A hypothesis on the desired postoperative position of the condyle in orthognathic surgery: a review

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Competing interests: None declared

Funding: None

Ethical approval: Not required

Abstract

It is very important to clarify the relationship between a dentofacial structure and a temporomandibular joint (TMJ) structure in orthognathic surgery. Recently, it was reported that the skeletal and occlusal patterns were associated with the TMJ morphology including the disc position. In orthognathic surgery, some surgeons state that alterations in the condylar position from surgery can lead to malocclusion associated with the risk of early relapse, and also favor the development of temporomandibular disorders (TMD). For these reasons, several positioning devices have been proposed and applied, but now there is no scientific evidence to support the use of condylar positioning devices. There are some reasons why scientific evidence cannot be obtained, however, it also includes the question whether the preoperative position of the condyle is the desired postoperative position. The purpose of this study was to verify the desired condylar position in orthognathic surgery, based on literature on the postoperative condylar position in orthognathic surgery. From the studies reviewed, it was suggested that the preoperative position of the condyle was not the desired postoperative position in orthognathic surgery.

Key words: orthognathic surgery, condylar position, temporomandibular joint

Introduction

Sagittal split ramus osteotomy (SSRO) is a standard surgical method for correcting jaw deformities.[1] Alterations in the condylar position from surgery can lead to malocclusion associated with the risk of early relapse,[2,3] and the development of temporomandibular disorders (TMD).[4-6] For these reasons, several positioning devices have been proposed and applied, but generally do not provide better long-term outcomes in either mandibular advancement or setback surgery.[7] These condylar repositioning devices seem to place the distal segment into the maxilla-mandibular fixation position, and the positioning plate is replaced, theoretically repositioning the condyle in all three dimensions.

Epker and Wylie[8] insisted that maintenance of the normal presurgical anatomic position of the mandibular condyles and contiguous proximal mandibular ramus segment after SSRO was important, and suggested 3 reasons for accurately controlling the mandibular proximal segment: to ensure the stability of the surgical result, to reduce the adverse effects on the temporomandibular joint (TMJ) and to improve masticatory function.

Ellis[9] concluded a comprehensive review of the literature regarding the need for condylar positioning devices (CPDs) in 1994 and also raised important questions. Is the preoperative position of the condyle the desired postoperative position? Are CPDs effective?

Costa et al[10] concluded that there was no scientific evidence to support the routine use of CPDs in orthognathic surgery, from the studies reviewed in 2007.

However, determination of the postoperative condylar position is still controversial, and the answer to the question, "where is the desired postoperative position of the condyle", has never been found. Furthermore, TMJ morphology including the discs in each skeletal and occlusal pattern was not discussed.

The purpose of this study was to verify the desired condylar position in orthognathic surgery, based on literature on TMJ in jaw deformity patients.

At first, we have to recognize that there is variation in the TMJ morphology in each skeletal and occlusal pattern fundamentally.

TMJ morphology in each skeletal and occlusal pattern

Disc position

Disc displacement is a common abnormality seen in images of the TMJ. Usually the displacement is anterior, anterior lateral, or anterior medial. In the normal joint, the posterior band of the biconcave disc is located superior to the condyle in the closed-mouth position.[11-15] Normal disc position has been defined in previous studies without reference to the skeletal pattern and occlusion.[16,17] However, images different from those for normal joint categories have been recognized in each skeletal and occlusal pattern.

Fernandez et al. found that the incidence of disc displacement was 11.1% in a Class I anterior open-bite group and 10% in a Class III group. When the Class II group was investigated, a displaced disc was diagnosed in 15 of the 28 joints (53.6%).[18] Schellhas et al. presented 100 patients with a retrognathic facial skeleton in whom the TMJs were analyzed with the aid of magnetic resonance imaging for signs of moderate to severe pathology.[19] They found that a Class II dentofacial deformity was strongly associated with moderate to severe TMJ pathology or an anteriorly displaced disc. The degree of joint degeneration directly paralleled the severity of the retrognathia.

Increased prevalence of disc displacement has been found in patients presenting with mandibular retrognathia at orthognathic surgery. Link and Nickerson studied 39 patients referred for orthognathic surgery, 38 of whom were found to have disc displacement before surgery.[20] All open-bite patients and 88% of the patients with Class II malocclusion had bilateral disc displacement.

