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British Journal of Oral and Maxillofacial Surgery 57 (2019) 1086–1091

BRITISH Journal of Oral and Maxillofacial Surgery

www.bjoms.com

Changes in the position of the condyle after bilateral sagittal split ramus osteotomy in patients with mandibular retrusion and protrusion: a new condyle: fossa matching concept

Q. Yin [a], R. Bi [a], B. Abotaleb [a,b], N. Jiang [a], Y. Li [a,*], S. Zhu [a,*]

[a] *State Key Laboratory of Oral Diseases &National Clinical Research Center for Oral Diseases & Other Research Platform & Dept. of Oral and Maxillofacial Surgery, West China Hospital of Stomatology, Sichuan University*

[b] *Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Ibb University, Ibb, Yemen*

Available online 14 October 2019

Abstract

The purpose of this study was to compare the condylar positional changes after bilateral sagittal split ramus osteotomy (BSSRO) in patients with mandibular retrusion and those with mandibular prognathism. We also studied the correlation between the degree of matching of the condyle and fossa, and condylar displacement. Thirty patients with mandibular retrusion (n = 11) or mandibular prognathism (n = 19) who underwent BSSRO were included. The condylar position was assessed from spiral computed tomographic (CT) scans taken preoperatively, during the first postoperative week, and at least 6 months postoperatively. All data were measured by MIMICS 17.0 and analyzed by Student's *t* test and Pearson's correlation analysis. The size of the condyles of patients with mandibular retrusion was significantly less than those of patients with mandibular prognathism (491.5 (172.8) compared with 823.2 (212.0) mm^3). The size of the glenoid fossa in those with mandibular retrusion (599.6 (110.4) mm^3) and those with prognathism (597.6 (151.6) mm^3) did not seem to differ. Postoperatively the condyles moved outwards, backwards, and downwards in both groups of patients. Correlation analysis between the condyle:fossa volume ratio and the condylar positional changes showed that a large condyle:fossa volume ratio correlated with the smaller positional changes in the condyle. The condylar position changed immediately after mandibular advancement and setback, and persisted in the long term. Larger condyles tended to have fewer positional changes.

Keywords: Temporomandibular joint; Mandibular retrusion; Mandibular prognathism; Condyle head; Sagittal Split Ramus Osteotomy

Introduction

Sagittal split ramus osteotomy (SSRO) has often been used to treat mandibular retrusion (Class II) and mandibular prognathism (Class III), and its considerable advantages include the better bony interface between cut segments and the easier implementation of rigid fixation that minimises the need for intermaxillary fixation.[1] Although SSRO has many advantages, the change in condylar position is still of concern to many surgeons because it changes the position of the mandible, which leads to variations in the joint space. Movement of the distal fragment, tension in the surrounding muscles, the method of fixation, and the surgeon's operative experience, all affect the postoperative position of the condyle.[2]

Several studies have reported changes in the condylar position after mandibular sagittal split osteotomy.[3–7] It has been shown that the condyles displace inferiorly, posteriorly and laterally in patients with skeletal class III,[4,5] and inferiorly, anteriorly, and laterally in patients with skeletal class II.[3,6]

* Corresponding authors at: State Key Laboratory of Oral Diseases & National Clinical Research Center for Oral Diseases & Other Research Platform & Dept. of Oral and Maxillofacial Surgery, West China Hospital of Stomatology, Sichuan University, No.14, Sec. 3, Renminnan Road, Chengdu Sichuan 610041, China.

E-mail addresses: doctorlyf@163.com (Y. Li), zss_1977@163.com (S. Zhu).

https://doi.org/10.1016/j.bjoms.2019.09.022

These reported condylar displacements have varied among published studies. However, to our knowledge there has been no systemic comparative research that compares changes in the condylar position after SSRO between Class III and Class II patients. The underlying mechanisms of condylar movement in different types of mandibular deformity need to be elucidated.

The condyle and the glenoid fossa are the main components of the temporomandibular joint (TMJ), which are interdependent and mutually restrictive. Previous studies have suggested that a large condyle leads to a more stable postoperative occlusion, particularly in patients with class III disease.[8–11]

The hypothesis of this study was that this may be related to the matching degree of the size between the glenoid fossa and the condylar head and this is referred to as the "condyle:fossa matching degree" in this paper.

