Int. J. Oral Maxillofac. Surg. 2019; 48: 1201–1208
https://doi.org/10.1016/j.ijom.2019.02.009, available online at https://www.sciencedirect.com

International Journal of Oral & Maxillofacial Surgery

Clinical Paper
Orthognathic Surgery

# Assessment of condylar changes after orthognathic surgery using computed tomography regional superimposition

**J. D. P. Claus[1], L. Koerich[2], A. Weissheimer[3], M. S. Almeida[4], R. Belle de Oliveira[1]**

[1]Department of Oral and Maxillofacial Surgery, Pontifical Catholic University, Porto Alegre, Brazil; [2]Private Practice, Charlotte, NC, USA; [3]Advanced Orthodontic Program, Herman Ostrow School of Dentistry, University of Southern California, Los Angeles, CA, USA; [4]Oral and Maxillofacial Surgeon, Private Practice, Brazil (Santa Catarina)

*J. D. P. Claus, L. Koerich, A. Weissheimer, M. S. Almeida, R. Belle de Oliveira: Assessment of condylar changes after orthognathic surgery using computed tomography regional superimposition. Int. J. Oral Maxillofac. Surg. 2019; 48: 1201–1208.* 

*Abstract.* This study aimed to investigate the effects of bimaxillary advancement orthognathic surgery on the condylar remodeling of the temporomandibular joint (TMJ) using voxel-based regional superimposition of cone-beam computed tomography (CBCT).

In this retrospective study, the sample comprised 56 condyles from 28 healthy patients (aged from 16 to 50 years) with mandibular retrognathism treated with bimaxillary advancement. CBCT scans were taken preoperatively and at $14.3 \pm 4.2$ months postoperatively. The scans at the two time points were superimposed using regional voxel-based registration to assess condylar changes in the follow-up period. The linear alterations were measured in six different areas of each condyle to determine the pattern of condylar remodeling.

Although no significant correlation was observed between changes in condylar surfaces, bone resorption occurred predominantly in the posterior and superior regions, while bone formation was predominantly on the anterior surface. Medial and lateral surfaces presented fewer bone changes. The overall bone changes were smaller than 1 mm bilaterally in 21 patients (75%) and, considering each condyle individually, were smaller than 1 mm in 48 condyles (85.7%).

The results suggested that mild condylar remodeling in healthy patients is a common finding after orthognathic surgery. Future studies may clarify the mechanisms involved in the remodeling and help to understand the reasons for the remodeling pattern.

Key words: cone-beam CT; 3D image registration; CBCT superimposition; orthognathic surgery.

Accepted for publication 21 February 2019
Available online 11 March 2019

 

Traditionally, orthognathic surgery has been used to treat dental and skeletal malocclusion. More than that, it provides improvements in the facial esthetics, airways, and the temporomandibular joint (TMJ). The impact of orthognathic surgery on the TMJ and diseases involving this joint has been widely discussed. One of the concerns is the resorption/remodeling process that takes place in mandibular condyles and could affect the stability, and compromises the results of the orthognathic surgery[1–5].

Cone-beam computed tomography (CBCT) has become a popular diagnostic tool, especially for virtual planning and outcomes assessment. Image superimposition or registration is a well-established technique in three-dimensional (3D) imaging and considered the gold standard procedure for evaluating treatment results in orthognathic surgery[6–11].

Cranial base superimposition of CBCT has been used to evaluate the effects of orthognathic surgery on the TMJs. However, when this registration technique is applied to study mandibular condyles, only position or displacement can be assessed. Morphologic condylar changes cannot be appropriately evaluated using cranial base superimposition[12–18]. Regional superimposition, using the condyle neck and the posterior region of the ramus as the registration area, is the technique of choice to evaluate condylar remodeling because it eliminates the bias caused by possible displacements of the condyles and allows different types of analysis[19,20].

This study aimed to evaluate the morphological condylar changes in patients subjected to bimaxillary orthognathic surgery using CBCT regional superimposition through the isolated overlapping of the condylar segment.

## Material and methods

This retrospective study was approved by the Ethics Committee of the Pontifical Catholic University of Rio Grande do Sul – PUCRS – School of Dentistry (reference number CAAE: 83104417.6.0000.5336). The sample comprised patients subjected to orthognathic surgery for bimaxillary advancement between 2014 and 2017. The exclusion criteria were syndromes, severe facial asymmetry, history of previous facial surgery/trauma, and diagnosis of TMJ disease/dysfunction, such as anterior disc displacement without reduction, with or without osteoarthritis.

Overall, 62 condyles were analyzed from 31 patients. Six condyles from three patients were excluded from the sample because osteoarthritis was diagnosed through CBCT showing joint degeneration before the orthognathic surgery. Finally, the sample comprised 56 healthy condyles in 28 patients (Table 1). CBCT scans were obtained up to a month before the surgery and $14.3 \pm 4.2$ months after surgery.