By using magnetic resonance imaging (MRI) the joints in prognathism patients could be classified into four types on the basis of disc position and shape: anteriorly displaced disc, anterior type, fully-covered type and posterior type.[21] The incidence of internal derangement in asymmetrical prognathia patients is higher than in symmetrical mandibular prognathia, and this difference is associated with the difference in TMJ morphology of both sides.[21] Anterior disc displacement has been observed mostly on the deviated side in patients with mandibular deviation.[20,21,23,24]

On the other hand, although there was no description regarding skeletal and occlusal patterns, MRI studies of symptom-free subjects have shown disc displacement in 33% of these subjects with clinically normal, undisturbed jaw function.[25,26] These results have led many authors to speculate that, in some instances, anterior disk displacement may be an anatomic variant or a precursor to TMJ dysfunction rather than a pathologic condition.[27,28]

Preoperative condylar position

The position of the condyle in the fossa depends on many factors, including the thickness of the disc and the tissues that line the condyle and eminence. The position of the condyle in the fossa may also affect its shape. Elias et al[29] found in a morphometric tomography study that condylar and fossal shapes were different between the groups; the Class III group had a more elongated and anteriorly inclined condylar head and a wider and shallower fossa. In the Class III group, the condyle was closer to the roof of the fossa. Class II Divisions 1 and 2 groups differed only in the position of the condyle in the fossa, which was situated more anteriorly in the Class II Division 1 group. Burke et al[30] investigated a sample of Class II subjects divided into 2 subgroups and exhibiting vertical and horizontal morphological characteristics. They assessed condylar shape as angled, concave, convex, and flat and reported no differences in condylar shape distribution between the subgroups.

Akahane et al[31] in a dry skull study, found a smaller eminence to the FH angle in the Class III group compared with the Class I group. Cohlmia et al[32] studied 232 patients with various malocclusions. The group with a reduced overjet had a smaller vertical height of the articular fossa. In the Class III asymmetry, the TMJ on the deviated side showed a significant eminence than that on the non-deviated side in another study[21].

Mongini[33] reported a correlation between condylar shape and position, a finding confirmed in a recent study on positional asymmetry of the condyles due to functional shift. Ricketts[34] and Pullinger et al[35] concluded that the condyle is positioned more forward in Class II Division 1 and more backward in Class III patients. Elias et al showed an intermediate position for Class III and a more backward position in Class II Division 2 patients.

Preoperative horizontal condylar angle

Westesson et al[36] found that the mean horizontal condylar angle was most acute in joints with a normal superior disc position (mean 21.2 degrees) and was less so in joints with disk displacement (29.7 degrees for disk displacement without reduction) and/or with degenerative joint disease (36.5 degrees). Fernandez Sanroman et al[18] found that the mean horizontal condylar angle in the Class II group was significantly larger than that in the control group, and that the larger condylar angle can be an aetiological factor for disc displacement and degenerative joint disease. Our previous study also showed a mean horizontal condylar angle for the Class III symmetry group of 12.0 degrees on the right and 11.8 degrees or the left[21].

These finding suggested that dentofacial deformity was strongly associated with variations in TMJ including disc position, condylar position and horizontal condylar long axis.

However, the biologic significance of shape is more important than shape categorization, and whether shape differs with age, pathological conditions, or malocclusion. It is widely accepted that the TMJ is subjected to loading under normal function. Such loading might not be similar between various malocclusions.

Preoperative chewing and condylar path

A comparison of the lengths of the axiographical protrusive curves showed significantly higher values in the Class II group than in the Class I group. Moreover, the inclinations of the protrusive and mediotrusive tracings were significantly flatter in the Class III group than in the Class I and Class II groups, demonstrating differences in the inclination of the functional protrusive and mediotrusive paths between the groups. Changes in the curvature of axiographic tracings showed a significantly less curved protrusive tracing in the Class III group than in the Class II group.[37] They suggested that the steepness of the posterior slope of the eminence in Class II patients adapts in response to the forward force on the condyle. Thus, patients with a Class II occlusion and an increased overjet must advance the mandible further forward to bring their incisors into occlusion. This encourages the teeth to take up a more anterior position.

When chewing movement in mandibular prognathism is examined, the presence or absence of symmetry must be distinguished, because the incidence of internal derangement is higher in patients with asymmetrical class Ⅲ than in patients with symmetrical mandibular prognathism. Although bilateral temporomandibular joint morphology is similar among cases with symmetry, it is noticeably different among cases with asymmetry[21]. In particular, the degree of mandibular deviation along the condylar long axis varies with mandibular movement[38]. Some researchers have reported that subjects with mandibular deviation have an asymmetrical sagittal condylar path angle and an asymmetrical length and curvature of the anterior condylar path[39-41]. Therefore, it is important to assess the relationship between maxillofacial morphology and gnathological function in patients with prognathism on the basis of symmetry or asymmetry.

