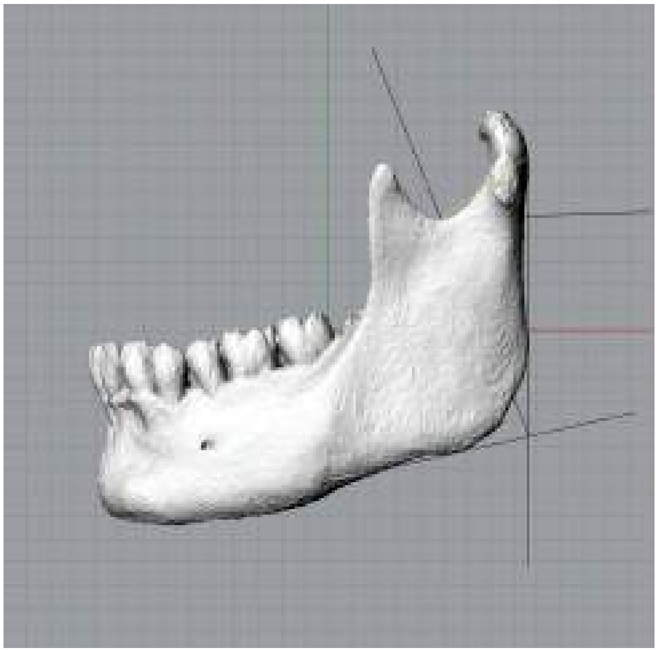

Figure 6. Parameter measurement: Linear distance between mandibular notch and posterior condyle.

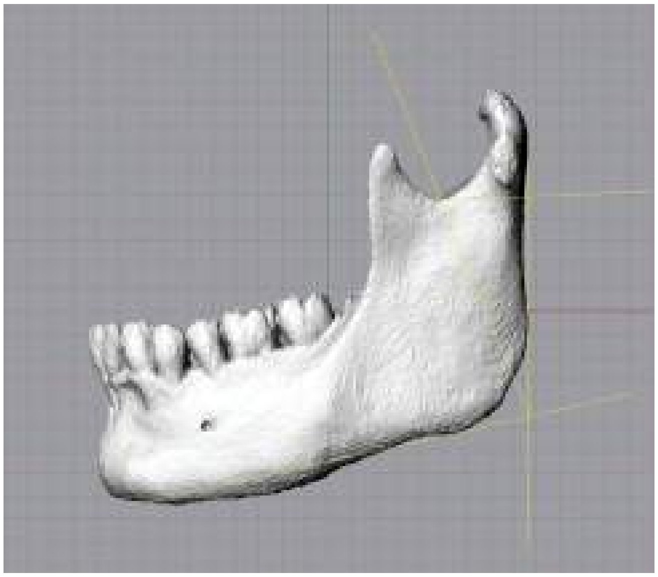

Figure 7. Creation of slices: gonion/mandibular notch – mandibular notch/posterior condyle.

The gonial angle was significantly lower in controls (8% difference), with respect to the TMD group, with an average value of 116° ± 6.5° and 128° ± 4.5°, respectively.

For the linear distance from the condylar posterior edge to the mandibular notch center, the between-group difference was not significant.

Discussion

The etiology of TMDs is not fully clarified yet, especially as far as the interaction between physical and psychological factors is concerned [10]. Among the anatomical factors, focus should be put on the study of craniofacial morphology, rather than dental occlusion [4,7,11].

Several studies evaluated linear and angular parameters of craniofacial morphology to identify skeletal features associated with TMJ disorders [8]. Notwithstanding, the available literature is mainly focused on bi-dimensional cephalometric features, while very few studies have assessed condylar morphology [8]. Some studies showed an association with mandible retro-

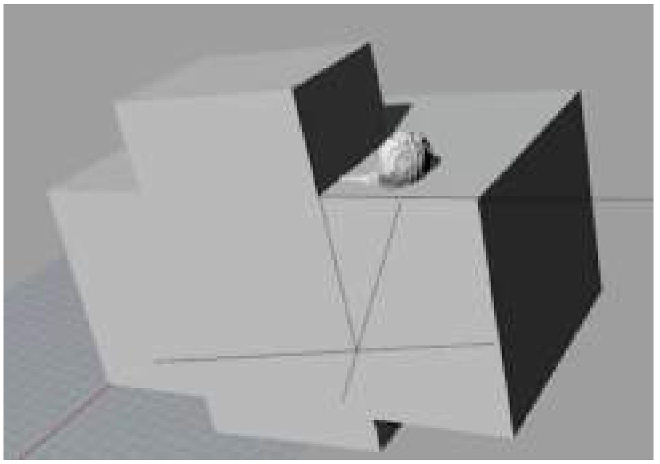

Figure 8. Creation of the geometric solid.