Following the stages of preoperative examinations, virtual planning, and surgical splint manufacturing, surgical procedures were performed by the same surgical team. The surgical sequence started in the mandible with bilateral sagittal split osteotomy. After intermediate splint and intermaxillary fixation (IMF), proximal segment repositioning was achieved with the condyle in proper position and bone contact between segments was passive with no tension. First, one bone plate was bent and positioned in the posterior body area to avoid condylar torque and, secondly, one bicortical 2-mm diameter screw was placed in the ascending ramus on each side. IMF was released and the condylar position checked by gentle attempt to verify the occlusal position. Subsequently, maxillary surgery was performed through conventional Le Fort I osteotomy and rigid fixation with four bone plates using 2-mm-diameter screws and bone grafting when indicated. After the surgery, temporary intermaxillary traction with intraoral elastics was applied in all patients for 3–4 weeks to ensure fully stable occlusion, followed by physiotherapy involving muscle and mouth-opening exercises.

All CBCT scans were obtained with i-CAT scanner (Imaging Sciences International, Hatfield, Pennsylvania, USA), field of view of $23\ cm \times 17\ cm$, voxel of $0.3\ mm^3$, 36.90 mA, 120 kV, and 40 s, generating DICOM (Digital Imaging and Communications in Medicine) files. The examinations were performed prior to surgery (T1) and 12–19 months after surgery (T2).

The DICOM files were imported into the OnDemand 3D software (Cybermed Inc., Seoul, Korea). The first step consisted in a cranial base superimposition between T1 and T2 scans, using the 'fusion' tool in the software. Mandibular advancement, between T1 and T2, was quantified through linear measurements between the B points at the medium plane (Fig. 1).

The second step was to use the sectioning tool to select and to isolate the mandibular condyles in both T1 and T2 scans, right and left sides, creating four new images: T1R, T1L, T2R, and T2L. Each condyle selection, containing the same amount of sections, was exported into a new DICOM file (Fig. 2).

The new condyle files were opened using the 'fusion' module in OnDemand 3D software. The first step was to perform a manual preliminary superimposition by moving the condyle from the T2 as close as possible to the condyle in T1. After manual registration, the 'specific region of interest' tool was used to select the condyle area which is less susceptible to changes due to the surgery: in this case, the neck of the condyle and the posterior region of the mandibular ramus above the lingula. The upper pole region as well as the region below the lingula were not included. After manual registration and selection of the specific area for regional registration, the next step was to use the automatic registration to superimpose the condyles at T1 and T2. The software uses an automated and voxel-based registration algorithm that identifies and match similar voxels (Figs. 3 and 4). After superimposition was recorded, the T2 files were saved in their new spatial orientation and exported as new DICOM files: T2Rr and T2Lr ('r' means registered). These new files were imported into the ITK-SNAP software (www.itksnap.org) for bone segmentation and construction of 3D surface models of the condyles (Fig. 5). These new ITK-Snap images were exported as STL (Standard Tessellation Language) files and imported into the VAM software (Canfield Scientific, Fairfield, NJ, USA) for comparative analysis between T1 and T2. 'Surface paint area' tool was used in five predetermined condylar areas with

*Table 1.* Sample demographic data and clinical characteristics.

| | Mean |
|---|---|
| Age | 31.07 years (16–50 years) |
| Gender | 53.6% female, 46.4% male |
| Advancement at B point | 9.06 mm (5.5–13.2 mm) |
| Follow-up interval[a] | 14.35 months (12–19 months) |

[a] Interval from the postoperative computed tomography scan (T2) and surgery.

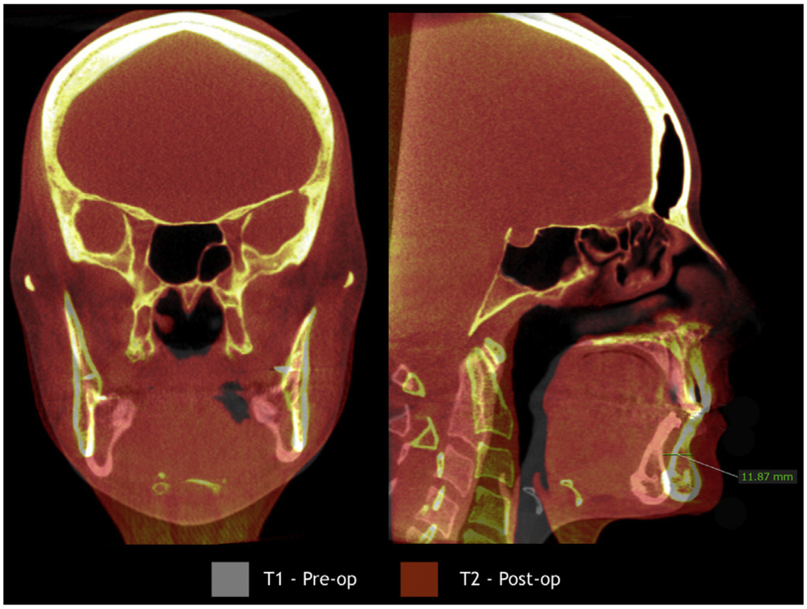


*Fig. 1.* Coronal section of the cone-beam computed tomography scan showing the voxel-based superimposition using the cranial base as reference. Sagittal section showing the measurement of mandibular advancement in point B. Example in a randomly selected patient.