Dynamic analysis of TMJ in each skeletal pattern

Most studies agree that the external and internal morphologies of a given bone or joint in an adult are determined by the biomechanical loads placed upon them during growth[42-44]. These loads arise from the functioning of the associated musculature. O'Ryan and Epker[45] have demonstrated different loading characteristics of the TMJ that are associated with different skeletal patterns. Through examination of the trabecular patterns of condyles from Class I, Class II open bite, and Class II deep bite skeletal patterns, they deduced the vectors of condylar loading in the functioning joint. They found that the functional loading patterns in these cases were significantly different. If the function loading patterns of the TMJ is different in different skeletal patterns, it is likely that the structural relationship is also different. However, their study examined only the trabecular pattern of the condyle and did not deal with the intra-articular disc. Furthermore, no dynamic analysis was performed.

TMJ is regarded as a load bearing organ in the human body. During mandibular movements, the TMJ components obviously undergo mechanical loading. The functional stress in the TMJ plays an important and inevitable role for the development of articular cartilage. Several theoretical approaches have been used in an attempt to understand various aspects of TMJ biomechanics[46-51]. Some finite element models (FEMs) of the TMJ have been developed to simulate condyle motion or stress change. However, few studies were on the relationship between TMJ stress and jaw deformity patients. Tanne et al[52] investigated stresses on the TMJ during clenching associated with skeletal discrepancies in the vertical direction by use of a 3-D finite element model, and demonstrated that stress increased for the condyle, glenoid fossa and disc with larger gonial and mandibular plane angles. In the skeletal open bite with large gonial or mandibular plane angle, the mean stress became approximately 2-5 times greater on the condyle and 1.5-4 times on the glenoid fossa than those in the standard model, which were also approximately two times larger than those in the dentoalveolar open bite model.

From the results on FEM using frontal cephalogram, Buranastidporn et al[53] concluded that the symptomatic sides were significantly related to the degree of inclination of the frontal occlusal plane and increasing its angulation resulted in a decrease in symptoms on the ipsilateral side and an increase on the contralateral side.

The geometry of the FEMs was, however, based on only one representative image of the TMJ with normal occlusion in most studies, although significant differences in TMJ morphologies among the skeletal and occlusal patterns were found.

On the other hand, our previous study demonstrated that temporomandibular joint (TMJ) stress was associated with TMJ morphology in Class III patients whether or not they were asymmetric using the rigid body spring theory model (RBSM)[54]. Correlation between classification and stress angulation indicated that the stress direction of the anterior displaced or anterior type disc was more anterior to the condyle. The stress directions of the fully-covered and posterior types had a tendency to be more superior to the condyle. In other words, disc position and morphology were related to stress distribution.

Another study demonstrated that the stress direction on the condyle in the Class II patients was more anterior than in the Class I and III patients. The stress direction in the Class III group was more forward in comparison to those in the Class I and III groups[55]. This result might make it possible to examine the relationship between the original disc position and skeletal pattern, on the basis of the dynamic principle. If the disc acts as a shock absorber, it would naturally be anterior in Class II cases, as previously reported.

In the study using frontal cephalogram, it was found that the difference in stress angulation on the bilateral condyles could be associated with mandibular prognathism with asymmetry[56]. From these studies, it is impossible to judge whether the disc and condylar positions are normal without assessing the skeletal and occlusal patterns.

Postoperative condylar position

Luhr who advocated the use of CPD stated that " To make sure that both the condyles are seated in the centric relation, it is absolutely necessary that the occlusion be established using an occlusal bite splint (which had been prefabricated from impressions in centric relation) and IMF".[57] No details of how the centric relation of the interocclusal registration was presented. In dentistry, centric relation is the mandibular jaw position in which the head of the condyle is situated as far superior and posterior as it possibly can be within the mandibular fossa/glenoid fossa. This position is used when restoring edentulous patients with removable or either implant-supported hybrid or fixed prostheses. Centric relation is an old concept in dentistry based on an old mechanical viewpoint of dentistry. There are over 26 different definitions of centric relation since the term was first developed as a starting point for making dentures. It is not a physiologic position but rather a border position that is used for reproducibility. The temporomandibular joint, does not normally function in a centric relation position. Long centric is a term that describes a functional position that patients restored in centric relation frequently migrate to. Centric relation is a border position that is inherently unstable.[58] Some researchers have argued that the centric relation position changes continuously or represents a range of positions, making our ability to reproducibly identify such a position somewhat limited.[59-63] It seems inadequate to apply the concept of centric relation to the mandibular ramus osteotomy, although the mandible is divided into 3 pieces, namely, one distal segment and two proximal segments, and the positional relation between condyle and dentition changes by ramus osteotomy.

