Changes in Condylar Position After Mandibular Reconstruction With Condylar Head Preservation by Computed Tomography

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Purpose: Condylar position can change after mandibular reconstruction using the free fibula flap. The present study evaluated changes in condylar position using computed tomography (CT) after mandibular reconstruction with condylar head preservation.

Materials and Methods: This retrospective study consisted of 16 patients. CT data of 32 temporomandibular joints (TMJs) were recorded before surgery (T0), 7 to 10 days after surgery (T1), and 16.8 ± 7.4 months after surgery (T2). The anteroposterior condylar position was evaluated using the method of Pullinger and Hollender (Oral Surg Oral Med Oral Pathol 62:719, 1986). Repeated-measures analysis of variance (P = .05) was performed.

Results: Data of 16 patients were obtained for statistical analysis. Condylar position changed over time after mandibular reconstruction. The ipsilateral condyles moved anteroinferiorly after surgery (T0 to T1) and tended to move anterosuperiorly during follow-up (T1 to T2). No major changes were noted in the contralateral condyles.

Conclusion: Condylar positions showed obvious changes over time after mandibular reconstruction with condylar preservation. Nevertheless, additional studies are warranted to further evaluate the relation between condylar position and TMJ function.

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Mandibular resection might be needed in cases of cancer, trauma, osteoradionecrosis, or infection, and the free fibula flap has proved to be the gold standard and workhorse flap for mandibular reconstruction.[1,2] Morphology and function are primary goals of mandibular reconstruction. To achieve these goals, accurate sizing and placement of the fibular segment, an essential ostectomy, and native mandibular positioning are required.[3] The temporomandibular joint (TMJ) is a complicated diarthrosis

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with an important functional role in mastication and it contributes to normal speech, deglutition, and cosmesis.[4,5] Studies have shown that the TMJ is rarely invaded by tumors of the body and superior ramus of the mandible; thus, condylar resection is seldom necessary.[4,5] Preservation of the condyle during free fibula mandibular reconstruction can improve TMJ function. However, condylar position can change after surgery, and this is a contributing factor to TMJ dysfunctions, such as TMJ pain, clicking, poor incisal opening, mandibular deviation, bone resorption, and malocclusion.[4,6]

Ricketts[7] introduced joint space measurements to describe condylar position. Condylar position can be evaluated using corresponding dimensions of radiographic joint spaces between the mandibular condyle and the glenoid fossa. Computed tomography (CT) provides optimum images of osseous components of the TMJ[8] and it is a practical choice for evaluating condylar displacement after mandibular reconstruction.[9] However, previous studies on mandibular reconstruction have primarily evaluated operative performance, whereas changes in condylar position have been inadequately studied.[3]

Hence, the purpose of this study was to evaluate changes in condylar position after mandibular reconstruction with condylar head preservation. The specific aims were to evaluate immediate postoperative and long-term changes in condylar position compared with its original position by measuring the anterior space (AS), posterior space (PS), and superior space (SS) on CT images. The authors hypothesized that condylar position would change over time after mandibular reconstruction with condylar preservation.

Materials and Methods

PATIENTS

A retrospective study was conducted to evaluate patients who underwent mandibular reconstruction using the free fibular flap with condylar preservation at the Peking University School and Hospital of Stomatology (Beijing, China) from January 1, 2013 to December 31, 2015. Each patient provided written informed consent, and the study protocol was approved by the institutional review board.

The inclusion criteria were *1)* unilateral mandibular defect with condylar preservation; *2)* sequential CT documentations; and *3)* a follow-up period of at least 6 months. Patients with preoperative TMJ dislocation and postoperative unstable occlusal relation were excluded from the study. Patients' gender, age, primary site, pathology, and type of defect were documented. CT images were recorded within 1 week before surgery (T0); 7 to 10 days after surgery (T1) to evaluate changes caused by surgery; and an average of 16.8 $\pm$ 7.4 months after surgery (T2) to assess long-term changes. The mandibular defect was reported according to the classification of Urken et al[10]: symphysis, body, ramus, condyle, or their combination.