*Fig. 2.* Coronal, sagittal, and axial sections and three-dimensional reconstruction of the area equivalent to each mandibular condyle cut from each cone-beam computed tomography scan.

similar sizes: anterior surface, posterior surface, upper surface, lateral surface, and medial surface (Fig. 6). Evaluating linear changes in the condyles in T2, the software provided minimum and maximum variation values with standard deviation. The most negative values refer to regions with greater bone resorption, whereas the highest positive values refer to regions with greater new bone formation.

A selection tool in the VAM software was standardized on a line from the highest point of the condyle, in the coronal direction, to a 20-mm distance toward the mandibular ramus for complete evaluation of the changes in each condyle (Fig. 7). The software identifies the changes through color-coded maps, generating visual graphs for the morphological changes. The parts with maximum bone loss are shown displayed in blue and bone formation are shown in red.

Statistical analysis was performed using SPSS for Windows software (SPSS Statistics 2015 Inc., Chicago, IL, USA). Descriptive statistical analysis was used to describe the post-surgical changes in mandibular condyles (T1–T2).

## Results

Demographic data and clinical characteristics of the sample are shown in Table 1. Mean interval between surgery and postoperative CBCT scan date (T2) was 14.3 months (range 12–19 months). Mean distance from T1 point B to T2 point B, to measure mandibular advancement, was 9.06 mm (range 5.5–13.2 mm), shown in Fig. 1.

Morphological changes in the mandibular condyles were observed during the follow-up period (T2), with the mean values presented in Table 2. The most common change found was of the reabsorption type; in 100% of the sample, one or more surfaces showed only negative values. Nevertheless, in 38 condyles (67.8%), one or more surfaces showed only positive values, i.e. new bone formation.

Overall, the upper and posterior surfaces of the condyles had the most negative values, indicating that these were the most susceptible areas to condylar resorption. The anterior surface had the lowest mean of negative values, being the region with the least bone loss. Conversely, the anterior surface had the highest means of positive values which means new bone apposition (Table 2). However, independent-samples t-test revealed no statistically significant difference between the surfaces when the incidences of minimum and maximum values were compared ($p < 0.05$).

Root mean square (RMS) values represent the sum of condylar morphological changes, regardless of the type of change (apposition or resorption). Independent-samples t-test showed no statistically significant RMS difference between the upper, posterior, and anterior surfaces ($p < 0.05$). However, the difference between these surfaces and the medial and lateral surfaces, where the RMS changes had the lowest values, was statistically significant.

Considering the condylar area containing the 20-mm portion, as shown in Fig. 7, the results are presented in Table 3. No