Ellis stated that there is probably no “best method “ for recording centric relation from a review of the literature, and the most important determination that should be made is identifying patients who have developed neuromuscular adaptations resulting in “functional shifts” of the occlusion.[9]

Summarizing the term “centric relation” is meaningless and quite dubious. In the review of Costa et al[10] three studies[6, 64-66] supported the use of CPDs, but only one[64] supported their application to improve clinical outcome concerning TMJ function and skeletal stability. One study[65], which was limited to Class III malocclusions, supported the use of CPDs only in the case of TMD. Two studies did not support the use of CPDs, because they failed to improve skeletal stability or TMJ function, irrespective of the skeletal deformities treated.[67,68] The condylar position could not be completely reproduced even if the CPD was used, although there was significant difference between the with and without CPD groups.

Reproduction of the preoperative “centric relation” by use of CPD lacks scientific evidence. It is impossible to completely reproduce the centric position prepared before surgery. Furthermore, the changes in the post-operative dynamic factor and ability of adaptation in TMJ were not considered in the concept.

Many researchers, using different radiographic methods, have studied the movements of the condyle that occur in patients who undergo orthognathic surgery. Freihofer and Petresevic[69], in a radiographic study of 38 patients who underwent SSRO for mandibular advancement, showed that 10 of 26 condyles appeared to be positioned anteriorly in the glenoid fossa. Will et al[70] similarly found that both condyles were positioned posteriorly in 41 patients who underwent SSRO to advance the mandible. However, in their study of 15 patients, Hackney et al[71] found no correlation between the amount of mandibular advancement and changes in condylar position or mandibular shape. In SSRO, rigid fixation of the mandible may create a greater change in the position of the condyle and a higher incidence of TMJ dysfunction compared with nonrigid fixation.[72]

In the study of Kim et al[73], the altered antero-posterior condylar position in the glenoid fossa after SSRO with rigid fixation moved from a concentric to anterior position for the post-retention period in the Class III cases.

Post-operative horizontal condylar angle

The angle of the condylar long axis has also been measured to evaluate condylar displacement by other investigators. Spitzer et al[74] measured the angulation of the condylar long axis on axial computed tomography scans and reported that rotational movement of the condyle was most commonly seen in patients who underwent SSRO with screw osteosynthesis. In contrast, Will et al[70] measured the angle between the long axis of the condyle and the midsagittal line in submentovertex projection in patients undergoing mandibular advancement and circumferential wiring, and noted that there was a tendency for counterclockwise inclination of the condyles, although it was not statistically significant. Hackney et al[71] measured the intercondylar angle defined as the long axis of each condyle, and reported no significant changes in the intercondylar angle after SSRO and screw osteosynthesis. Nishimura et al[75] reported that although inward rotation of the condyle frequently occurs after SSRO, the change was within the range of adaptability.

Lee et al[76] showed that the condyle tends to move inferiorly and rotate inward on the axial view and backward on the sagittal view in Class III cases by3-dimensional computed tomography (CT).

In our previous study, the horizontal condyle long axis increased significantly on the right side in the SSRO alone group.[77] However, there were no differences between the pre and postoperative angles of the condylar long axis, and we found no medio-lateral or antero-posterior displacement. This result suggests that even if the condylar repositioning device was not used, the condylar position and angle would not change significantly, even though we did not strive to maintain the preoperative condylar position.

On the other hand, the postoperative horizontal angle of the condylar long axis on an axial cephalogram decreased more than the preoperative ones on both sides after IVRO with and without Le Fort I osteotomy.[78] IVRO could decrease temporomandibular dysfunction and improve ADD with or without reduction, thus, this change in the condylar long axis could be physiological.

Post-operative disc position

The disc-condyle relationship is a more important parameter in assessing changes in TMJ morphology and symptoms. Recently, studies regarding the TMJ disc have been reported, because the TMJ structure could not be understood based solely on condylar position.