SURGICAL TECHNIQUE

A 2-team procedure was used. The head and neck team performed the mandibular ostectomy, in view of surgical margin and subsequent fixation, and preserved the condylar head in the glenoid fossa. The other team used the lateral approach to harvest fibula flaps. All flaps were osteotomized according to the defect size for contouring. Intermaxillary fixation (IMF) was applied based on occlusion. In situ fixation of the condylar head and fibula was accomplished using titanium miniplates. Subsequently, microsurgical vascular anastomosis was performed. IMF was removed 1 week after surgery.

DATA ACQUISITION

The condylar movements at 3 stages were evaluated using an 8-slice spiral CT device (GE Brightspeed Series; GE Healthcare, Pittsburgh, PA). Spiral CT parameters were 16.75 mm per rotation, 1.25-mm collimation, and 1:1.675 pitch. All patients were asked not to swallow or move the tongue and were guided to bite in the intercuspal position. In addition, the Frankfort horizontal (FH) plane was adjusted perpendicular to the floor.

PRIMARY PREDICTOR AND OUTCOME VARIABLES

The primary predictor variable was the measurement of the condylar position, and the outcome variables were the condylar positional changes based on quantitative and qualitative measurements. Two-dimensional images were used to evaluate condylar position. The axial view, in which the condyle could be viewed with the widest transverse diameter, was selected as the reference view for secondary reconstruction. The sagittal plane image was adjusted perpendicular to the axial plane through the middle point of the condyle.

On a sagittal multiplanar reconstruction (MPR) image, point A was defined as the most prominent anterior aspect of the condyle; point B was defined as the most prominent posterior aspect of the condyle; and point C was defined as the most superior surface of the glenoid fossa. The lines tangent to point A (line A) and point B (line B) were drawn from point C. Line C was drawn through point C parallel to the FH plane. The FH plane was constructed using the right

and left sides of the porion and the right side of the orbitale. The AS (vertical distance from point A to the glenoid fossa), PS (vertical distance from point B to the glenoid fossa), and SS (vertical distance from point C to the condyle) were measured.[11] The condylar positions were classified as *1)* concentric if ln(PS/AS) was at least −0.25 to no greater than 0.25; *2)* posterior if ln(PS/AS) was less than −0.25; or *3)* anterior if ln(PS/AS) was greater than 0.25 (Table 1, Fig 1).

QUANTITATIVE MEASUREMENT OF CONDYLAR POSITIONAL CHANGES

The AS, PS, and SS were measured using a thrice-enlarged MPR image using the method proposed by Kamelchuk et al[11] (Table 1, Fig 1).

QUALITATIVE ASSESSMENT OF CONDYLAR POSITIONAL CHANGES

After the AS, PS and SS were measured, the condylar position was calculated as ln(PS/AS) according to the method proposed by Pullinger and Hollender.[12] All measurements were repeated 3 times, and the mean value was used for statistical analysis.

STATISTICAL ANALYSIS

Data were statistically analyzed using IBM SPSS Statistics 19.0 (IBM Corp, Armonk, NY). Systematic error was assessed using paired *t* test, and the random error was calculated using the formula of Dahlberg.[13] Condylar positions related to the glenoid fossa indicated by values of the AS, PS, and SS and by ln(PS/AS) at T0, T1, and T2 were compared using repeated-measures analysis of variance, with a significance level set at a *P* value equal to .05. Pairwise multiple comparisons were performed using the Bonferroni correction (*P* = .05). *P* values less than .05 were considered statistically significant.

Results

DEMOGRAPHICS

This retrospective study included 16 patients (5 men, 11 women; mean age, 37.38 ± 18.5 yr; range, 15 to 72 yr). The primary cause for mandibular resection was squamous cell carcinoma (31.25%); the second most common pathology was ameloblastoma (25%), the third was ossifying fibroma (18.75%), and the remaining indications included osteoblastoma, dentinogenic ghost cell tumor, and odontogenic myxoma (6.25%; 1 each of 16). Ten cases showed involvement of the right mandible, whereas the left mandible was involved in the remaining 6 cases. The average follow-up duration was 16.88 months (range, 6 to 31 months; Table 2). The mean length of the remaining condyle was 30.7 ± 5.6 mm (range, ~22.5 to 39.7 mm). Paired *t* test showed no significant differences in probabilities less than .05. The random error of linear measurement ranged from approximately 0.13 to 0.15 mm.