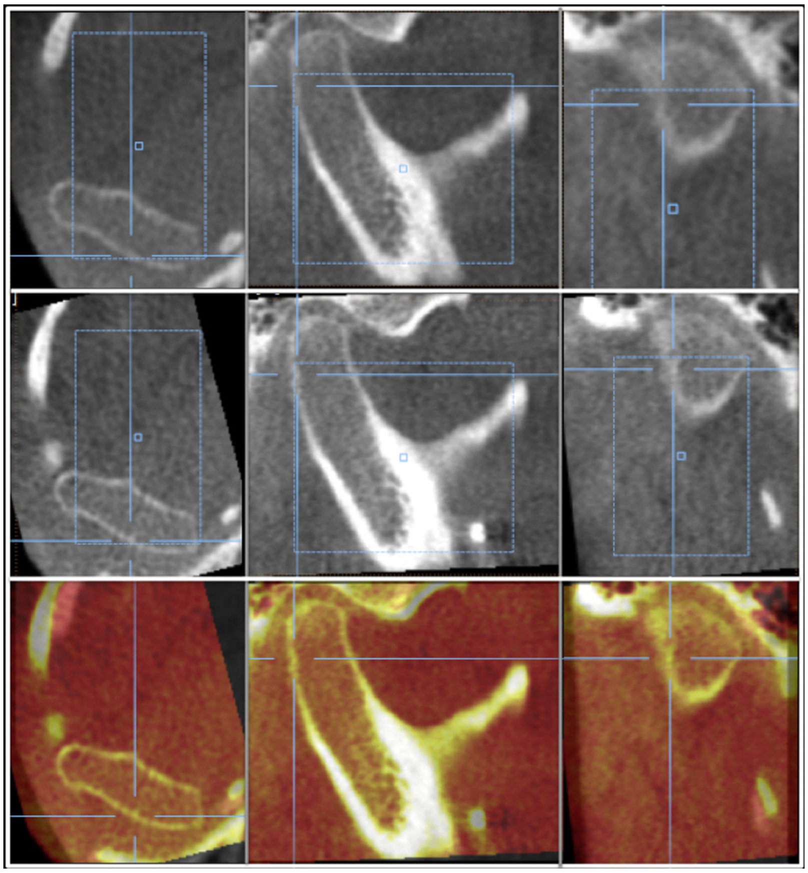

*Fig. 3.* Regional superimposition process observed in the three sections in a randomly selected patient. The upper part represents T1D, the central part represents T2DR, and the lower part represents both the T1D and T2DR. After regional superimposition, both exams were in the same position. In detail, the blue rectangle shows the area of interest selected for voxel coincidence. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

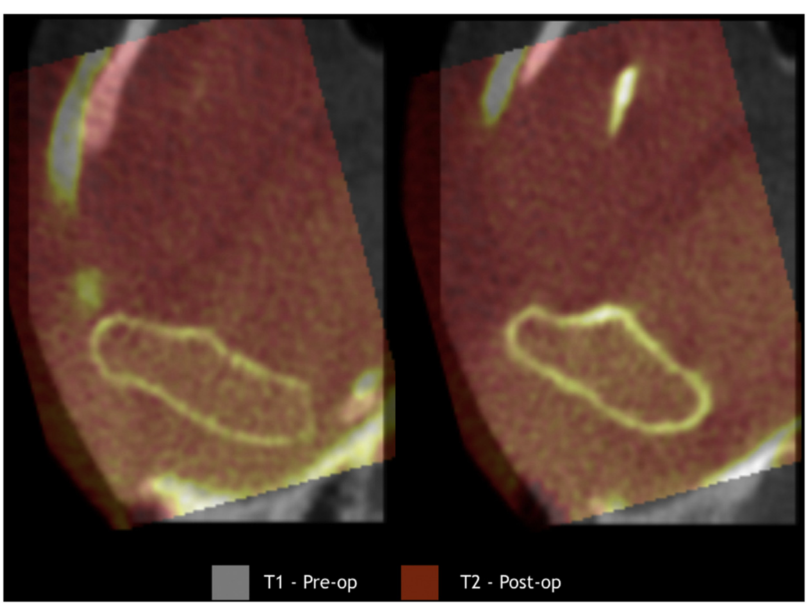


*Fig. 4.* Axial sections of the same superimposition at different time points, showing the exact overlap of condyles, with the difference between the zygomatic arches in the detail.

changes were equal to or greater than 3 mm, i.e. no condyle showed resorption or new bone formation greater than 3 mm. Negative values between −1 and −3 mm were obtained in five (8.9%) condyles in four patients (14.2%). There were changes ranging from −1 to +1 mm in 48 (85.7%) condyles in 21 patients (75%). Only three condyles (5.3%) in three patients (10.7%) showed changes between +1 mm and +3 mm. Therefore, although most surfaces presented measurements indicating changes in condylar morphology, particularly of the resorption type, the vast majority of the condyles presented changes smaller than 1 mm.

## Discussion

Assessment of TMJ behavior is a routine procedure for surgeons and orthodontists. In this respect, superimposition using cephalometric radiographs has been widely presented in the literature. However, several limitations have been described, which justifies its recent replacement with computed tomography to perform superimpositions to evaluate the changes between different time points.

There are three basic types of computed tomography superimposition as follows: based on anatomical landmarks, based on surfaces, and based on voxels. Superimposition based on voxels is the most efficient method because it compares non-modifiable reference structures of volumetric data (voxel by voxel), does not depend on the identification of anatomical landmarks, and does not feature error limitation during the process of segmentation, which is required for the superimposition based on surfaces. Cevidanes et al., in 2005, were the first to introduce superimposition based on voxels using the cranial base as reference to overlay two or more CBCT of adult patients[12]. Since then, CBCT voxel-based superimposition on the cranial base has been the method of choice for most publications evaluating the results of orthognathic surgery. It allows an appropriate assessment of the changes in the maxilla, mandible, and facial soft tissues in three-dimensions. However, cranial base superimposition only enables the evaluation of spatial displacements of the structures. In most orthognathic surgery cases, there are postoperative adaptations in the mandibular position that may change both occlusion and condylar position over time. Therefore, cranial base superimposition can be used for condylar displacement evaluation, but it is not appropriate for

