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# The relationship between mouth opening and computerized tomographic features of posttraumatic bony ankylosis of the temporomandibular joint

Yingbin Yan, PhD,[a] Yi Zhang, MD,[b] Zhipeng Sun, MD,[c] Jiangming Li, MD,[a] E. Xiao, PhD,[a] and Jingang An, MD,[d] Beijing, China
SCHOOL AND HOSPITAL OF STOMATOLOGY, PEKING UNIVERSITY

***Objective.*** The purpose of this paper was to investigate the relationship between mouth opening and computerized tomography (CT) features in patients with bony ankylosis of the temporomandibular joint.
***Study design.*** A series of morphologic parameters—the diameters of bony mass (D1), the width of bony fusion area (D2), the ratio of D2/D1, and the degree of calcification in bony fusion area (D3)—were measured by Mimics 10.0 software. Correlation analysis and stepwise multiple linear regression analysis were the statistical methods used.
***Results.*** Nine patients (23.68%) with bony fusion area fully calcified were completely unable to open their mouth, whereas 29 patients (76.32%) with bony fusion area calcified incompletely had a slight degree of mouth opening. No correlation was found between mouth opening and D1. A negative correlation was observed between mouth opening and D2 ($r = -0.670$; $P < .01$), between mouth opening and D2/D1 ($r = -0.697$; $P < .01$), and between mouth opening and D3 ($r = -0.744$; $P < .01$). Multiple stepwise regression analysis identified D2 and D3 as predictive factors of residual mouth opening.
***Conclusions.*** D2 and D3 were independent factors affecting the mouth opening. The insufficient calcification of bony fusion area, which cannot fully limit the motion of ankylosed joint, may be an important cause of residual mouth opening in patients with complete bony ankylosis. **(Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2011;111: 354-361)**

Temporomandibular joint ankylosis (TMJA) is a severe disabling disease. One of the main clinical manifestations is progressive limitation of mouth opening, which may seriously interfere with masticatory function.[1] TMJ trauma, as the leading cause of TMJA, accounts for 69%-74% cases in China,[2] and for 31%-98% in other areas.[3]

Surgical treatment is usually the only means to remobilize the ankylosed joint and restore oral function.[4] The effective treatment requires preoperative evaluation of the severity of ankylosis.[5] The limited degree of mouth opening, which is often measured by maximal interincisal opening, has been used as an indicator of the severity of ankylosis.[6] Another way to evaluate the severity is radiographic evaluation of the ankylosed joint,[7] usually focusing on the extent of bony fusion area. A typical example was Sawhney's classification based on the plain films and traditional tomography,[8] of which type II was considered to be partial bony ankylosis and type III/IV complete bony ankylosis.[2]

It is not uncommon that there is a limited range of mouth opening even in complete bony ankylosis as established by conventional radiographic evaluation.[8-10] According to popular opinion, this phenomenon was not attributed to the mobility of the affected joint, but to the inherent elasticity of the mandible or the movement within the cranial sutures.[8-10] however, this viewpoint was derived from a subjective feeling that the movement of the affected joint was completely absent. The

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[a]Resident, Department of Oral and Maxillofacial Surgery.
[b]Professor, Department of Oral and Maxillofacial Surgery.
[c]Attending Doctor, Department of Oral Radiology.
[d]Associate Professor, Department of Oral and Maxillofacial Surgery.
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Fig. 1. Measurement of mouth opening. **A,** Arrow indicates the baseline marked in the labial surfaces of inferior incisors. **B,** Distance between the baseline and the superior incisal edge measured by a common ruler on maximal mouth opening.

objective evidences for the relationship between the mouth opening and the imaging features of bony ankylosis are deficient.

Our previous study revealed that there was correlation between mouth opening and Sawhney classification, suggesting the extent of bony fusion area as one of factors influencing mouth opening.[2] However a few patients with Sawhney III or IV could open their mouth wider than those with Sawhney II, which suggested that the extent of bony fusion area was not the only factor affecting mouth opening.

In fact, owing to problems of image distortion and superimposition,[11] plain films and traditional tomography could not accurately display the lesion characteristics of TMJA. Allowing bilateral visualization without osseous superimposition, computerized tomography (CT) has been recognized as a suitable modality for detection osseous changes of TMJ pathologic conditions, including ankylosis.[12-16] The analysis of CT features of bony ankylosis reported by Aggarwal et al.[17] demonstrated that the lesion was not a simple bony mass as it appears in plain film, but a bony mass consisting of 2 bone blocks separated by a radiolucent zone in most patients.

