Are condylar morphologic changes associated with temporomandibular disorders in patients with orthognathia?

CATHERINE, Zulma Marie Quitterie, COURVOISIER, Delphine, SCOLOZZI, Paolo

Abstract
To determine the association between morphologic condylar changes and temporomandibular disorders (TMDs) in patients with orthognathia.

Reference

DOI : 10.1016/j.oooo.2016.03.006
PMID : 27220603
Are condylar morphologic changes associated with temporomandibular disorders in patients with orthognathia?

Zulma Catherine, MD, a Delphine S. Courvoisier, PhD, b and Paolo Scolozzi, MD, DMD c

Objective. To determine the association between morphologic condylar changes and temporomandibular disorders (TMDs) in patients with orthognathia.

Study Design. Data from 89 patients were analyzed. TMDs were classified according to the Research Diagnostic Criteria for TMDs. TMD severity was scored according to the Helkimo indices. Calculation of the condylar area, perimeter, and height was performed by using a specific computational method including panoramic radiography.

Results. Sixty-five (73%) patients presented with morphologic condylar changes. Decreases in condylar perimeter and area were found to be predictors of postoperative TMDs (P = .009; odds ratio [OR] = 3.66) and disk displacement (P = .008; OR = 4.43), respectively. Condylar area and height decreases were associated with worsening of TMDs (P = .03 and 0.04).

Conclusions. This study demonstrated that in orthognathic patients, postoperative condylar changes are associated with postoperative TMDs as well as with the degree of TMD severity and that preoperative TMDs are associated with such condylar changes. (Oral Surg Oral Med Oral Pathol Oral Radiol 2016;122:e44-e50)

Temporomandibular joint disorder (TMD), an umbrella term for a number of disorders, is commonly found in the literature.1-3 This term refers to various muscle and joint problems, among which myofascial pain dysfunction (MPD) and disk displacement (DD) or internal derangement represent, by far, the most frequent pathologic entities encountered routinely in the clinic.1-3 The association among TMDs, orthognathic surgery, and condylar morphologic changes continues to be an unresolved source of debate, as represented in the literature.4-16 Some studies have shown a positive effect from surgery relative to preoperative TMD, whereas others have shown a negative outcome.4-16 It has been shown that between 3.7% and 21% of patients with no TMDs before surgery will subsequently develop de novo postoperative TMDs.4,7 Studies have tried to highlight clinical predictors of postoperative TMDs to screen at-risk patients; thus far, the only significant independent predictor has been anamnestic temporomandibular joint (TMJ) clicking.16

Although condylar morphologic and positional changes following orthognathic surgery have been extensively studied, this association remains unclear.17-29 Two main categories of condylar morphologic changes have been reported, mainly based on differences between the right and left ramus height: condylar remodeling and condylar resorption.17-30 Although the physiopathologic mechanism of such changes still remains obscure and thus largely speculative, it has been demonstrated that condylar resorption resulted in more severe clinical consequences, such as a high risk of developing an anterior open bite, compared with simple bone surface remodeling.17,23,24,30 Conversely, the borderline between these two entities has never been scientifically established, and for this reason, we prefer to use the general term condylar morphologic changes. Studies on this particular association have mainly focused on methods of quantification of condylar changes with radiologic measurements, ranging from simple condylar height assessment on conventional radiographs to more sophisticated three-dimensional analysis using computed tomography (CT), cone beam CT (CBCT), and magnetic resonance imaging (MRI).31-39 To the best of our knowledge, only one study has investigated the association between condylar bony changes and postoperative TMDs in patients with orthognathia, based on a three-dimensional analysis with CT.28 However, the association between condylar morphologic changes, as measured with standard panoramic radiography, and

Statement of Clinical Relevance

Our study showed that postoperative condylar morphologic changes in patients with orthognathia are significantly associated with postoperative temporomandibular disorders (TMDs) as well as with the degree of TMD severity. Moreover, preoperative TMDs were also significantly associated with postoperative condylar morphologic changes.
postoperative TMDs in patients receiving combined orthodontic and orthognathic treatment and the predictive value of preoperative TMDs on postoperative condylar changes remain unreported.

The aim of this study was to use a validated method of measurement on panoramic radiographs from patients with orthognathia to determine whether (1) the radiologic morphologic condylar changes were associated with postoperative TMDs and/or to TMD severity or (2) the preoperative TMDs could predict such condylar changes.