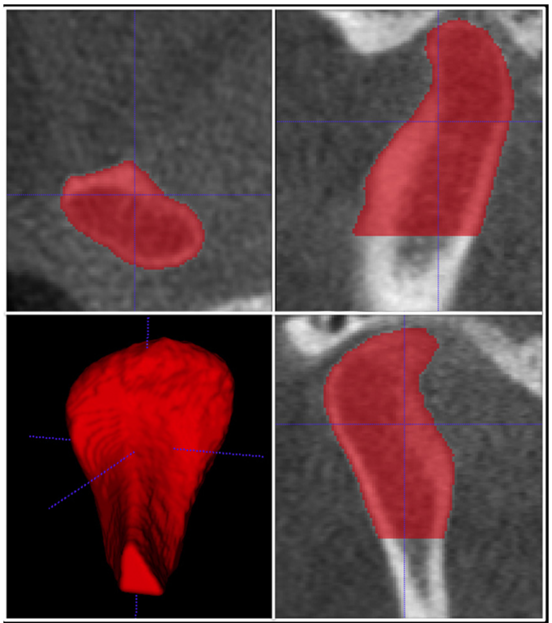

*Fig. 5.* Mandibular condyle bone tissue segmentation in three sections and three-dimensional reconstruction.

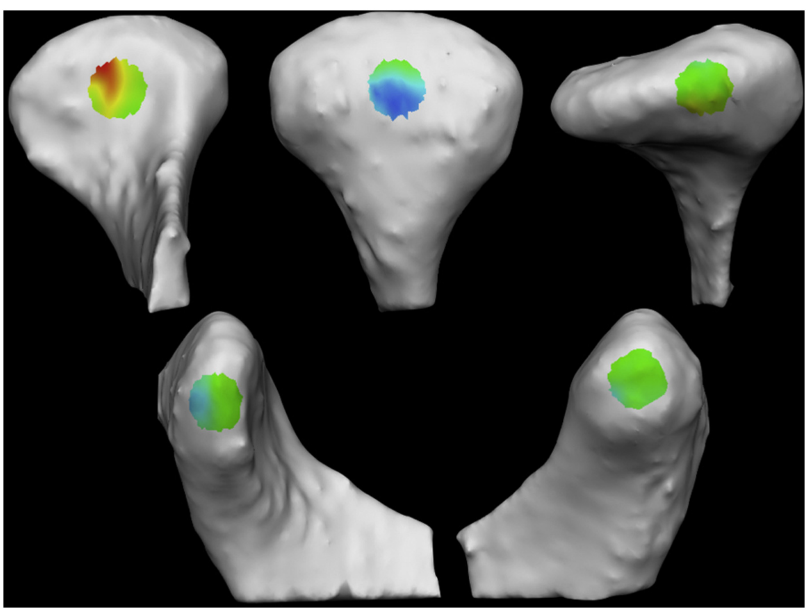

*Fig. 6.* Regions of interest to evaluate the condylar remodeling process. Clockwise from the top left image: anterior pole, posterior pole, upper pole, medial pole and lateral pole.

the study of condylar morphological changes[21].

The recommended technique for morphologic analysis of bone structures, such as size and shape, is to superimpose the same bone, at the stable areas, in two different time points. This is the definition of 3D regional superimposition of CBCT. Recent studies have shown the potential use of maxillary and mandibular voxel-based regional superimposition for bone graft assessment, implant positioning accuracy, and alveolar resorption[19,21]. Besides that, the authors stated regional superimposition is the ideal technique for morphologic evaluation such as condylar resorption or hyperplasia[20].

Several studies have investigated TMJ changes before and after orthognathic surgery using cranial base superimposition[1–5]. The results are interesting and contribute to a better understanding of condylar spatial changes such as position and angulation. However, the findings regarding condylar morphology are limited because cranial base superimposition does not allow an appropriate evaluation of morphologic changes in the condyles. For that reason, the present study used regional voxel-based superimposition of CBCTs to study condylar morphologic changes in patients subjected to bimaxillary advancement surgery. Both current cranial base and regional superimposition methods used in this research have been validated by previous studies, but not applied specifically to studying the condyles[17,20]. The present study showed the application of a proper method for 3D condyle assessment after orthognathic that is user friendly. Our results showed that orthognathic surgery usually promotes minor bone alterations to the TMJs. The evaluation of morphological changes in the condyles 14 months after bimaxillary advancement surgery has shown changes smaller than 1 mm in 48 condyles (85.7%). Considering both condyles of the same individual, in 21 patients (75%) the changes were smaller than 1 mm. RMS, which means the sum of the changes regardless of direction, was 0.27 mm for all samples. This study showed that the upper and posterior surfaces of the condyles were the most susceptible areas to resorption. However, the results for condylar resorption before and after the orthognathic surgery were not statistically significant. The anterior surface was the most susceptible area to new bone formation. The medial and lateral surfaces were the ones with the least changes.