We have attempted to introduce a concept of condyle:fossa matching degree based on the size of the condyle and the glenoid fossa, and analysed the difference in changes to the condylar displacement after BSSRO in patients with mandibular retrusion and mandibular prognathism. We have also investigated the correlation between this new concept and the condylar positional changes that may affect postoperative stability after BSSRO.

Patients and methods

Patients

The study involved 30 consecutive patients who had had single-jaw operations (BSSRO) by the same surgeon from 2014 - 2017 in the West China Hospital of Stomatology, Sichuan Province, China.

The inclusion criteria were: patients with skeletal Class III or Class II malocclusion with no severe mandibular asymmetry (the distance of the median line of maxillary incisors apart from mandibular incisors was less than 3 mm), cleft, craniofacial syndrome, or trauma; and patients treated with single jaw BSSRO.

The patients were divided into two groups, those with mandibular retrusion (n = 11) and those with prognathism (n = 19). All patients had cephalometric radiographs and spiral computed tomography (CT) (in the rest position) preoperatively (T1); repeat spiral CT one week postoperatively (T2); and again at the completion of orthodontics (T3, at least six months postoperatively).

Quantitative analysis

CT data were processed by MIMICS 17.0 software (Materialise). All of the images in the Digital Imaging and Communication in Medicine (DICOM) files were transferred to MIMICS software and analysed by the same assessor. The "CT Bone Segmentation" mode segments mandible and maxilla, and is used to calculate mandibular and maxillary 3-dimensional models.

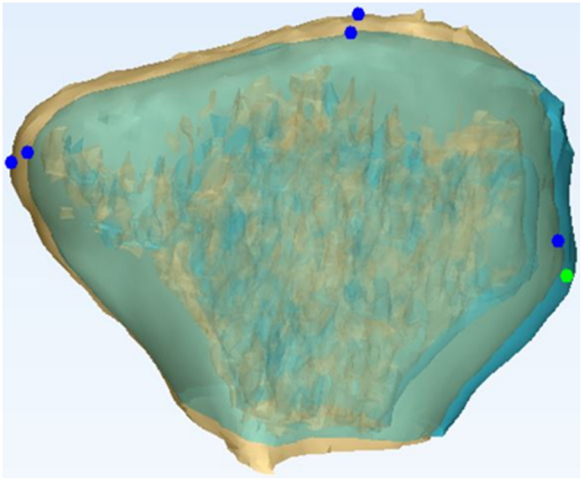

Fig. 1. The process of fitting the model of the condyle.

It is essential to adjust the position of jaw model in a coronal position, a sagittal position, and a horizontal position. We measured the angle of the Frankfort horizontal plane that deviates from the horizontal line in both the sagittal and coronal positions. In the horizontal position we chose one of the sections that crosses the foramen magnum, then connected the centre of the foramen magnum to the frontal point of the nasal septum, and measured the angle between it and the midline. Based on these angles, we finally repositioned the skull in a three-dimensional direction.

Three points were used to calculate the condylar position, including the medial pole, the external pole, and the upper pole of the condylar head (the projecting point on the inside, outside, and top on the model of the condyle). Nasion was used as the reference point in the coordinate system (x = 0, y = 0, z = 0) so that the condylar positions were comparable among patients. To compare the change in the condylar position in the same patient before and after operation, we fitted the preoperative and postoperative models of the skull by "N Points Registration" in Materialise 3-matic Research software. After that, the points of the medial, external, and upper poles of the condyle were marked on bilateral condyles, and their coordinates recorded (Fig.1).

To compare the volume of the glenoid fossa among patients, a plane at 5 mm below the top of the glenoid fossa parallel to the FH plane was made, and the volume of the glenoid fossa above this plane was calculated. The condyle:fossa matching degree was calculated as the ratio of the condylar volume surrounded by glenoid fossa to the volume of the glenoid fossa. The measurements of the size of the condyle for different patients were also the volume of the condyle surrounded by glenoid fossa.

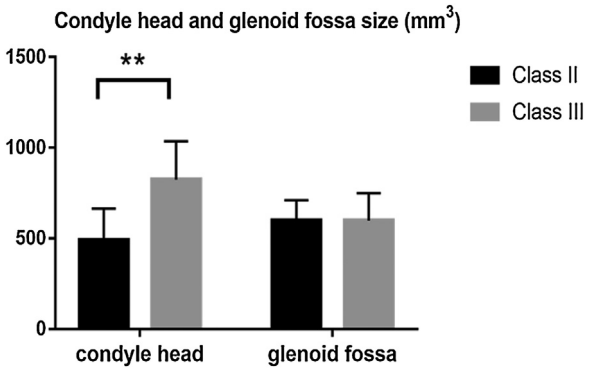

Fig. 2. Size of the condylar head and of the glenoid fossa in patients with mandibular retrusion and prognathism.