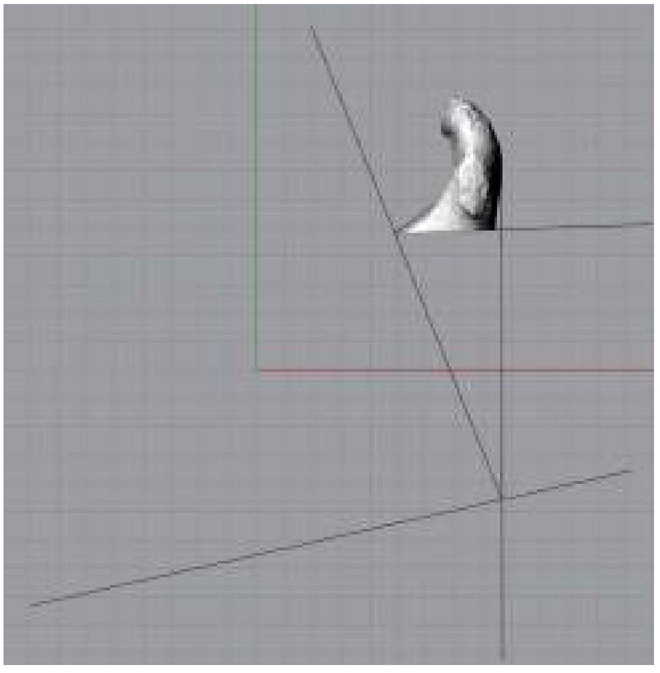

Figure 9. Isolation of the relevant portion of the condyle.

Table 1. Descriptive statistics pertaining to the variables and differences between the two groups assessed using Student's *t*-test (statistical significance: $p < 0.01$).

TMD			TMD-FREE			
Means ± SD	Min	Max	Means ± SD	Min	Max	Diff.
128.0 ± 4.5	119.5	136.5	116.0 ± 6.5	103.5	132.5	**0.0000002821; S**
21.5 ± 3.0	17.0	28.5	22.5 ± 2.0	18.5	26.0	1.151405097; NS
837.5 ± 230.0	439.5	1461.5	1305.5 ± 315.5	879.5	2095.5	**0.0000160789; S**

TMD: Temporomandibular disorders; TMD-FREE: temporomandibular disorders-free; SD: standard deviation; Min: minimum; Max: maximum; Diff.: differences; S: significant ($p < 0.05$); NS: not significant.

gnathism [12–14] and a short posterior ramus height [15,16], thus hypothesizing that condylar size and shape in TMD patients are worthy of investigation.

Based on that premise, this study assessed some jaw and condylar morphological features in individuals with and without TMJ pain in the absence of degenerative joint disease. Software reconstruction strategies were adopted for a 3D evaluation.

Findings are in accordance with the orthodontic literature [13,17–21], reporting an association between hyperdivergent jaw growth pattern, i.e., high gonial angle and TMDs.

It must be noted that most studies have addressed such features in patients with disc displacement or with degenerative TMJ disease, rather than the presence of clinical symptoms. On the other hand, a study by Hwang et al. [17] suggested that there is a significant correlation between the structure of the lower face, with focus on a hyperdivergent facial profile, and TMD symptoms.

Regarding condylar morphology, findings supported the study hypothesis that lower-volume condyles are associated with the presence of TMD symptoms. Such a finding is hard to compare with the literature [21,22], due to the low number of available papers and their bi-dimensional evaluation. Cho et al. [22] found that the condylar and ramus height in osteoarthritic joints are shorter than in TMD-free individuals. Such findings also agree with Sun et al. [21], who showed a shorter condyle in patients with osteoarthrosis.

Thus, to summarize, the current results suggest that low condylar volume (Figures 10–12) and hyperdivergent jaw growth pattern are associated with TMJ pain.

Such associations might have interesting explanations in terms of TMD pathophysiology. As for the high gonial angle, a mechanical disadvantage concerning the load exerted on the TMJs in subjects with hyperdivergent jaw growth pattern has been described [23,24]. In addition, there might be a predisposing condylar morphology in subjects with skeletal Class II profile, viz., a low-volume condyle that is less suitable to bear loads than normo-volume condyles [25].