MATERIALS AND METHODS

Study design
This retrospective study included 89 patients who underwent orthognathic surgery between 2007 and 2014 at the Hôpitaux Universitaires de Genève, Switzerland. The study was designed and conducted in accordance with the Helsinki Declaration of 1975, as revised in 2000, and was approved by our local ethics board.

Patients who had LeFort I osteotomy only, bilateral sagittal split osteotomy (BSSO) only, or BSSO combined with LeFort I osteotomy were included in this study.

The exclusion criteria were (1) history of facial surgery or trauma, (2) history of TMD treatment (conservative and/or surgical), and (3) history of genioplasty alone.

The variables reviewed were (1) age, (2) gender, (3) type of dentofacial deformity, (4) type of surgical procedure, (5) TMDs and the Helkimo index, and (6) radiologic measurements on panoramic radiographs by using our specific computational method (i.e., condylar height, area, and perimeter).

The TMDs were classified according to the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD), and two main categories were thus analyzed: (1) muscle disorders (MPDs) and (2) disk displacement (DD). The severity of the TMDs was scored by using the Helkimo index, which ranged from 0 to II for the clinical dysfunction index (Di) and from 0 to III for the anamnestic dysfunction index (Ai) scored by using the Helkimo index, which ranged from 0 to II for the anamnestic dysfunction index (Ai).

All patients had clinical and radiologic preoperative (t0) and 6- or 12-month postoperative (t1) examinations.

Surgical considerations
Maxilla repositioning was performed either with conventional one piece LeFort I osteotomy or with two- or three-piece maxillary osteotomy. The repositioning of the mandible was performed with bilateral sagittal split osteotomy (BSSO) by using the Hunsuck/Epker-type procedure, with the placement of two bicortical positioning screws and osteosynthesis. Adjunctive postoperative maxillomandibular fixation was not performed on any patient.

Image acquisition
From 2007 to 2012, panoramic radiographs were taken with a digital panoramic radiograph system (Gendex Orthoralix 9200; Gendex, Hatfield, PA; power supply 115–250 V AC ± 10%; frequency 50/60 Hz ± 2 Hz; maximum line power rating 10 A at 250 V; 20 A at 115 V; anode voltage 70–78 kV, in 2-kV steps; anode current 3–15 mA, in 1-mA steps; exposure time 12 second for standard pan, total cycle 24 seconds; focal spot 0.5 mm, distance spot sensor 505 mm; pixel size 48 µm; resolution 10.4 lp mm; image size 1536 × 2725 pixels; active area sensor 146 × 6 mm; ×1.25 magnification; delivered dose 0.325 µGy s⁻¹ at 70 kV 10 mA).

Since 2013, the image acquisition switched to a numerical panoramic radiograph system (Planmeca ProMax; Planmeca, Helsinki, Finland; technique 9–10 mA and 66 kV 16 s; anode voltage 54–84 kV ± 5%; anode current 1–16 mA ± 10%; exposure time 16 seconds for total cycle; focal spot 0.5 × 0.5 mm; pixel size 33 µm; image pixel size 99/130 µm; total filtration 2.5 mm Al; delivered dose 103.3 mGy/cm²).

Computer image analysis
The Digital Imaging and Communications in Medicine (DICOM) data were processed by using OsiriX imaging software (version 3.0.2, 64-bit, Pixmeo, Geneva, Switzerland; www.osirix-viewer.com) running on a MacOSX 10.8.5 (Apple Inc., Cupertino, CA). All condylar radiologic landmarks (area, perimeter, and height of each condyle) were measured by using our previously described and validated computational method36 (Figure 1). The measurements were made by two different investigators before surgery (t0) and 6 or 12 months after surgery (t1).

Statistical analysis
Data were analyzed by using R 3.1.1 statistical software (R Development Core Team, Vienna, Austria).

Patients were categorized as having a clinically significant change in condylar area, perimeter, or height if the decrease in one of the parameters was above the measurement error margin obtained in our previous study.36 The thresholds were a decrease of 0.16 mm² for area, 0.34 mm for perimeter, and 0.04 mm for height.

The association of the reduction in condylar parameters and TMDs, MPD, or DD at 1-year follow-up was estimated by using logistic regression, adjusting for type of surgery and type of dentofacial deformity. When the outcome was TMDs, the analysis was further
adjusted for the presence of the specific preoperative TMDs (e.g., general TMD before surgery when the outcome was TMD after surgery; MPD before surgery when the outcome was MPD after surgery). For the Helkimo indices, we used linear regression to examine the association between the Helkimo indices before surgery and reduction in each condylar parameter, adjusting for type of surgery, type of dentofacial deformity, and the Helkimo indices before surgery. Confusion bias would arise if patients with TMD before surgery had a higher prevalence of preoperative clinical signs, and thus an increased likelihood of a TMD in the 1-year follow-up, compared with patients without TMD. Therefore, we adjusted all analyses for initial TMD status in the description of the multivariate model.