Statistical analysis

The coordinate transformation of the position of the condyle was calculated using Excel-Microsoft. The IBM SPSS Statistics for Windows software (version 22 IBM Corp) was used for statistical analysis. The single-sample, independent-sample *t* test and ANOVA were used to assess the significance of differences in the positional changes, size of the condyle head, and size of the articular fossa in both groups. The data are shown as mean (SD). We used Pearson's correlation coefficient to evaluate the significance of positional changes of the condyle according to the condyle:fossa matching degree. Differences were considered significant if the probability was less than 0.05.

Results

The mean (range) age of the patients was 23 (18-30) years. The mandibular retrusion group consisted of two male and nine female patients (mean (SD) age 24 (3) (range 21-30) years), and the mandibular prognathism group consisted of nine male and 10 female patients (mean (SD) age 23 (3) (range 18-28) years). There were no significant differences in patients' ages.

The size of the condyle in the patients with mandibular retrusion was significantly smaller than that of those of mandibular prognathism ($p < 0.01$), but comparison of the glenoid fossa size showed no apparent difference (Fig. 2).

Postoperatively the condylar positions moved outwards, backwards, and downwards on both mandibular retrusion and mandibular prognathism. The distances of the three points of the condyle were recorded respectively, and we then combined the positional changes of these three points. The positional changes from T1 to T2 were significantly different ($p<0.05$) (Table 1).

By comparing the positional change between the two groups of patients, we found that there was a significant difference in the positional change of the condyle in antero-

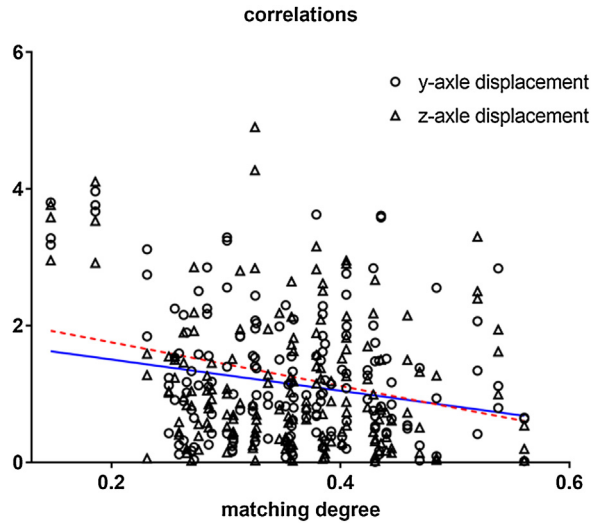

Fig. 3. Correlations between positional changes with condyle: fossa matching degree.

posterior (y axis) and upper-lower directions (z axis) between them ($p < 0.05$) (Table 2).

When we compared the positional changes in the condyle during T1-T2 and T1-T3, the p value was greater than 0.05, and showed that the condylar positions were stable over a long period of observation postoperatively (Table 3).

Correlation analysis of the changes in the position of the condyle and the condyle:fossa matching degree showed that the positional changes in the anteroposterior (y axis) and superoinferior (z axis) directions had negative correlations with the condyle:fossa matching degree, which means that the higher matching degree leads to less change in the position of the condyle. The Pearson correlation value was from 0.4 - 0.6, so the correlation between positional change and the articular matching degree was moderate (Fig. 3).

Discussion

The aim of this retrospective study was to evaluate the correlation between the condyle:fossa matching degree and the change in the position of the condyle after BSSRO, and compare differences in the positions of the condyle between patients with mandibular retrusion and prognathism. The changes in position before and after BSSRO have been reported in previous studies. Ueki et al[12] noted changes in the temporomandibular joint space after mandibular advancement and setback with Le Fort I osteotomy by comparing preoperative CT and CT at one year postoperatively. However, we know of no study that directly compared the condylar position in three dimensions after BSSRO between patients with mandibular retrusion and prognathism.

The position of the condyle in the glenoid fossa is not fixed, but varies during life. It has been reported that the condyle moves when head posture changes.[13] The force from the operation will displace the condyle even more. By measur-

Table 1
Vectors of surgical change between preoperative and postoperative computed tomographic images at the condylar head. Data are mean (SD).