Gaggl et al[79] reported that in skeletal Class II patients, displacement of the articular disc was seen by MRI in 38 of 50 joints preoperatively and in only 28 postoperatively. In the study of Saka et al[80] 15/28 TMJs (54%) that had not been positioned underwent a change in disc position from physiological to anterior disc derangement (ADD) with and without reduction postoperatively in Class II cases. In the 28 that had been positioned, changes were found in only 3 TMJs (11%) postoperatively. They concluded that fixing the condylar process in the center of the articular fossa intraoperatively before bilateral sagittal split osteotomy was a factor in preventing postoperative structural changes in the temporomandibular joint.

We reported that SSRO with and without Le Fort I osteotomy could not improve anterior disc displacement, intra-oral vertical ramus osteotomy (IVRO) with and without Le Fort I could improve anterior disc displacement for a short postsurgical period, and both procedures could improve TMJ symptoms in Class III patients.[77,78]

Lee JA et al[81] found that the change of articular disc position after SSRO was not statistically significant, but it tended to be postioned posteriorly in the Class III cases.

Kim YK et al[82] also found that the disc positions showed no statistically significant differences between the pre and postoperative states in the closed state in the Class III setback cases.

Fang et al[83] also reported that there was no significant difference in the disc length with MRI between the pre- and postoperative states in 24 skeletal Class III patients.

From these studies using MRI, anterior disc displacement could be improved after SSRO in Class II advance cases in Gaggle's study only. In Class III setback cases, all authors reported that anterior disc displacement could not improve after SSRO. In another study, a comparison of the lengths of the axiographic protrusive curves showed significantly higher values in the Class II group than the Class I group. Moreover, the inclinations of the protrusive and mediotrusive tracings were significantly flatter in the Class III group than the Class I and II groups, demonstrating differences in the inclinations of the functional protrusive and mediotrusive paths between the groups. Changes in the curvatures of axiographic tracings showed significantly less curved protrusive tracings in the Class III group than the Class II group.[37] In other words, Class III patients can open their mouths wide without a condylar protrusive movement because they have a longer mandible. Therefore condylar movement after SSRO with and without Le Fort I osteotomy was also comparatively limited in the Class III patients.

However, it was found that IVRO can improve anterior disc displacement in our previous studies. The condylar position in the joint that improved anterior disc displacement was obviously different from the pre-operative position.[78] If the hypothesis that the post-operative condylar position is the same as the pre-operative position is true, then the disc position cannot improve.

TMJ symptom

Signs and symptoms of TMJ dysfunction have previously been studied in patients with dentofacial deformities[20, 84-86]. Fernandez Sanroman et al[18] found that the incidence of disc displacement was 11.1% for the Class I anterior open-bite group and 10% for the Class III group. When the Class II group was studied, an ADD was diagnosed in 15 of the 28 joints

(53.6%).

Changes in TMJ symptoms before and after orthognathic surgery have been discussed in several clinical investigations. Kerstens et al[85] reported postoperative improvement in 66% of patients who underwent orthognathic surgery; White and Dolwick[86] reported 89.1%. Similar data were found by Karabouta and Maris.[87] Hu et al[88] reported postoperative improvement in only 30% of the patients who had undergone SSRO but in 75% of the patients who had undergone IVRO. In our study, symptoms were improved by surgery in 76.5% of patients who underwent SSRO only, in 25.0% of patients who underwent SSRO with a Le Fort I osteotomy, in 91.7% of patients who underwent IVRO only, and in 76.9% of patients who underwent IVRO with a Le Fort I osteotomy. Overall, symptoms improved in 88% of patients who underwent IVRO and in 66.7% of patients who underwent SSRO; however, no statistically significant difference was found between the two procedures. Although SSRO did not change the disc position, the incidence of TMJ symptoms decreased after SSRO.[89] This suggests that TMJ symptoms are not always triggered by disc displacement. Thus, alteration of the disc-condyle relationship or reduction of a displaced disc may not always be necessary.

Al-Riyami et al[90] reported a review on orthognathic surgery and TMD, however, surgical factors such as amount of movement, the fixation method and post-operative condylar position were not investigated in detail. In their review, the results from all meta-analyses were subjected to considerable statistical heterogeneity, and it was not possible to draw strong inferences relating to the percentage of orthognathic surgery patients with TMD with any degree of certainty. However, they concluded that patients receiving orthognathic treatment to correct their dentofacial deformities and who are also suffering from TMD appear more likely to see improvement rather than deterioration in their signs and symptoms.

Ellis reported that the entire controversy between condylar position and TMD seems to be based on strong emotion and weak data in the review.[9] From the review, he mentioned that changes in condylar position induced by orthognathic surgery do not seem to increase the incidence of signs and symptom of TMD.