Therefore, we hypothesized that the radiolucent zone may indicate the degree of calcification in bony fusion area and may, therefore, be one of the factors influencing mouth opening. In the present study, we aimed to test the truth of the hypothesis by observing the CT data of a series of patients with TMJA and analyzing the relationships between mouth opening and several possible influencing factors: the diameter of bony mass (D1), the width of bony fusion area (D2), the ratio of D2/D1, and the degree of calcification in bony fusion area (D3).

## MATERIALS AND METHODS

### Patients

This clinical sample consisted of 38 cases with posttraumatic unilateral TMJA treated in the Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology, from January 2002 to December 2009. Informed written consent approved by the local Ethics Committee was obtained from patients to use their data for research purposes. According to Sawhney's classification, all patients were diagnosed as bony ankylosis (type II/III/IV) by panoramic radiography and CT. Of the 38 patients, 27 cases were male and 11 were female. The male-to-female ratio was 2.45:1. Mean age at presentation was 22.7 ± 13.4 years (range 4-57 years), mean age at injury was 13.7 ± 13.1 years (range 0.67-53 years), and mean interval between injury and diagnosis establishment with ankylosis was 8.9 ± 9.3 years (range 0.75-36 years). Twenty-two of 38 patients (57.9%) suffered trauma within their first decade, and 20 (52.6%) visited doctors after the age of 20. All cases were secondary to condylar fractures, of which 13 cases (34.2%) had concomitant mandibular fractures and 10 cases (26.3%) received treatment of their fracture(s) at a local hospital after injury.

### Investigation methods

*Measurement of the mouth opening.* The degree of mouth opening usually refers to the distance of interincisal edges when mouth opening is maximal. In this study, we also took the overbite into account. The projection of superior incisal edge on the labial surfaces of inferior incisors was marked in the intercuspal position and taken as the baseline (Fig. 1, *A*). The distance between the baseline and the superior incisal edge on maximal mouth opening is defined as the degree of mouth opening (Fig. 1, *B*).

*Spiral CT scanning protocol and postprocessing techniques.* CT examinations were performed using a 16-slice spiral CT machine of the GE Brightspeed series. The spiral scans were carried out with a rotation time of 1 second, a pitch of 1:1, a slice thichness of 2 mm, a voltage of 120 kV, and a

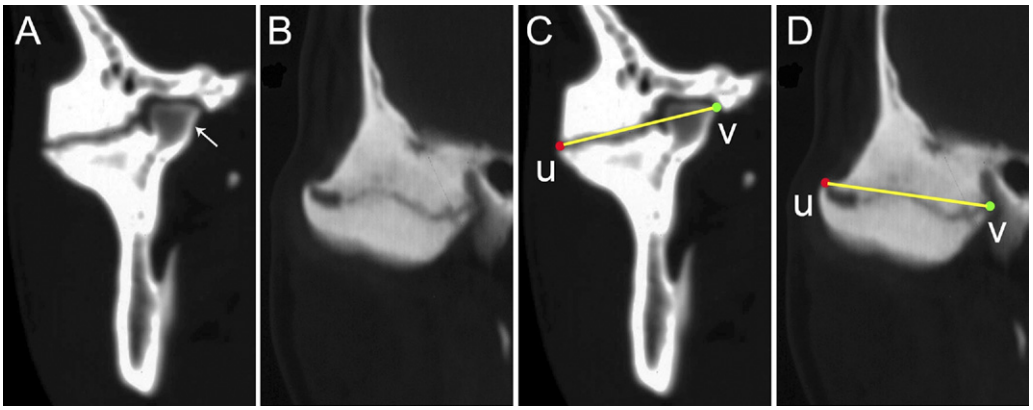


Fig. 2. Morphology of ankylosed joint and diameter measurement of bony mass. **A,** Partial joint fusion (type M ankylosis); arrow indicates the medial dislocation of condylar head. **B,** Total joint fusion (type N ankylosis). **C, D,** Diameter measurement of bony mass in 2 types of bony ankylosis. Points u and v represent the lateral and medial poles of the condyle, respectively. The distance between point u and v is defined as the diameter of bony mass, denoted as D1.