The present sample included only individuals with healthy TMJs, according to imaging exams. In a recent systematic review by Veldhuis et al. (2017), the information regarding the effects of orthognathic surgery on the TMJ is limited due to the diversity of techniques and particularly of methods used for condylar assessment[1]. The authors concluded that orthognathic surgery appears to have no or minimal impact on the TMJ and on oral function. A systematic review with meta-analysis by Al-Moraissi et al. (2017) demonstrated similar conclusions, including the expectation of different results according to the preoperative condition of the TMJ involved[2].

In 2017, Al-Moraissi and Wolford conducted a systematic review and meta-analysis to investigate whether the preoperative condition of the TMJ could

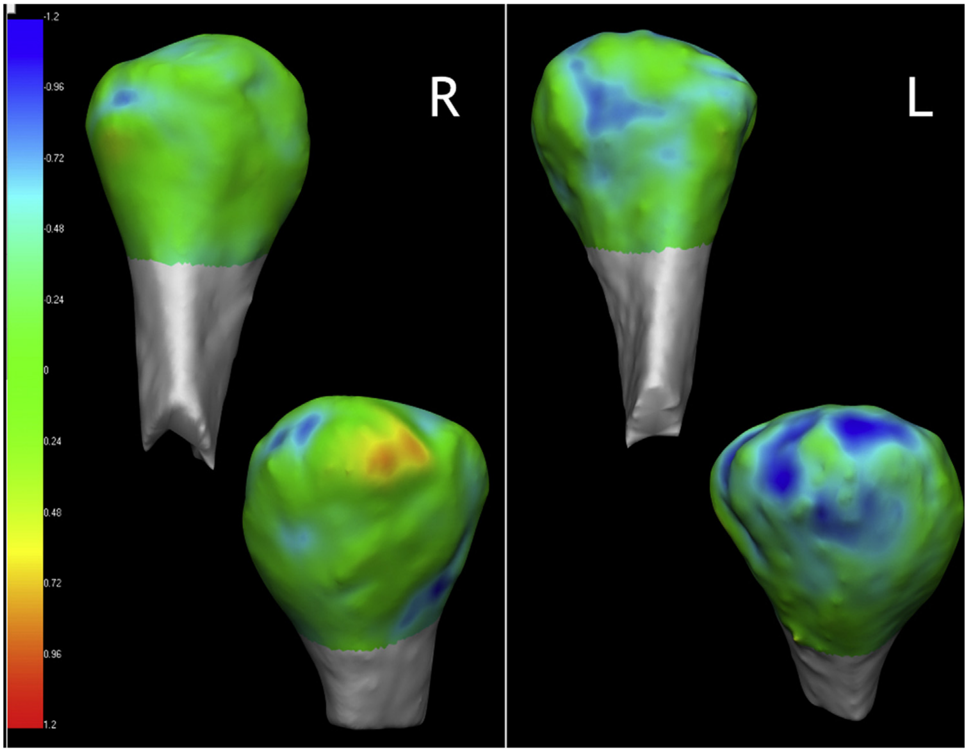


*Fig. 7.* Evaluation of condylar remodeling in the area containing the 20-mm uppermost portion of the condyle with color-coded distance maps. Example in a randomly selected patient in the right and left sides. In blue are the areas with bone resorption, the color on the left indicates new bone formation. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

*Table 2.* Mean values for postoperative changes[a] (T1–T2) according to the region of interest.

| | Min | Max | sd | rms |
|---|---|---|---|---|
| Anterior surface | −0.31 | 0.51 | 0.17 | 0.27 |
| Posterior surface | −0.58 | 0.21 | 0.17 | 0.35 |
| Superior surface | −0.55 | 0.27 | 0.19 | 0.34 |
| Lateral surface | −0.42 | 0.34 | 0.19 | 0.32 |
| Medial surface | −0.38 | 0.41 | 0.18 | 0.27 |
| Area[b] | −0.38 | 0.41 | 0.18 | 0.27 |

Min, minimun; Max, maximun; SD, standard deviation; RMS, root mean square.
[a] Negative values indicate bone resorption and positive values indicate bone apposition.
[b] Selected region of interest with the uppermost 20-mm portion of the condyles.

*Table 3.* Morphologic linear changes at the uppermost 20-mm condylar area; bone alterations from T1 to T2.

| Classification | Scale in mm[a] | Patients n = 28 | Condyles n = 56 |
|---|---|---|---|
| Resorption | −3 to −1 | 4 (14.2%) | 5 (8.92%) |
| Few alteration | −1 to +1 | 21 (75%) | 48 (85.7%) |
| Bone apposition | +1 to +3 | 3 (10.7%) | 3 (5.3%) |

[a] Negative values indicate bone resorption and positive values indicate bone apposition.

influence the stability of the results of orthognathic surgery when counterclockwise rotation of the maxillomandibular complex was performed. With a total of 12 studies and 345 patients, the authors concluded that bimaxillary advancement with a counterclockwise rotation is a stable procedure in patients with healthy TMJs, concurrent with disc-repositioning surgery or unstable TMJ prosthesis in patients with displaced discs[22].