			Mandibular retrusion		Mandibular prognathism	
			Positional change (T1-T2)	p value	Positional change (T1-T2)	p value
External pole	Left	x	1.158 (1.616)*	0.039	0.857 (1.849)	0.058
		y	0.901 (1.704)	0.110	−0.517 (1.659)	0.191
		z	0.465 (1.964)	0.451	−0.568 (1.313)	0.076
	Right	x	−1.210 (1.383)*	0.016	−0.332 (1.443)	0.328
		y	1.396 (1.626)*	0.017	0.010 (0.936)	0.964
		z	0.115 (1.196)	0.757	−0.645 (1.246)*	0.037
Upper pole	Left	x	1.066 (1.947)	0.099	1.274 (2.037)*	0.014
		y	1.301 (1.393)*	0.011	0.226 (1.533)	0.529
		z	−0.097 (1.892)	0.868	−0.747 (1.405)*	0.032
	Right	x	0.867 (1.713)	0.124	−0.526 (1.535)	0.152
		y	−0.160 (1.623)	0.750	0.719 (1.050)**	0.008
		z	1.063 (2.557)	0.198	−0.604 (1.443)	0.085
Medial pole	Left	x	1.030 (2.018)	0.121	1.381 (2.012)**	0.008
		y	1.119 (1.485)*	0.031	1.123 (1.583)**	0.006
		z	−0.254 (2.271)	0.718	−0.765 (1.521)*	0.042
	Right	x	−0.960 (1.699)	0.090	−0.925 (1.802)*	0.038
		y	1.268 (1.734)*	0.036	1.272 (0.993)**	0.000
		z	−0.330 (1.575)	0.502	−0.537 (1.269)	0.081
Total	Left	x	1.085 (1.810)**	0.002	1.171 (1.946)**	0.000
		y	1.107 (1.493)**	0.000	0.277 (1.704)	0.224
		z	0.038 (2.009)	0.914	−0.694 (1.393)**	0.000
	Right	x	−1.051 (1.549)**	0.000	−0.595 (1.591)**	0.007
		y	1.424 (1.559)**	0.000	0.667 (1.106)**	0.000
		z	−1.216 (1.380)	0.376	−0.595 (1.299)**	0.001

X is a component of the vector in the lateral (+) and medial (-) directions, Y in anterior (-) and posterior (+) directions and Z in upper (+) and lower (-) directions.
* $p < 0.05$.
** $p < 0.01$.

Table 2
Comparison of mean (SD) positional changes between Class II and Class III.

		Mandibular retrusion	Mandibular prognathism	p value
Total change	x	−0.017 (1.988)	0.288 (1.979)	0.378
	y	1.265 (1.523)	0.472 (1.444)	0.001
	z	−0.089 (1.715)	−0.644 (1.342)	0.017

It is not possible to distinguish between the left and right condyles.

ing positional coordinates before operation (T1), within one week of operation (T2), and at the completion of orthodontic treatment (T3, at least six months postoperatively), we found that the positional changes from T1 to T2 were significant. However, the positional changes from T2 to T3 tend to be stable. This suggests that the condyle is repositioned immediately after BSSRO, and that this position remains for six months or even longer. Kim et al[14] found that the condylar position in the glenoid fossa moved from the anterior to the central position, and tended to return slightly towards the original position after the mandibular setback with Le Fort I osteotomy. We found that the condyles of patients with mandibular retrusion were kept in the posterior and upper position after mandibular advancement, whereas the condyles were kept in their natural position after mandibular setback in patients with mandibular prognathism. The effective maxillomandibular fixation might be the reason that the condyles stay in a stable position for more than six months.

In patients with mandibular prognathism, the condyle moves outwards, backwards, and downwards by one week after BSSRO, which is consistent with previous studies.[4,5] In a mandibular advancement operation, the condyle moved outwards, backwards, and downwards, which conflicts with previous reports.[3,4,6] These discrepancies may be caused by different methods of measurement, and the variation among the cases.

In BSSRO, the mandible is divided into three parts: the distal fragment and two proximal fragments that connect with the condyles. When the bony segments are fixed, the condyle will move, which will increase risks of relapse and disorders of the TMJ. The study of the positions of the condyle before and after operation is important for surgeons to locate the condyle precisely. Previous studies have advocated that the type of operation, method of fixation, distance and direction of jaw movement, and muscular traction, might possibly affect the position of the condyle.[15–18] In addition, the articu-

Table 3
Mean (SD) positional changes for short-term and long-term postoperative observations.