The presence of a larger gonial angle in TMD subjects, with respect to controls, is in line with the literature and is not new a finding [8]. Thus, the main topic for discussion is the finding on condylar size, which was evaluated in 3D, as recommended for standard of reference purposes [26].

The relationship between low condylar volume and TMDs may have two possible, opposite explanations. The small condylar size in TMD patients may be consequent to arthrosis-related adaptations and modifications. On the other hand, such an event should be accompanied by some typical features of degenerative changes, e.g., condylar flattening, sclerosis, osteophytes, and breakage, which were exclusion criteria for this study. Contrarily, small-sized condyles could be a preexisting condition that weakens the TMJ [27,28]. Based on this hypothesis, certain skeletal morphologies and/or features might predispose to TMJ disorders because they are less suitable to bear loads, due to the unfavorable muscle force vectors acting on the TMJ and/or the low volume of condyles [23–29]. Colombo et al. [30] provided support for this concept by using a mathematical model. Individuals with a small condyle and a wide glenoid fossa have such a poor reciprocal fitting of the articular surfaces that they are potentially at risk of developing TMD symptoms [31].

Despite the potentially interesting findings, this investigation has limitations, such as a low sample size and the poorly specific clinical diagnosis, even comprising the information of TMJ disc position.

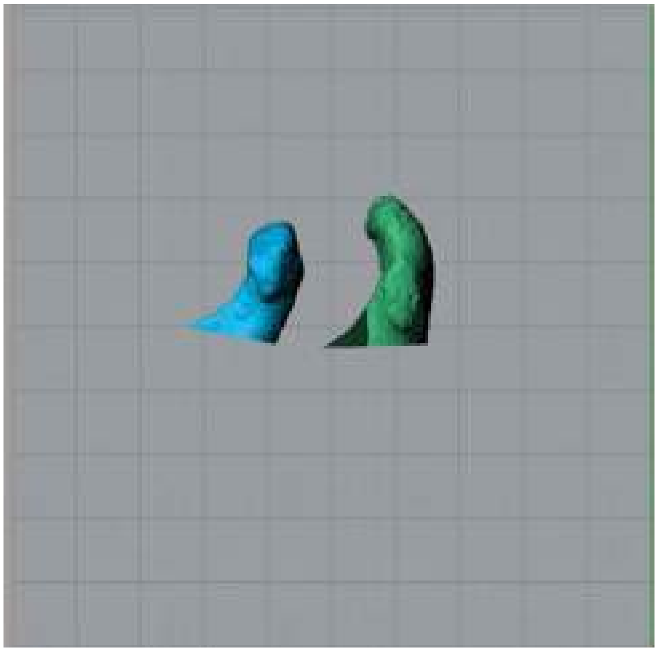

Figure 10. Condyle portion: lateral view (TMD-blue (left); TMD-FREE-green (right)).

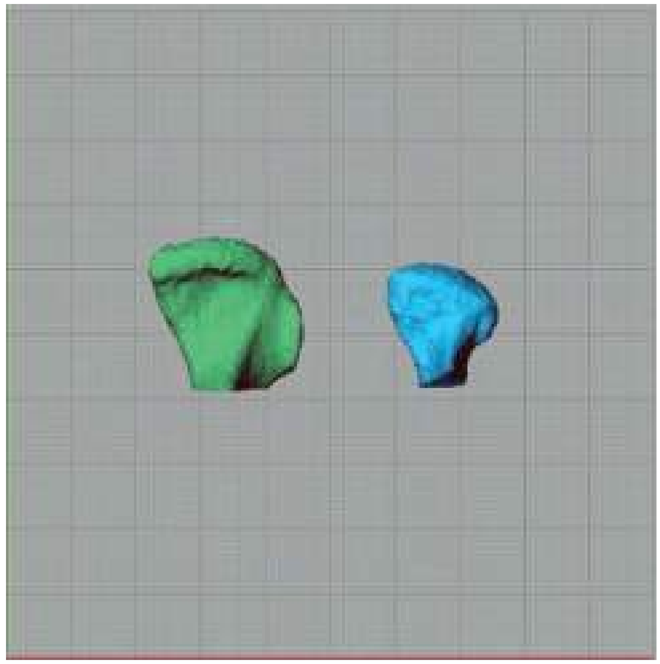

Figure 11. Condyle portion: frontal view (TMD-blue (right); TMD-FREE-green (left)).