Park et al. (2012) conducted a metric analysis of condylar changes using both anterior cranial base and regional superimposition of mandibular condyles and concluded that orthognathic surgery has an impact on the remodeling process. However, the authors only provided subjective interpretation of the observed data, without a tool to measure these changes[3]. Gomes et al. (2017) presented a comprehensive evaluation of condylar changes, including superimposition using the cranial base and regional superimposition. All the patients were subjected to orthognathic surgery with a concurrent TMJ-disc-repositioning surgery due to a diagnosis of anterior disc displacement. The authors concluded that the positional changes of the condyles had a weak association with the condylar remodeling process[23]. Da Silva et al. (2018) evaluated the volume of the condyles after bimaxillary surgery in Class II patients. They did not find correlation between the amount of advancement and condylar volume change. Their results also showed that approximately 33% of the condyles evaluated showed volume reduction of 23% of its initial size, while 21% showed an increase in volume of approximately 17%. The study did not perform superimposition, therefore, it was not possible to identify areas of resorption or deposition[24].

The results of this study suggest that changes in the TMJ after orthognathic surgery occur as a natural adaptive response in healthy patients and differ from a pathological process. This hypothesis is supported by recent publications in which clinical, radiographic, and tomographic evaluations were conducted in patients undergoing orthognathic surgery and which, despite using different methodologies, showed similar results that highlight the adaptational character of condylar changes[4,16,25]. The present study showed an innovative 3D assessment of mandibular condyles after orthognathic surgery. However, limited information regarding mandibular movements (advancement measurement only) are available to correlate with condylar changes. Further studies can address this limitation using a similar 3D methodology with a comprehensive data analysis of the surgical movements such as rotations and impactions. It may help to clarify the mechanisms involved in cases in which the condylar remodeling process is more present.

In conclusion, the present study supports the hypothesis that TMJs in healthy individuals can experience the changes caused by orthognathic surgery in the short term. In their routines, both orthodontists and surgeons should evaluate the TMJ before offering the treatment to patients.

## Funding

This study received no funding.

## Competing interests

None declared.

## Ethical approval

This work was approved by the Ethics Committee of the Pontifical Catholic University of Rio Grande do Sul – PUCRS – School of Dentistry (reference number CAAE: 83104417.6.0000.5336).

## Patient consent

All patients signed an informed consent form for hospital admission, surgical procedures, and release of information for research purposes.