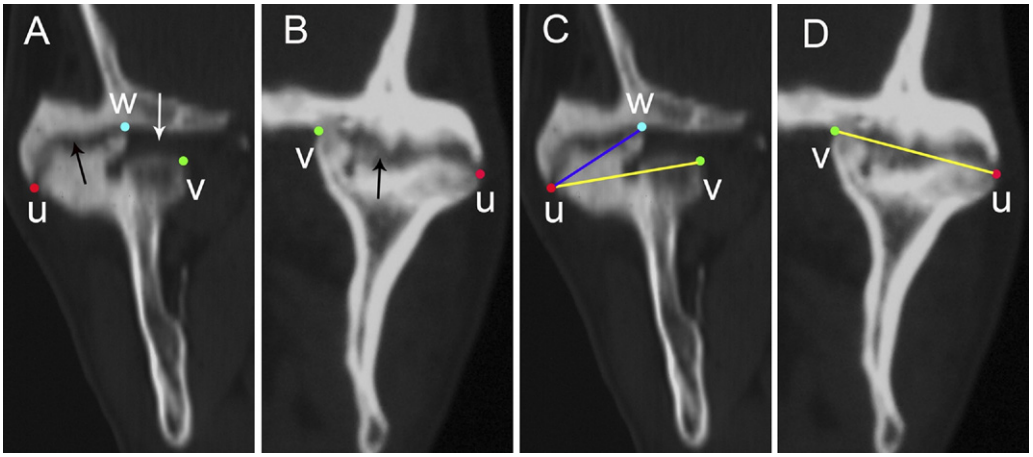


Fig. 3. Definition of bony fusion area and its width measurement. **A,** Type M ankylosis; white arrow indicates the residual joint space, and black arrow indicates the bony fusion area. **B,** Type N ankylosis; black arrow indicates the bony fusion area occupying the entire joint space. **C, D,** Points u, v, and w represent the lateral and medial poles of the condyle and the inner stop point of the bone fusion area, respectively. In *C*, the distance between points u and v refers to the diameter of bony mass, denoted as D1, whereas the distance between points u and w refers to the width of bony fusion area, denoted by D2. In *D*, the distance between points u and v represents both the diameter of bony mass and the width of bony fusion area.

maximum current of 180 mA in automatic exposure control. The technique of multiplanar reformation was used to generate coronal CT images of the TMJ. The bone window setting was selected for observation of the structures of TMJ.

*Morphologic classification of ankylosed joint.* Referring to the classifications of Aggarwal et al.[17] and Ferretti et al.,[7] bony ankylosis can be divided into 2 types according to the morphology of ankylosed joint on coronary CT: type M, partial joint fusion presenting with medial dislocation of condylar head and fusion between the lateral ramus stump and the articular fossa (Fig. 2, *A*); and type N, total joint fusion manifesting as no medial dislocation of condylar head and fusion between the total condyle and the glenoid fossa (Fig. 2, *B*). It should be noted that clear bone marrow cavity can always be found in the medial dislocation of condylar head which does not fuse with the glenoid fossa in type M ankylosis (Fig. 2, *A*). However, in type N ankylosis, the medial part of deformed condyle shows disappearance of bone marrow cavity, osteosclerosis, and fusion with the glenoid fossa (Fig. 2, *B*).

*Measurement of the diameter of bony mass and the width of bony fusion area.* The diameter of bony mass, denoted as D1, is defined as the distance between the lateral pole and medial pole of the involved joint in