As a sensitivity analysis, and because the Helkimo indices were not normally distributed, we verified the robustness of the linear regression analyses by replicating the analyses, using the Wilcoxon rank sum test (without adjusting). Since the results were very similar, only the results of the linear regression analyses are presented in the Results section below.

RESULTS
Of the 89 patients included, 48 (53.9%) were women, and almost all were white (85 white, 3 African, 1 Asian). The types of surgery were LeFort only (n = 10), BSSO only (n = 25), and LeFort I with BSSO (n = 54). Dentofacial deformities were open bite (n = 29), skeletal Class II malocclusion (n = 32), or Class III malocclusion (n = 28). Patients were, on average, 24 years old (standard deviation [SD] = 9.5), with a median age of 20 years.

On average, there were no significant changes in TMJ characteristics over time except for maximum opening of the mouth and protrusion, both of which significantly decreased after surgery (P = .003 for both parameters). Radiologic condylar characteristics also remained stable over time (Table I). However, 44 (49.4%) patients had a reduction greater than the measurement error threshold in area, 44 (49.4%), perimeter, 59 (66.3%), and height, and 65 (73%) had a reduction in at least one condylar parameter. Postoperatively, TMDs occurred in 18 (37.5%) of the 48 patients who did not have TMDs before surgery. These resolved in 14 (34.1%) of 41 patients who had preoperative TMDs. Overall, 65 (73%) patients had a reduction of one or more condylar parameters.

Generally, decreases in condylar area, perimeter, or height were more frequent among patients with TMDs compared with patients who did not have a decrease. The association between decrease in condylar parameters and TMDs was stronger and significant in patients who developed TMDs after the surgery (P = .02), even when adjusting for surgery and type of dentofacial deformity (Table II). Preoperative TMDs were clinically (50.8% of patients), albeit not statistically, associated with a postoperative decrease in condylar parameters.

The multivariate analysis after adjustment for gender, age, dentofacial deformity, surgical procedure and preoperative TMDs showed that decrease in condylar perimeter was found to be a significant predictor of postoperative TMDs (P = .009; OR = 3.66). Decrease in area or height showed the same pattern of results, although these associations were not significant. Decrease in condylar area was found to be a significant predictor of postoperative DD (P = .008; OR = 4.43), and decrease in perimeter was found to be a very close to significance predictor (P = .08; OR = 2.51) (Table III). MPD showed only a small and
Table I. Patients characteristics

<table>
<thead>
<tr>
<th>Presence of TMD</th>
<th>Before surgery</th>
<th>After surgery</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TMJ dysfunction, N (%)</td>
<td>41 (46.0%)</td>
<td>45 (50.6%)</td>
<td>.65</td>
</tr>
<tr>
<td>MPD</td>
<td>17 (19.1%)</td>
<td>25 (28.1%)</td>
<td>.22</td>
</tr>
<tr>
<td>DD</td>
<td>34 (38.2%)</td>
<td>25 (28.1%)</td>
<td>.20</td>
</tr>
</tbody>
</table>

| TMJ function             |                 |               |         |
| Ai, mean (SD)            | 0.53 (0.74)     | 0.49 (0.74)   | .85     |
| Di, mean (SD)            | 1.02 (0.66)     | 1.06 (0.66)   | .74     |
| Maximal opening of the   | 48.75 (7.52)    | 46.72 (8.07)  | .03     |
| mouth, mean (SD)         |                |               |         |
| Protrusion, mean (SD)    | 7.02 (3.49)     | 6.16 (2.22)   | .03     |

| Condylar characteristics |                 |               |         |
| Height                   | 2.24 (0.55)     | 2.22 (0.61)   | .62     |
| Area                     | 2.63 (1.01)     | 2.55 (1.02)   | .56     |
| Perimeter                | 6.10 (1.82)     | 6.31 (3.15)   | .63     |

TMD, temporomandibular joint; TMJ, temporomandibular joint; MPD, myofascial pain syndrome; DD, disk displacement; Ai, anamnestic dysfunction index; Di, clinical dysfunction index; SD, standard deviation.