			Short-term observation (after one week)	Long-term observation after six months or more	p value
External pole	left	x	0.431 (1.071)	0.429 (1.151)	0.609
		y	0.912 (1.626)	−0.025 (1.198)	0.294
		z	0.473 (1.628)	0.073 (1.176)	0.744
	right	x	−0.537 (1.221)	0.133 (0.751)	0.162
		y	0.636 (1.305)	0.188 (1.168)	0.701
		z	−0.068 (1.673)	−0.137 (2.179)	0.474
Upper pole	left	x	0.894 (1.358)	−0.404 (1.429)	0.255
		y	1.248 (1.446)	0.245 (1.108)	0.439
		z	−0.011 (1.444)	−0.672 (1.145)	0.499
	right	x	−0.910 (1.461)	−0.434 (1.031)	0.548
		y	1.120 (1.528)	0.042 (1.818)	0.289
		z	0.019 (1.676)	−0.645 (1.707)	0.935
Medial pole	left	x	0.450 (1.257)	0.231 (1.728)	0.504
		y	1.697 (1.418)	0.188 (1.168)	0.156
		z	−0.111 (1.744)	−0.846 (1.739)	0.543
	right	x	−0.858 (1.665)	0.282 (0.878)	0.084
		y	1.369 (1.081)	0.404 (1.722)	0.220
		z	−0.213 (1.442)	−0.733 (1.618)	0.814

lar structure may also be important for calculating the position of the condyle. The structure of the TMJ governs whether the condyle could sufficiently and stably move in the condylar fossa.

Current studies about TMJ have mainly focussed on the position and shape of the condyle and the glenoid fossa, rather than their sizes. The condyle:fossa matching degree is a new point of interest. Arnett and Gottesman[8] indicated that the large size of the condyle improves the articular stability when the occlusion is changed, as a result of the close contact between condyle and glenoid fossa, particularly for most of Class III patients. Cohlmia et al[19] found a more anterior condyle position in Class III patients than Class I, and no difference in condylar position between Class I and Class II. However, Kikuchi et al[20] indicated that a patient with a Class II skeletal pattern would have a condyle that was positioned more anteriorly than that of a Class III patient. Katsavrias and Halazonetis[11] concluded that the condyle was more elongated and inclined forwards, and the fossa was wider and shallower, in patients with Class III than Class II, and the condyle was closer to the fossa vertically. The closer distance between fossa and condyle explains that the condyle moves less in the fossa in the Class III group, which is consistent with our results. Mandibular retrusion of a patient's condylar volume is significantly smaller than that of those patients with mandibular prognathism, but the volumes of their glenoid fossas are similar. After being divided by condylar volume, therefore, the condyle:fossa matching degree in patients with mandibular retrusion is significantly smaller than that in patients with mandibular prognathism.

It can also be confirmed that the condyle:fossa matching degree has a negative correlation with positional variation, which suggests that the smaller condyles and similar glenoid fossas in patients with mandibular retrusion, cause a smaller condyle:fossa matching degree and more condylar displacement. The comparison of condylar positional change between patients with mandibular retrusion and prognathism shows that the displacement of the condyle in patients with mandibular retrusion is larger than that of patients with mandibular prognathism in an anteroposterior horizontal direction. The lower condyle:fossa matching degree could be the reason that the condylar position in patients with mandibular retrusion changed more postoperatively.

The structure and size of the condyle and TMJ are only the anatomical basis of condylar motion. The external force is also important. In mandibular advancement surgery the distal fragment of the mandible is moved anteriorly, then the muscles around the osteotomy line (suprahyoid muscles and descending muscles) are tensed, so that the condyles in the proximal fragment are moved more by muscles in the TMJ when bony sections are fixed. Previous studies have concluded that tension in paramandibular connective tissue was implicated as one of the aetiological factors that provide the potential for skeletal relapse after surgical advancement of the mandible.[21] This is similar to our result. In mandibular setback surgery, the muscles are not tensed so the condyles move less.

This study suggests that stability may be related to the size of the condyle, and that because condyles are smaller in patients with mandibular retrusion, they will have a less stable postoperative position. This should be considered when providing postoperative stabilisation.

Conflict of interest

We have no conflicts of interest.

Ethics statement/confirmation of patients' permission

Our study was based on spiral computed tomographic images, and all patients gave their signed informed consent.

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