CONDYLAR POSITION AT DIFFERENT STAGES

Table 3 presents CT analysis results of TMJ spaces at different stages. The distance between the condyle and the glenoid fossa is illustrated in Figure 2. The distance of the ipsilateral side showed obvious changes at different stages, whereas that of the contralateral side

Table 1. DEFINITIONS OF LANDMARKS AND LINEAR MEASUREMENTS ON THE CONDYLAR MIDSAGITTAL VIEW

Points	
Point A	Most prominent anterior aspect of condyle
Point B	Most prominent posterior aspect of condyle
Point C	Most superior surface of glenoid fossa
Lines	
Line A	Line tangent to point A from point C
Line B	Line tangent to point B from point C
Line C	Line drawn through point C parallel to Frankfort horizontal plane
Distances	
AS	Vertical distance from point A to glenoid fossa
PS	Vertical distance from point B to glenoid fossa
SS	Vertical distance from point C to condyle
Condylar position	
Anterior	ln(PS/AS) >0.25 indicates an anterior position
Concentric	ln(PS/AS) of −0.25 to approximately 0.25 indicates a concentric position
Posterior	ln(PS/AS) <−0.25 indicates a posterior position

Note: The anteroposterior condylar position was calculated as ln(PS/AS) according to the method proposed by Pullinger and Hollender.[12]

Abbreviations: AS, anterior space; PS, posterior space; SS, superior space.

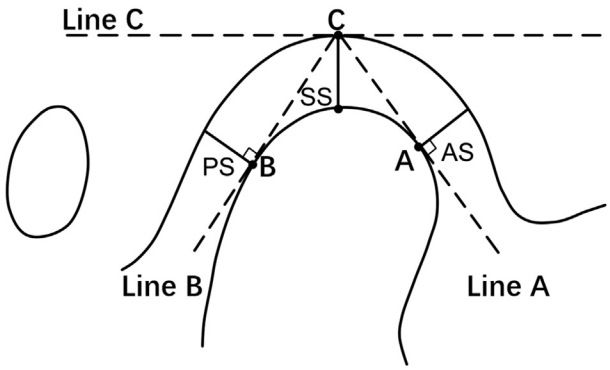

FIGURE 1. Landmarks and linear measurements on the condylar midsagittal view. Lines tangent to point A (line A) and point B (line B) were drawn from point C. Line C was drawn parallel to the Frankfort horizontal plane through point C. The AS and PS were measured from points A and B to the glenoid fossa. The SS was measured as the vertical distance from point C to the condyle using the method proposed by Kamelchuk et al.[11] A, point A (most prominent anterior aspect of the condyle); AS, anterior space; B, point B (most posterior aspect of the condyle); C, point C (most superior surface of the glenoid fossa); PS, posterior space; SS, superior space.

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did not change over time. Anteroposterior condylar positional changes calculated by ln(PS/AS) are illustrated in Figure 3. Values of ln(PS/AS) were significantly different between the contralateral and ipsilateral condyles ($P < .001$). The ln(PS/AS) in the contralateral group did not change over time but that of the ipsilateral group changed considerably. Ipsilateral condylar changes are discussed in the following sections.

PREOPERATIVE CONDYLAR POSITION

Table 4 presents the distribution of condylar positions in the ipsilateral and contralateral groups. The concentric position was the most common in the contralateral (50%) and ipsilateral (62.5%) groups.

POSTOPERATIVE CHANGES

When comparing the TMJ space from T0 to T1, the SS and PS increased markedly in the ipsilateral group, suggesting that the condyles had moved anteroinferiorly after surgery. As observed in Figure 3, the condylar position had moved from concentric to anterior.