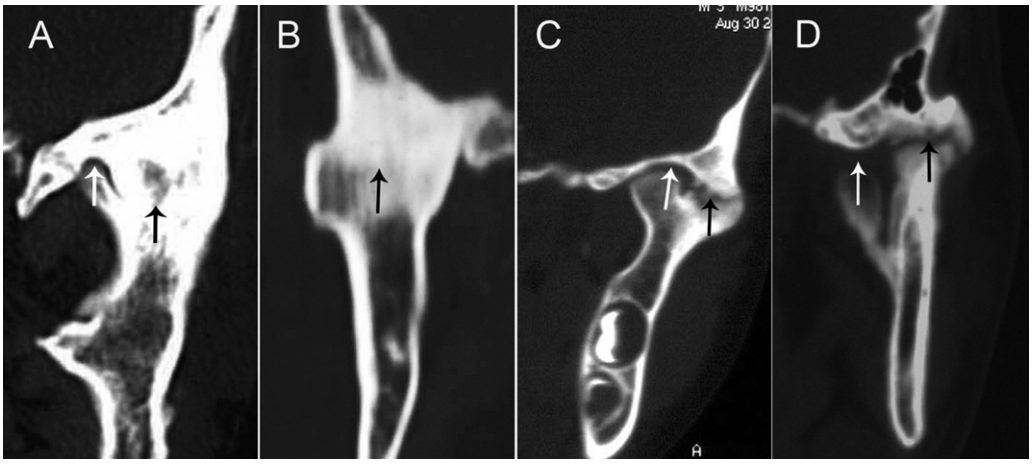


Fig. 4. Classification of degree of calcification in the bone fusion area: Black arrows show the bony fusion area, and white arrows indicate the residual joint space. **A, B,** Bone fusion area fully calcified without vague radiolucent zone (grade II). **C, D,** Bone fusion area incompletely calcified with vague radiolucent zone (grade I).

both types (Fig. 2, *C* and *D*). For type M ankylosis, the bony fusion area refers to the fusion region between the lateral ramus stump and the glenoid fossa, whereas the gap between the medial dislocation of the condylar head and the glenoid fossa is defined as the residual joint space where the density is significantly lower than that of the bony fusion area (Fig. 3, *A*). For type N ankylosis, the bone fusion area refers to the entire joint space (Fig. 3, *B*). The width of the bony fusion area, denoted as D2, was defined as the distance between the lateral pole of the condyle and the inner stop point of the bone fusion area (Fig. 3, *C* and *D*). The ratio D2/D1 was also calculated.

*Classification of the degree of calcification in bone fusion area.* The residual joint space in type M ankylosis presents with continuous and clear radiolucent zone on coronal CT (Fig. 4, *A*, *C*, and *D*). For both types M and N ankylosis, in most patients, the degree of calcification (denoted by D3) in the bony fusion area is significantly lower than that of cortical bone but significantly higher than that of the residual joint space, manifesting as a vague radiolucent zone in the bony fusion area (Fig. 4, *C* and *D*). In these cases, it is easy to distinguish the trace of fusion between the condyle and the glenoid fossa. For both types M and N ankylosis, however, the bone fusion area can be completely calcified in a small number of patients, and the mineral density is similar to cortical bone. In these cases, the fusion line between the condyle and the glenoid fossa cannot be discerned (Fig. 4, *A* and *B*). Therefore, the degree of calcification (D3) in the bone fusion area can be divided into 2 grades: grade I, incomplete calcification with a vague radiolucent zone (Fig. 4, *C* and *D*); and grade II, full calcification without a vague radiolucent zone (Fig. 4, *A* and *B*). To quantify the ranked data, we assigned 0 to grade I, and 1 to grade II.

*Measurement tool and section selection.* Mimics 10.0 software was chosen as the measurement tool. Three typical sections in which the width of bony fusion area was larger than the others were selected for measuring in each patient. The measurement parameters included D1, D2, D2/D1, and D3. The mean value of 3 sections was used as the final result.

### Statistical analysis

The Pearson correlation coefficient was used to assess correlations between mouth opening and D1, D2, D2/D1. The Spearman correlation coefficient was applied to evaluate correlation between mouth opening and D3. A stepwise multiple linear regression analysis was also performed, with mouth opening as the dependent variable, and D1, D2, D2/D1, and D3 as independent variables. The SPSS 17.0 software package was used for the statistical analysis. The level of statistical significance was taken as $P < .05$.

## RESULTS

Measurements were taken in a total of 38 patients (Table I). Among the 38 cases, the ability to open the mouth varied between 0 and 25 mm, with a mean of 9.37 $\pm$ 6.98 mm. The results of mouth opening in different classifications are shown in Table II. It is interesting that mouth opening was 0 mm in patients with bone fusion area fully calcified (grade II), whereas slight mouth opening existed in patients with bone fusion area calcified incompletely (grade I). The results