Table II. Association between presence of TMD (t0: preoperative; t1: postoperative) and decrease in condylar parameters, adjusted for type of surgery, type of dentofacial deformity

<table>
<thead>
<tr>
<th>Decrease</th>
<th>N = 65</th>
<th>No decrease</th>
<th>N = 24</th>
<th>Odds ratio</th>
<th>P Value</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>TMD</td>
<td>1.24</td>
<td>.21</td>
<td>.03</td>
<td>2.19</td>
<td>.13</td>
<td>0.81; 6.31</td>
</tr>
<tr>
<td>MPD</td>
<td>1.24</td>
<td>.21</td>
<td>.03</td>
<td>2.19</td>
<td>.13</td>
<td>0.81; 6.31</td>
</tr>
<tr>
<td>DD</td>
<td>1.24</td>
<td>.21</td>
<td>.03</td>
<td>2.19</td>
<td>.13</td>
<td>0.81; 6.31</td>
</tr>
</tbody>
</table>

TMD, temporomandibular disorder; MPD, myofascial pain syndrome; DD, disk displacement.

nonsignificant increase in the risk of having a reduction in any condylar parameter (Table III). Of note, the confusion bias regarding the possibility that the clinical signs could have a different predictive ability among patients with preoperative TMDs compared with patients without preoperative TMDs was eliminated by adjusting for TMD status.

Morphologic condylar changes were associated with the Helkimo indices. Condylar area and height decreases were also significantly associated with a worsening of Ai ($P = .03$ and 0.04, respectively). By contrast, condylar perimeter decrease showed a close to significant trend with regard to worsening of the Di ($P = .08$) (Table IV).

**DISCUSSION**

Our results indicated that a decrease in the three condylar morphologic parameters was associated with a clinically significant increase in postoperative TMDs and more specifically, with regard to DD. Concerning severity of TMDs, a decrease in two condylar parameters (height and area) was significantly associated with postoperative TMD Ai, whereas condylar perimeter decrease approached significance as a predictor of postoperative TMD Di. The co-association between condylar changes and TMDs was also found in the other direction with preoperative TMDs associated with a clinically significant (more than half the patients) decrease in at least one condylar morphologic parameter. The mean difference between preoperative and postoperative values of condylar parameters was not significant. Thus, we considered postoperative morphologic changes to be the consequence of adaptive bone “remodeling,” according to the classic, albeit not validated, nomenclature. Results, based on first impression, showing that condylar parameters do not decrease on average could falsely reassure surgeons. However, average results can hide large individual decreases for a specific patient. Indeed, a more nuanced analysis allowed for the identification of such large individual decreases. To do so, we used a cutoff for decrease based on twice the measurement error for each condylar parameter and found that decreases in condylar perimeter, area, and height were associated with postoperative TMD status. Moreover, multivariate analysis, adjusting for type of dentofacial deformity and type of surgical procedure, showed that these conclusions can be interpreted as the additional effect of preoperative anamnestic and clinical signs of TMDs on postoperative morphologic changes, irrespective of patients’ dentofacial deformities and surgical procedures.

Comparison of our results with analogous data in the literature was limited by the lack of similar studies.

The literature is replete with studies focusing on the effects of orthognathic surgery on TMDs, predicting that these effects as well as their possible impact on condylar bony changes represent a great challenge and still remain an unresolved issue. Moreover, studies have mainly investigated the prevalence of the intra-articular aspect of TMDs, that is, DD, with or without reduction, and information regarding masticatory muscular dysfunction is rather sparse. The high prevalence of DD in patients with orthognathia has been well documented and is present in up to 97% of cases. In contrast, very few studies have correlated DD to condylar bony changes. In the majority of cases, this association was found by using CT and by assessing qualitative changes, such as bone flattening, bone erosion, and osteophyte formation, rather than by quantifying dimensional changes. Some investigators have suggested that untreated TMJ internal derangement, such as DD, as well as osteoarthritis...
could act as negative factors in postoperative outcomes for the TMJ. Link and Nickerson found signs of arthrosis—based on conventional radiography—in 50% of patients with a follow-up greater than 12 months after orthognathic surgery. Unfortunately, no details of dimensional condylar changes were given. The association between condylar resorption and TMDs has been described, particularly in patients with a Class II long face who underwent maxillomandibular surgery. However, these conclusions have been empirically drawn and not based on pertinent statistical analysis. Thus, given that no studies have documented a possible reciprocal association between postoperative dimensional changes in condylar shape and TMDs, this possible relationship could be only speculative. Moreover, the majority of these studies have focused mainly on detection of specific risk factors for developing a particular form of resorption, such as idiopathic condylar resorption. A detailed analysis of such risks has been reported previously in the literature, and a discussion of this is beyond the scope of this article. Furthermore, an objective analysis of the literature is impossible, given the lack of consensus on the terminology used with regard to the different types of “resorptive” condylar changes, which sometimes are classified according to qualitative scores and sometimes by metric quantitative analysis. This confusion is further complicated because of differences in the radiologic modality used, that is, conventional radiography versus CT, CBCT, and/or MRI.