Post-operative chewing path and condylar path

Mandibular ramus osteotomy induces not only morphological but also functional improvements. Aragon et al[91] reported that protrusive movement and lateral excursion of the mandible did not recover to the preoperative levels after a sagittal split osteotomy was performed to advance the mandible. Boyd et al[92] also reported a significant reduction in protrusive movement in patients who had undergone sagittal split osteotomies for correction of mandibular retrusion. On the other hand, Nagamine et al[93] reported that the mean maximum anterior and posterior excursions, as well as the lateral excursion, of the mandible increased significantly after corrective surgery. Youssef et al[94] reported that mandibular excursions and cycle duration during mastication changed significantly with surgery. However, these studies did not deal with the habitual chewing path. In the study on the chewing path before and after SSRO and IVRO for mandibular prognathism with and without asymmetry, a surgically induced increase in the condylar long axis was correlated with an increase in the side range and incisor path angle.[95] However, surgical orthodontic treatment did not significantly change the chewing pattern. These results suggest that the change in the condylar long axis is very important for the postoperative chewing path and that the preoperative angle of the condylar long axis is not always adequate postoperatively.

In the study on maximal open-close movement of the jaw, and protrusive and lateral excursion movements, Hashimoto et al[96] reported that mandibular deviation was strongly related to the morphologic and functional asymmetries in patients with mandibular prognathism and deviation, and the condylar path length and condylar position were improved after correcting the mandibular deviation with IVRO.

These studies suggested that changing the condylar position could improve TMJ function after IVRO. If accurate condylar repositioning in SSRO is performed on the deviation side of the mandibular asymmetry with a TMJ that has an anteriorly displaced disc, improvement in TMJ function will not be expected.

Dynamic analysis of TMJ before and after orthognathic surgery

In the field of orthopedic surgery, simulation surgery using stress analysis on hip or knee joint has been reported. However, there is no report in English language on stress changes on the TMJ after orthognathic surgery, using FEM. Therefore, we have developed a stress analysis on TMJ using RBSM. The study by RBSM suggested that the stress on the TMJ could change after mandibular setback surgery; the degree and direction of the force vector, and the resulting displacement coordinates can be used as parameters in a surgical model.[97]

The results by RBSM using frontal cepalogram suggest that the difference between the right and left sides could also be improved after surgery in the symmetric group, however it could not be improved completely in the asymmetric group.[98] The frontal cephalograms 3-6 months post-operative were used in this study. Therefore, the shapes of the bilateral condylar surface that adapted the pre-operative mandibular asymmetry did not change immediately after surgery and were not stable dynamically within this period. However, more information including that on the remodeling process would have been gained if the registrations were done for example, atone, three and 12 months after the operation and even after a longer period of follow-up.

TMJ formation and morphology depend on the biomechanical force. Therefore, the simulation in orthognathic surgery should include not only geometric factors such using imaging treatment, but also dynamic factors. This may be one of the methods for obtaining an answer to the question “where is the condylar position after orthognathic surgery”.

Conclusion

Most surgeons rely on manual repositioning after sagittal split osteotomy to obtain the best mandibular proximal segment relationship with the condylar fossa. In repositioning the proximal segment, skilled surgeons feel the degree and direction of stress on the proximal segment and remember the data of the condylar position experienced previously. Recently, application of 3D CT for orthognathic surgical planning, especially the function of 3D virtual osteotomy, has been presented.[99-102] Multimodal 3D data fusion was also introduced to improve the accuracy of simulation and to apply it in surgical navigation.[103] However, only static images were handled, while other factors such as biomechanical force were not included. Furthermore, the description of postoperative condylar position was not found. To further develop orthognathic surgery, apart from geometric data, other numeric data such as cephalogram, CT and MRI should be proposed to evaluate the condylar position.

We think that the most favorable postoperative condylar position including the disc position and horizontal condylar angle may not match the preoperative one, but would not be dramatically different except for cases with TMD or asymmetry. The dynamic stable position in TMJ can be the most favorable on the basis of our previous study.[54-56, 97,98] The ideal post-operative position should be the position where the remodeling volume of the TMJ induced by postoperative biomechanical stress would be the smallest and degenerative change is not induced. However, it is still difficult to predict postoperative stress on the TMJ including disc tissues. We expect further development of orthognathic surgery simulation including the postoperative adaptation ability of the TMJ as well as the maxillofacial morphology.

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