LONG-TERM CHANGES

As presented in Table 4, approximately 75% of ipsilateral condyles were in the anterior position at T2 compared with T1 (50%) and T0 (6.25%), which was consistent with observations presented in Figure 3. In addition, the AS decreased from 2.93 ± 1.43 to 2.03 ± 0.67 mm ($P < .05$), indicating continuous anterior movement of the condyles. The distance from the condyle to the glenoid fossa decreased from 5.0 ± 2.1 mm after surgery to 4.44 ± 1.24 mm at T2 (16.8 ± 7.4 months after surgery), which indicated a tendency of the condyle to move back to its original position; however, the difference was not relevant.

Discussion

Mandibular reconstruction using the free fibula flap remains the most popular and gold standard method

Table 2. CLINICAL DATA OF PATIENTS WHO UNDERWENT MANDIBULAR RECONSTRUCTION

Case	Gender	Age (yr)	Primary Site	Pathology	Follow-Up (mo)	Condyle Preserved (mm)
1	Man	15	Right mandible	Osteoblastoma	19	39.69*
2	Woman	17	Left mandible	Ameloblastoma	17	26.09
3	Woman	21	Left mandible	Ossifying fibroma	14	31.90
4	Woman	22	Right mandible	Ossifying fibroma	26	35.79
5	Woman	26	Left mandible	Ameloblastoma	14	28.37
6	Woman	26	Right mandible	Ameloblastoma	31	28.67
7	Man	27	Right mandible	DGCT	23	31.10*
8	Woman	27	Right mandible	Ossifying fibroma	26	27.39
9	Woman	31	Right mandible	Ameloblastoma	6	26.06
10	Man	34	Right mandible	Myxoma	15	39.33
11	Man	45	Right tongue	SCC	13	36.91
12	Man	50	Left mandible	Odontogenic myxoma	8	26.53
13	Woman	61	Left mandible	SCC	18	22.47
14	Woman	62	Left mandible	SCC	9	28.98
15	Woman	62	Right mandible	SCC	24	38.28
16	Woman	72	Right mandible	SCC	7	23.86

Abbreviations: DGCT, dentinogenic ghost cell tumor; SCC, squamous cell carcinoma.
* Patients whose condyle returned to the preoperative position at the last follow-up at 16.8 ± 7.4 months after surgery.

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Table 3. QUANTITATIVE MEASUREMENTS OF TEMPOROMANDIBULAR JOINT SPACES AT DIFFERENT STAGES (N = 16)

	T0	T1	T2
Anterior space (ipsilateral)	2.33 ± 0.8[a]	2.93 ± 1.43[a]	2.03 ± 0.67[b]
Superior space (ipsilateral)	3.24 ± 0.85[a]	5.0 ± 2.1[b]	4.44 ± 1.24[b]
Posterior space (ipsilateral)	1.97 ± 0.57[a]	4.01 ± 2.04[b]	3.89 ± 1.74[b]
Anterior space (contralateral)	2.17 ± 0.7[a]	2.08 ± 0.65[a]	2.14 ± 0.71[a]
Superior space (contralateral)	3.33 ± 0.86[a]	3.34 ± 0.94[a]	3.2 ± 0.78[a]
Posterior space (contralateral)	2.0 ± 0.5[a]	1.97 ± 0.51[a]	2.03 ± 0.55[a]

Note: Distance is presented in millimeters. The same superscript letters indicate no significant differences among the indicated groups ($P > .05$). Adjustment of multiple comparisons was performed using the Bonferroni test.

Abbreviations: T0, before surgery; T1, 7 to 10 days after surgery; T2, last follow-up at 16.8 ± 7.4 months after surgery.

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for patients undergoing mandibular resection.[1,2] However, condylar position can change after mandibular reconstruction using the free fibula flap, which might lead to TMJ pain, clicking, poor incisal opening, mandibular deviation, bone resorption, or malocclusion.[4] To the best of the authors' knowledge, previous studies on microvascular reconstruction of the mandible have focused on operative performance and the relation of bony constructs, with few evaluations of condylar position.[3] In the present study, changes in condylar position after mandibular reconstruction with condylar head preservation were evaluated.