**Table I.** Details of 38 patients with posttraumatic temporomandibular joint bony ankylosis

| Patient no. | Ankylosis type* | Mouth Opening (mm) | Diameter of bony mass (D1, mm) | Width of bony fusion area (D2, mm) | Ratio D2/D1 | Degree of calcification (D3) |
|---|---|---|---|---|---|---|
| 1 | M | 0 | 36.90 | 30.90 | 0.84 | 1 |
| 2 | N | 0 | 23.00 | 23.00 | 1.00 | 1 |
| 3 | N | 0 | 23.40 | 23.40 | 1.00 | 1 |
| 4 | M | 0 | 22.20 | 18.00 | 0.81 | 1 |
| 5 | N | 0 | 35.70 | 35.70 | 1.00 | 1 |
| 6 | M | 0 | 28.10 | 25.10 | 0.89 | 1 |
| 7 | M | 0 | 21.90 | 18.60 | 0.85 | 1 |
| 8 | N | 0 | 39.00 | 39.00 | 1.00 | 1 |
| 9 | N | 0 | 25.30 | 25.30 | 1.00 | 1 |
| 10 | M | 4.00 | 22.60 | 13.00 | 0.58 | 0 |
| 11 | M | 5.00 | 30.90 | 26.00 | 0.84 | 0 |
| 12 | M | 7.00 | 32.00 | 23.80 | 0.75 | 0 |
| 13 | N | 7.00 | 29.50 | 29.50 | 1.00 | 0 |
| 14 | M | 8.00 | 29.00 | 18.30 | 0.63 | 0 |
| 15 | M | 8.00 | 34.10 | 21.30 | 0.62 | 0 |
| 16 | M | 8.00 | 24.50 | 16.40 | 0.67 | 0 |
| 17 | M | 9.00 | 27.00 | 16.40 | 0.74 | 0 |
| 18 | M | 9.00 | 29.10 | 16.00 | 0.55 | 0 |
| 19 | M | 10.00 | 17.20 | 16.20 | 0.94 | 0 |
| 20 | N | 10.00 | 25.90 | 25.90 | 1.00 | 0 |
| 21 | M | 10.00 | 28.00 | 17.50 | 0.63 | 0 |
| 22 | M | 10.00 | 32.50 | 20.50 | 0.63 | 0 |
| 23 | M | 11.00 | 26.00 | 19.20 | 0.74 | 0 |
| 24 | M | 12.00 | 29.10 | 17.20 | 0.59 | 0 |
| 25 | M | 12.00 | 23.20 | 15.80 | 0.68 | 0 |
| 26 | M | 12.00 | 22.70 | 16.40 | 0.75 | 0 |
| 27 | M | 12.00 | 34.20 | 18.10 | 0.53 | 0 |
| 28 | M | 12.00 | 32.80 | 21.00 | 0.64 | 0 |
| 29 | M | 12.00 | 25.60 | 22.10 | 0.86 | 0 |
| 30 | M | 13.00 | 31.30 | 20.40 | 0.65 | 0 |
| 31 | M | 15.00 | 11.00 | 9.10 | 0.83 | 0 |
| 32 | M | 15.00 | 27.80 | 17.30 | 0.62 | 0 |
| 33 | M | 17.00 | 33.00 | 19.60 | 0.59 | 0 |
| 34 | M | 20.00 | 28.70 | 22.90 | 0.80 | 0 |
| 35 | M | 20.00 | 29.10 | 12.20 | 0.42 | 0 |
| 36 | M | 20.00 | 26.50 | 10.40 | 0.40 | 0 |
| 37 | M | 23.00 | 17.60 | 9.65 | 0.55 | 0 |
| 38 | M | 25.00 | 12.70 | 5.38 | 0.42 | 0 |

For the degree of calcification in bony fusion area (D3), to quantify the ranked data, 0 is assigned to grade I, and 1 to grade II.
*Type M: partial joint fusion presenting with medial dislocation of condylar head and fusion between the lateral ramus stump and the articular fossa; type N: total joint fusion manifesting as no medial dislocation of condylar head and fusion between the total condyle and the glenoid fossa.

indicated that patients were completely unable to open their mouth as long as there was no radiolucent zone in the bony fusion area, and vice versa.

The measurement results of D1, D2, D2/D1, and D3 are shown in Table III. A negative correlation was found between mouth opening and D2 ($r = -0.670$; $P < .01$; Fig. 5), indicating that mouth opening decreases with the increase of the width of bony fusion area. No correlation was observed between mouth opening and the diameter of bony mass (D1) ($r = -0.295$; $P = .072$; Fig. 6). However, a negative correlation was found between mouth opening and D2/D1 ($r = -0.697$; $P < .01$; Fig. 7), indicating that mouth opening decreases with the increase of the ratio D2/D1. A negative correlation was observed between mouth opening and D3 ($r = -0.744$; $P < .01$; Fig. 8), indicating that mouth opening decreases with the increase of the degree of calcification in bony fusion area.