To date, only Yamada et al. have investigated the association between condylar bony changes and postoperative TMD. They showed that advanced condylar bony changes, such as erosion and/or osteophytes, were associated with postoperative TMJ clicking in patients with mandibular retrusion and open bite. However,
the diagnosis of TMD was based only on the presence of three clinical signs (i.e., TMJ clicking, TMJ pain, and maximum mouth opening) rather than on the RDC/TMD criteria, and they did not use the Helkimo indices.\textsuperscript{18} In contrast to our method, the radiologic analysis used was qualitative and not quantitative and made by using CT scans and not conventional radiographs.\textsuperscript{18}

With regard to the radiologic modalities used for condylar change assessment, quantitative methods to determine the condylar morphologic changes seen on panoramic radiographs have been previously reported and proved reliable, although they are limited to the condylar height measurement.\textsuperscript{27,31,34} This is because a decrease of condylar height has been used traditionally by the majority of investigators as the unique reference parameter in determining a diagnosis of condylar resorption versus remodeling.\textsuperscript{27,31,34} The most important bias found in all of the previous studies is that the diagnosis of condylar resorption versus remodeling was based on a misinterpretation of the results of Habets et al.’s study.\textsuperscript{31} In fact, Habets et al. suggested that more than a 6% difference in vertical ramus dimensions between the right and left sides should be considered condylar asymmetry, based on their experimental model.\textsuperscript{31} The original meaning of these results was subsequently changed by Moore et al., who used data from five patients to stipulate that a decrease of more than 6% in vertical ramus dimension should be considered condylar resorption, which then became the standard.\textsuperscript{18} However, no investigators have conducted studies to assess a possible association between condylar height and TMD clinical signs and/or symptoms. Our study is the first that specifically aimed to correlate TMDs with changes in condylar morphology. The most critical question is, are these morphologic changes merely the consequence of “physiologic” and adaptive bone remodeling following surgery, or should they be considered precursors of further condylar resorption? Our study could not answer this question. None of the patients developed the classic clinical manifestations associated with condylar resorption, such as anterior open bite and/or a mandibular clockwise rotation, nor did they develop condylar arthritic changes or require specific treatment for TMDs. Thus, it seems reasonable to assume that in our group of patients, the condylar morphologic changes observed were minor and represented bone remodeling. Even so, these signs were sufficiently large to be associated with the development of TMDs and with their severity. This is in contrast to the findings of Brooks et al., who stated that minimal condylar changes were probably of no clinical significance. Unfortunately, their study sample was too small to obtain sufficient statistical power for further stratification based on the type of dentofacial deformity and surgical procedure.\textsuperscript{12} The design of our study criticized because our analyses were not stratified on the basis of the type of surgery. Although this could be considered a deficiency, the advantage of including patients who underwent the three most common types of surgical procedures is that the sample better represents the real-life situation. Such an analysis improved the external validity or generalizability of the study. However, better external validity has the disadvantage of low internal validity, and the diversity of surgical procedures may potentially “hide” the ability of some radiologic signs to predict TMD postoperatively when patients undergo a specific type of surgery. Nevertheless, we believe that obtaining good generalizability with overall estimates of the association between radiologic signs and TMD in a general population of patients is clinically more relevant to most maxillofacial surgeons.

Our study has shown that postoperative condylar morphologic changes in patients with orthognathia are significantly associated with postoperative TMDs as well as with the degree of TMD severity. Additionally, preoperative TMDs were significantly associated with postoperative condylar morphologic changes.

REFERENCES

11. Dervis E, Tuncer E. Long-term evaluations of temporomandibular disorders in patients undergoing orthognathic surgery compared

OOOO

Volume 122, Number 2
Catherine, Courvoisier and Scolozzi

e49

Reprint requests:
Paolo Scolozzi, MD, DMD
Head, Division of Oral and Maxillofacial Surgery
Department of Surgery
University of Geneva & University Hospitals of Geneva
Geneva
Switzerland
Paolo.scolozzi@hcuge.ch