Postoperative and long-term changes of the condylar positions were evaluated using linear measurements on CT images. The present findings indicated that condyles on the ipsilateral side moved anteroinferiorly immediately after surgery and tended to continually move anteriorly during follow-up, whereas no major positional changes were noted on the contralateral side. Thus, the hypothesis that the ipsilateral condylar position would change over time after mandibular reconstruction with condylar preservation has been confirmed.

The TMJ is a complicated diarthrosis,[4] and the condylar head plays a vital role in mandibular growth. Anatomic studies have proved that the condyle has an adequate blood supply (external carotid artery, superficial temporal, and internal maxillary arteries), and histopathologic studies have shown that tumors originating in the mandibular body and ramus rarely invade the condyle; thus, it is seldom necessary to remove the condyle during tumor resection.[4,14-17] In addition, careful review of high-quality CT scans can make condylar preservation a safe procedure.[4]

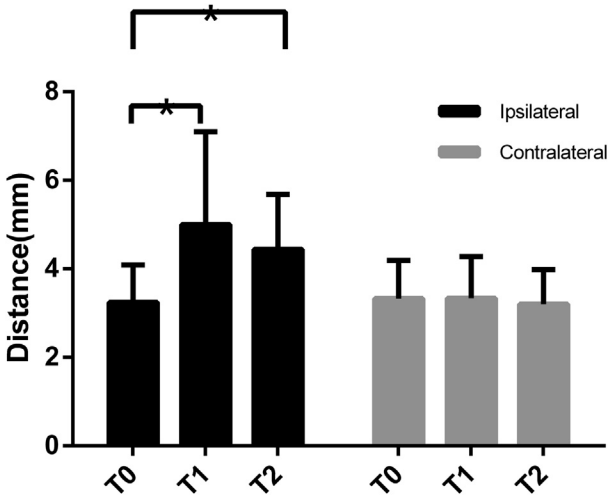

FIGURE 2. Distance from the condyle to the glenoid fossa in the sagittal plane. Significant differences were noted between the ipsilateral and contralateral groups (*$P < .05$). Adjustment for multiple comparisons was performed using the Bonferroni test. T0, before surgery; T1, 7 to 10 days after surgery; T2, last follow-up at 16.8 ± 7.4 months after surgery.

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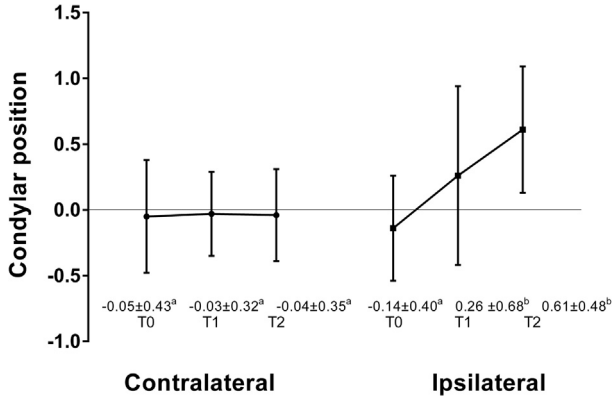

FIGURE 3. Anteroposterior condylar positions using the formula of Pullinger and Hollender[12] at different stages. The same superscript letters indicate no significant differences among the indicated groups ($P > .05$). Adjustment for multiple comparisons was performed using the Bonferroni test. T0, before surgery; T1, 7 to 10 days after surgery; T2, last follow-up at 16.8 ± 7.4 months after surgery.

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Table 4. QUALITATIVE ASSESSMENT OF ANTERO-POSTERIOR CONDYLAR POSITIONS AT DIFFERENT STAGES

	Contralateral Condylar Position (N = 16)			Ipsilateral Condylar Position (N = 16)		
	T0	T1	T2	T0	T1	T2
Anterior	4	3	3	1	8	12
Concentric	8	5	9	10	3	4
Posterior	4	8	4	5	5	0

Abbreviations: T0, before surgery; T1, 7 to 10 days after surgery; T2, last follow-up at 16.8 ± 7.4 months after surgery.