Among the 4 factors D1, D2, D2/D1, and D3, multiple stepwise regression analysis showed that D2 and D3 were independent factors affecting the mouth opening (Table IV). The linear regression equation was as follows: mouth opening = 18.900 − 0.558 D3 − 0.366 D2 ($P < .01$). The multiple correlation coefficient ($R$) of this prediction model was 0.817, and the coefficient of determination ($R^2$) was 0.668.

**Table II.** Mouth opening in different classifications

| *Classification of ankylosis** | *Cases (%)* | *Mouth opening, mm (mean ± SD)* |
|---|---|---|
| According to morphology of ankylosed joint | | |
| *Type M* | *31 (81.6%)* | *10.94 ± 6.54* |
| Type N | 7 (18.4%) | 2.43 ± 4.24 |
| According to degree of calcification in bony fusion area | | |
| Grade I | 29 (76.32%) | 12.28 ± 5.24 |
| Grade II | 9 (23.68%) | 0 ± 0 |

*Type M, partial joint fusion presenting with medial dislocation of condylar head and fusion between the lateral ramus stump and the articular fossa; type N, total joint fusion manifesting as no medial dislocation of condylar head and fusion between the total condyle and the glenoid fossa; grade I, incomplete calcification with a vague radiolucent zone in the bony fusion area; grade II, full calcification without a vague radiolucent zone in the bony fusion area.

**Table III.** Measurement results for D1, D2, D2/D1, and D3

| | *n* | *Mean* | *SD* |
|---|---|---|---|
| Diameter of bony mass (D1), mm | 38 | 27.08 | 6.14 |
| Width of bone fusion area (D2), mm | 38 | 19.91 | 6.89 |
| Ratio D2/D1 | 38 | 0.74 | 0.18 |
| Degree of calcification in the bony fusion area (D3) | 38 | 0.24 | 0.43 |

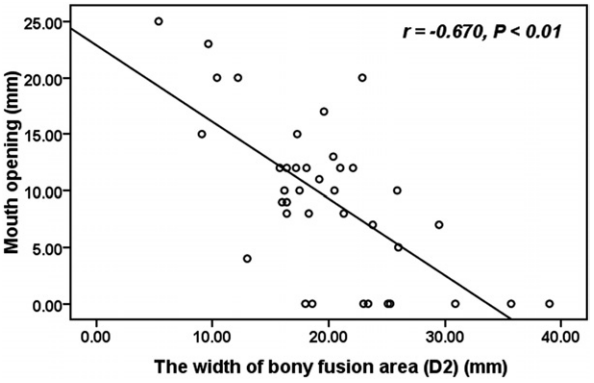


Fig. 5. Relationship between mouth opening and width of bony fusion area (D2).

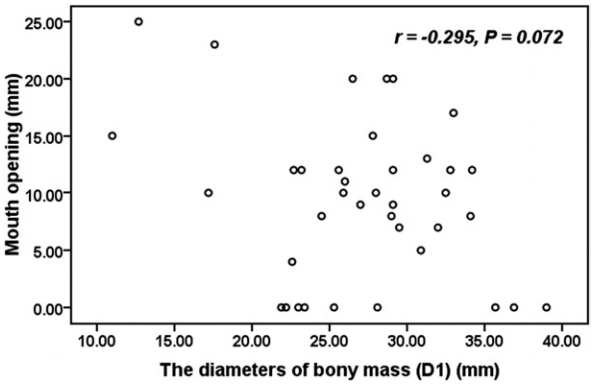


Fig. 6. Relationship between mouth opening and diameter of bony mass (D1).

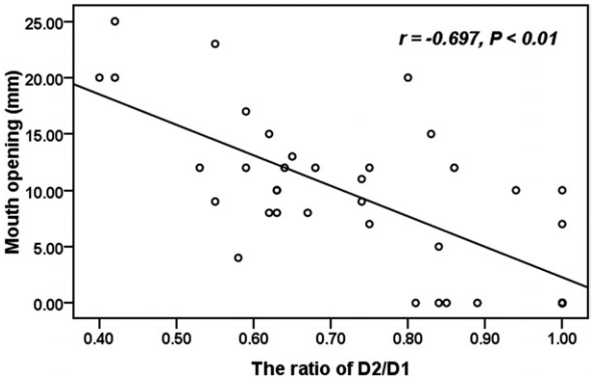


Fig. 7. Relationship between mouth opening and ratio D2/D1.