## References

1. Veldhuis EC, Veldhuis AH, Bramer WM, Wolvius EB, Koudstaal MJ. The effect of orthognathic surgery on the temporomandibular joint and oral function: a systematic review. *Int J Oral Maxillofac Surg* 2017;**46**:554–63.
2. Al-Moraissi EA, Wolford LM, Perez D, Laskin DM, Ellis E. Does orthognathic surgery cause or cure temporomandibular disorders? A systematic review and meta-analysis. *J Oral Maxillofac Surg* 2017;**75**:1835–47.
3. Park SB, Yang YM, Kim YI, Cho BH, Jung YH, Hwang DS. Effect of bimaxillary surgery on adaptive condylar head remodeling: metric analysis and image interpretation using cone-beam computed tomography volume superimposition. *J Oral Maxillofac Surg* 2012;**70**:1951–9.
4. Han YS, Jung YE, Song IS, Lee SJ, Seo BM. Three-dimensional computed tomographic assessment of temporomandibular joint stability after orthognathic surgery. *J Oral Maxillofac Surg* 2016;**74**:1454–62.
5. Valladares-Neto J, Cevidanes LH, Rocha WC, Almeida GA, Paiva JB, Rino-Neto J. TMJ response to mandibular advancement surgery: an overview of risk factors. *J Appl Oral Sci* 2014;**22**:2–14.
6. Gateno J, Xia J, Teichgraeber JF, Rosen A. A new technique for the creation of a computerized composite skull model. *J Oral Maxillofac Surg* 2003;**61**:222–7.
7. Lagravère MO, Carey J, Toogood RW, Major PW. Three-dimensional accuracy of measurements made with software on cone-beam computed tomography images. *Am J Orthod Dentofacial Orthop* 2008;**134**:112–6.
8. Ballrick JW, Palomo JM, Ruch E, Amberman BD, Hans MG. Image distortion and spatial resolution of a commercially available cone-beam computed tomography machine. *Am J Orthod Dentofacial Orthop* 2008;**134**:573–82.
9. Swennen GRJ, Mommaerts MY, Abeloos J, De Clercq C, Lamoral P, Neyt N, Casselman J, Schutyser F. A cone-beam CT based technique to augment the 3D virtual skull model with a detailed dental surface. *Int J Oral Maxillofac Surg* 2009;**38**:48–57.
10. Swennen GRJ, Mollemans W, De Clercq C, Abeloos J, Lamoral P, Lippens F, Neyt N, Casselman J, Schutyser F. A cone-beam CT triple scan procedure to obtain a three-dimensional augmented virtual skull model appropriate for orthognathic surgery planning. *J Craniofac Surg* 2009;**20**:297–307.
11. De Vos W, Casselman J, Swennen GRJ. Cone-beam computerized tomography (CBCT) imaging of the oral and maxillofacial region: a systematic review of the literature. *Int J Oral Maxillofac Surg* 2009;**38**:609–25.
12. Cevidanes LH, Bailey LJ, Tucker Jr GR, Styner MA, Mol A, Phillips CL, Proffit WR, Turvey T. Superimposition of 3 D cone-beam CT models of orthognathic surgery patients. *Dentomaxillofac Radiol* 2005;**34**:369–75.
13. Li G, Xie H, Ning H, Capala J, Arora BC, Coleman CN, Camphausen K, Miller RW. A novel 3D volumetric voxel registration technique for volume- view-guided image registration of multiple imaging modalities. *Int J Radiat Oncol Biol Phys* 2005;**63**:261–73.
14. Cevidanes LH, Styner MA, Proffit WR. Image analysis and superimposition of 3-dimensional cone-beam computed tomography models. *Am J Orthod Dentofacial Orthop* 2006;**129**:611–8.
15. Motta AT, Cevidanes LH, Carvalho FA, Almeida MA, Phillips C. Three-dimensional regional displacements after mandibular advancement surgery: one year of follow-up. *J Oral Maxillofac Surg* 2011;**69**:1447–57.
16. Paula LK, Ruellas ACO, Paniagua B, Styner M, Turvey T, Zhu H, Wang J, Cevidanes LHS. One-year assessment of surgical outcomes in Class III patients using cone beam computed tomography. *Int J Oral Maxillofac Surg* 2013;**42**:780–9.
17. Weissheimer A, Menezes LM, Koerich L, Pham J, Cevidanes LH. Fast three-dimensional superimposition of cone beam computed tomography for orthopaedics and orthognathic surgery evaluation. *Int J Oral Maxillofac Surg* 2015;**44**:1188–96.
18. Ruellas AC, Tonello C, Gomes LR, Yatabe MS, Macron L, Lopinto J, Goncalves JR, Garib Carreira DG, Alonso N, Souki BQ, Coqueiro S, Cevidanes LH. Common 3-dimensional coordinate system for assessment of directional changes. *Am J Orthod Dentofacial Orthop* 2016;**149**:645–56.
19. Schilling J, Gomes LC, Benavides E, Nguyen T, Paniagua B, Styner M, Boen V, Gonçalves JR, Cevidanes LH. Regional 3D superimposition to assess temporomandibular joint condylar morphology. *Dentomaxillofac Radiol* 2014;**43**:20130273.
20. Koerich LD, Burns D, Weissheimer A, Claus JDP. Three-dimensional maxillary and mandibular regional superimposition using cone beam computed tomography: a validation study. *Int J Oral Maxillofac Surg* 2016;**45**:662–9.
21. Koerich L, Weissheimer A, Koerich LE, Luz D, Golob Deeb J. A technique of CBCT superimposition in implant dentistry. *J Oral Implantol* 2018;**44**(5):365–9.
22. Al-Moraissi EA, Wolford LM. Does temporomandibular joint pathology with or without surgical management affect the stability of counterclockwise rotation of the maxillo-mandibular complex in orthognathic surgery? A systematic review and meta-analysis. *J Oral Maxillofac Surg* 2017;**75**:805–21.
23. Gomes LR, Cevidanes LH, Gomes MR, Ruellas AC, Ryan DP, Paniagua B, Wolford LM, Gonçalves JR. Counterclockwise maxillomandibular advancement surgery and disc repositioning: can condylar remodeling in the long-term follow-up be predicted? *Int J Oral Maxillofac Surg* 2017;**46**:1569–78.
24. da Silva RJ, Valadares Souza CV, Souza GA, Ambrosano GMB, Freitas DQ, Sant'Ana E, de Oliveira-Santos C. Changes in condylar

volume and joint spaces after orthognathic surgery. *Int J Oral Maxillofac Surg* 2018;**47**(4):511–7.

25. Kim YI, Cho BH, Jung YH, Son WS, Park SB. Cone-beam computerized tomography evaluation of condylar changes and stability following two-jaw surgery: Le Fort I osteotomy and mandibular setback surgery with rigid fixation. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2011;**111**:681–7.

Address:
*Jonathas Daniel Paggi Claus*
*Av Trompowsky*
*291sala 103*
*88015-300*
*Florianopolis*
*SC*
*Tel.: +55 48 984141828*
*E-mail: cirurgiaofacial@gmail.com*