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Using the method of Pullinger and Hollender,[12] the anteroposterior condylar position was classified into anterior, concentric, and posterior. The optimal condylar position has remained a controversial issue in dentistry. Studies have reported that the concentric condylar position was most common in patients without TMJ disorders.[7,18,19] In the present study, the condylar position was mostly concentric on the contralateral (50%) and ipsilateral (62.5%) sides before surgery.

During orthognathic surgery, the condyle can move in different directions (anteroinferior, posteroinferior, or with equal distributions in the vertical direction), which could be affected by various factors, such as fixation methods, rotational movement of the distal segment, masticatory muscle tension, and the surgeon's experience.[20,21] In the present study, during mandibular reconstruction, the condyle moved anteroinferiorly on the ipsilateral side immediately after surgery (T1). This can be explained by multiple factors. The displacement might be affected by the position and placement of segments.[3] Most masticatory muscles were peeled off or resected with the tumor during surgery, which disturbs the balance of the muscular system. Excessive fibula shaping resulted in bone deficiency, and the condyle was pulled forward to fill the gap. Moreover, the remaining condyle was extremely small and deep, posing a great challenge for fixation. Furthermore, excessive manipulation can cause intra-articular edema, which can be verified using magnetic resonance imaging.[22] Other factors contributing to condylar displacement might be muscles in a state of relaxation under general anesthesia[8] and bony interference in the osteotomy gap.[23]

In the present study, long-term changes of condylar position were assessed, and findings showed that preserved condyles tended to move anterosuperiorly from T1 to T2. Approximately 75% of condyles were in the anterior position at T2 compared with 50% at T1 and 6.25% at T0. This was different from orthognathic surgery, in which condyles tended to return to the preoperative position 3 months after surgery and tended to remain stable during 1 year of follow-up.[8,24]

Reasons for the different outcomes noted in this study are manifold. Reconstruction surgery changed patients' occlusion and neuromuscular environment, which would require time to recover. Moreover, although masticatory muscles reattached and balanced in new positions during the recovery period, the strength of overexertion and stretching of muscles was not sufficient to maintain the condyles in the preoperative position. Furthermore, certain teeth were resected with the mandible, and most patients could not receive timely and effective dental rehabilitation. Unstable occlusion could cause changes in the morphologic structure of the TMJ.[19] The distance from the condyle to the glenoid fossa decreased from T1 to T2, which indicated a tendency of the condyle to return to its original position, suggesting that the TMJ can adapt to slight condylar displacement over time.[25] Hence, the condylar movement might be a combined result of an adaptive response from the musculature and ligaments and the resolution of edema.[19]

In the present study, only 2 of the 16 patients' condyles moved back to their preoperative positions. The lengths of the remaining condyle were 39.69 and 31.10 mm, respectively, and longer than the mean length (30.7 mm). Hence, the authors speculated that leaving more of the condyle would make it more stable, because the attached masticatory muscles would be better preserved and a new balance might be achieved in a shorter duration. However, this needs further investigation because the number of patients enrolled in the present study was small. Further study with a larger sample is warranted.

In this retrospective study, the TMJ function of the 16 patients was not recorded, but some studies have found that patients can adapt well to nonideal condylar positions.[19] There have been few previous studies on changes of the condylar position after mandibular reconstruction using the fibula flap; in the present study, condylar position was evaluated preliminarily by CT. Indeed, results of the present study could have been affected by various factors, such as sample size, condylar position measuring method, radiographic technique used, and accuracy of clinical examination. Therefore, additional investigations are warranted to further evaluate the relation between condylar position and TMJ function.

The findings of the present study showed obvious condylar positional changes after mandibular reconstruction using the free fibular flap with condylar

preservation. The ipsilateral condyles moved anteroinferiorly immediately after surgery and tended to move anterosuperiorly during follow-up. No major changes were noted in the contralateral condyles. Additional studies must be conducted to further evaluate TMJ function and condylar position in patients with preserved condyles.

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