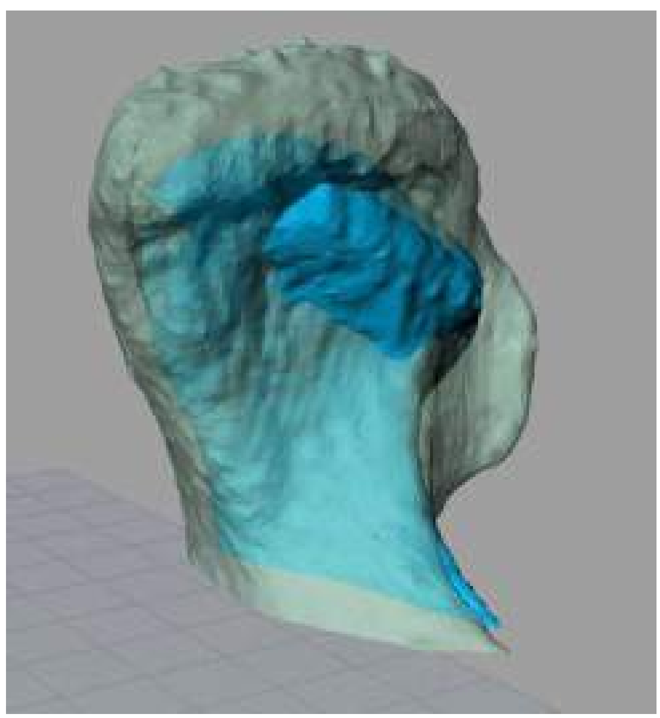

Figure 12. Superimposition of condyle volumes: study group (blue) and control group (green).

Ethical considerations limit the possibility of extending the control group, which should be recruited within populations of patients undergoing CT for other reasons than TMDs. On the other hand, the choice of relying on generic clinical symptoms of TMJ pain as an inclusion criterion was based on the need to avoid potential imaging-related bias.

Future studies, possibly adopting magnetic resonance assessment of disc position as well as taking into account age-related condylar growth could be an option for refining these findings with more specific designs.

Conclusion

The results of this study suggest there is an association between TMJ pain and certain features of craniofacial morphology. Individuals with TMJ pain have a lower condylar volume and a higher gonial angle than controls. The role of such findings within the broader context of TMD pathophysiology should be better understood with future investigations.

Conflict of interest

The authors report no conflict of interest.

Funding

No funding was received for this study.

ORCID

Anna Colonna DDS http://orcid.org/0000-0002-5869-2068
Daniele Manfredini DDS, PhD, MSc http://orcid.org/0000-0002-4352-3085

References

[1] Okeson JP. The classification of orofacial pains. Oral Maxillofac Surg Clin North Am. 2008;20(2):13–184.
[2] Manfredini D, Guarda-Nardini L. TMD classification and etiology. In: Manfredini D, editor. Current concepts of temporomandibular disorders. Berlin, Germany: Quintessence Publishing; 2010. p. 25–40.
[3] Goulet JP, Schiffman E, Manfredini D. Clinical examination and adjunctive laboratory test. In: Sessle BJ, editor. Orofacial pain. Recent advances in assessment, management and understanding of mechanism. Washington, D.C., USA: IASP Press; 2014. p. 99–120.
[4] Turp JC, Greene CS, Strub JR. Dental occlusion: a critical reflection on past, present and future concepts. J Oral Rehabil. 2008;35(6):446–453.
[5] Manfredini D, Lombardo L, Siciliani G. Temporomandibular disorders and dental occlusion. A systematic review of association studies: end of an era? J Oral Rehabil. 2017;44(11):908–923.
[6] Pullinger AG, Seligman DA. Quantification and validation of predictive values of occlusal variables in temporomandibular disorders using a multifactorial analysis. J Prosthet Dent. 2000;83(1):66–75.
[7] Manfredini D, Peretta R, Guarda-Nardini L, et al. Predictive value of combined clinically diagnosed bruxism and occlusal features for TMJ pain. CRANIO®. 2010;28(2):105–113.
[8] Manfredini D, Segù M, Arveda N, et al. Temporomandibular joint disorders in patients with different facial morphology. A systematic review of the literature. J Oral Maxillofac Surg. 2016;74(1):29–46.
[9] Fedorov A, Beichel R, Kalpathy-Cramer J, et al. 3D slicer as an image computing platform for the Quantitative Imaging Network. Magn Reson Imaging. 2012;30(9):1323–1341.
[10] De Leeuw R, ed. Orofacial pain: guidelines for assessment, diagnosis, and management. 4th ed. Chicago, IL, USA: Quintessence Pub. Co; 2008. p. 129–204.
[11] Mohlin B, Axelsson S, Paulin G, et al. TMD in relation to malocclusion and orthodontic treatment. A Systematic Review. Angle Orthod. 2007;77(3):542–548.
[12] Miller JR, Burgess JA, Critchlow CW. Association between mandibular retrognathia and TMJ disorders in adult females. J Public Health Dent. 2004;64(3):157–163.
[13] Ahn SJ, Baek SH, Kim TW, et al. Discrimination of internal derangement of temporomandibular joint by lateral cephalometric analysis. Am J Orthod Dentofacial Orthop. 2006;130(3):331–339.
[14] Flores-Mir C, Nebbe B, Heo G, et al. Longitudinal study of temporomandibular joint disc status and craniofacial growth. Am J Orthod Dentofacial Orthop. 2006;130(3):324–330.
[15] Yang IH, Moon BS, Lee SP, et al. Skeletal differences in patients with temporomandibular joint disc displacement according to sagittal jaw relationship. J Oral Maxillofac Surg. 2012;70(5):349–360.
[16] Jung WS, Kim H, Jeon DM, et al. Magnetic resonance imaging verified temporomandibular joint disk displacement in relation to sagittal and vertical jaw deformities. Int J Oral Maxillofac Surg. 2013;42(9):1108–1115.
[17] Hwang CJ, Sung SJ, Kim SJ. Lateral cephalometric characteristics of malocclusion patients with temporomandibular joint disorder symptoms. Am J Orthod Dentofacial Orthop. 2006;129(4):497–503.
[18] Byun ES, Ahn SJ, Kim TW. Relationship between internal derangement of the temporomandibular joint and dentofacial morphology in women with anterior open bite. Am J Orthod Dentofacial Orthop. 2005;128(1):87–95.
[19] Gidarakou IK, Tallents RH, Kyrkanides S, et al. Comparison of skeletal and dental morphology in asymptomatic volunteers and symptomatic patients with unilateral disk displacement with reduction. Angle Orthod. 2004;74(2):212–219.
[20] Ioi H, Matsumoto R, Nishioka M, et al. Relationship of TMJ osteoarthritis/osteoarthrosis to head posture and dentofacial morphology. Orthod Craniofac Res. 2008;11(1):8–16.
[21] Sun ZP, Zou BS, Zhao YP, et al. Craniofacial morphology of Chinese patients with bilateral temporomandibular joint osteoarthrosis. Chin J Dent Res. 2011;14(1):21–27.
[22] Cho BH, Ahn YW, Jung YH. Comparison of mandibular morphology between patients with temporomandibular joint osteoarthritis and asymptomatic normal subjects. Quintessence Int. 2009;40(8):49–54.
[23] Manfredini D, Vano M, Peretta R, et al. Jaw clenching effects in relation to two extreme occlusal features: patterns of diagnoses in a TMD patient population. CRANIO®. 2014;32(1):45–50.
[24] Ferrario VF, Sforza C, Sartori M, et al. The mechanical advantage of the masseter muscle in subjects with different vertical and sagittal facial morphology. Clin Orthod Res. 1999;2(3):162–170.

[25] Zegarra-Baquerizo H, Moreno-Sékula K, Casas-Apayco L, et al. Mandibular condyle dimensions in Peruvian patients with Class II and Class III skeletal patterns. J Oral Res. 2017;6(10):264–266.
[26] Zhang Y, Xianchao XU, Zhan L. Comparison of morphologic parameters of temporomandibular joint for asymptomatic subjects using the two-dimensional and three-dimensional measuring methods. J Healthc Eng. 2017;5680708. doi:10.1155/2017/5680708.
[27] Tanne K, Tanaka E, Sakuda M. Stress distributions in the TMJ during clenching in patients with vertical discrepancies of the craniofacial complex. J Orofac Pain. 1995;9(2):153–160.
[28] Ueki K, Nakagawa K, Takatsuka S, et al. Comparison of the stress direction on the TMJ in patients with class I, II, and III skeletal relationships. Orthod Craniofac Res. 2008;11(1):43–50.
[29] Manfredini D, Stellini E, Marchese-Ragona R, et al. Are occlusal features associated with different temporomandibular disorder diagnoses in bruxers? CRANIO®. 2014;32(4):283–288.
[30] Colombo V, Palla S, Gallo LM. Temporomandibular joint loading patterns related to joint morphology. A theoretical study. Cells Tissues Organs. 2008;187(4):295–306.
[31] Peretta R, Manfredini D. Future perspectives in TMD pathophysiology. In: Manfredini D, editor. Current concepts on temporomandibular disorders. Berlin, Germany: Quintessence Publishing; 2010. p. 153–170.