## DISCUSSION

Owing to multiple sections of CT data, measuring all sections for each patient is complicated and unnecessary. However, substituting 1 section for all may be prone to selection bias. Therefore, choosing an appropriate number of typical sections which can represent the features of bony ankylosis is the basis of measurement. In the present study, 3 sections in which the width of bony fusion area was larger than the others were selected. The reasons are described as follows. Bony fusion area cannot be found in every section of the coronal CT for the vast majority of bony ankylosed joints. On the contrary, it occurs in only a few sections in many cases according to our observation. Obviously, the degree of calcification in sections with bony fusion area is higher than in sections without it. The confirmation of sections with bony fusion area has actually taken the degree of calcification into account. Therefore, we considered that the 3 sections with largest width of bony fusion area were the most serious sections of ankylosis, and could be regarded as typical sections reflecting the features of bony ankylosis. In addition, all coronary sections can be continuously observed by Mimics software, which makes the selection of sections practicable and reliable.

Among the 3 possible parameters affecting mouth opening—the diameter of bony mass (D1), the width of

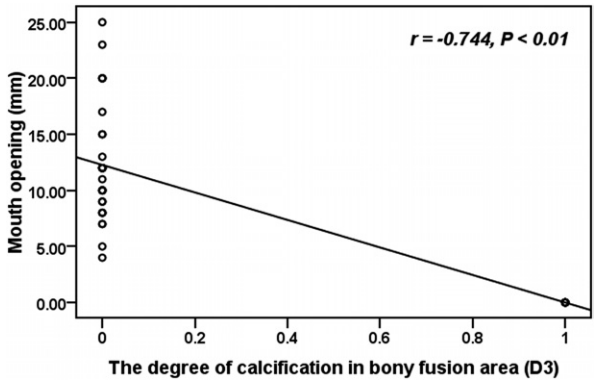


Fig. 8. Relationship between mouth opening and degree of calcification in the bony fusion area (D3).

**Table IV.** Result of multiple stepwise regression analysis

| | *Unstandardized coefficients* | | *Standardized coefficient* | | |
|---|---|---|---|---|---|
| *Variable* | *B* | *SE* | *Beta* | *t* | *P value* |
| Constant | 18.900 | 2.239 | 0 | 8.442 | .000 |
| D3 | −9.043 | 1.884 | −0.558 | −4.801 | .000 |
| D2 | −0.371 | 0.118 | −0.366 | −3.151 | .003 |

bony fusion area (D2), and the ratio D2/D1—D1 is on behalf of the degree of condylar enlargement, D2 represents the extent of bony ankylosis in the medial direction, and D2/D1 is calculated to rule out the interference of condylar enlargement on D2, equivalent to the standardization value of D2. No correlation was found between mouth opening and D1. Although a negative correlation was observed between mouth opening and both D2 and D2/D1 in univariate analysis, D2/D1 was removed in the multivariate analysis. These results suggested that in the 3 parameters, only D2 contributed to the limited mouth opening.

For most patients (type M ankylosis), D1 is approximately equal to the sum of D2 and the width of residual joint space, which has nothing to do with the limited of mouth opening. Therefore, the independence between D1 and mouth opening may be the consequence of the effect of D2 being diluted by the width of residual joint space. We believe that it is the collinearity between D2 and D2/D1 that makes the latter correlate with the mouth opening in the univariate analysis and be removed in the multivariate analysis.

The study revealed that there was vague radiolucent zone in the bony fusion area in most patients, which was in accordance with earlier reports.[7,15,17] The calcification of bony fusion area (D3) was roughly divided into 2 grades to be judged easily and avoid interobserver bias. However, this classification also led to loss of large amounts of information, which may partly explain the relatively low coefficient of determination ($R^2$) of the regression equation. A bone density measurement in the bony fusion area in terms of Hounsfield units may be a good method to quantify the degree of calcification. However, it is actually difficult to get accurate CT values, because the bony fusion area is not homogeneous and the radiolucent zone is too narrow. Further study of this issue would be worthwhile.

One important purpose of the present paper was to explain the reasons some patients with bony ankylosis of TMJ can open their mouth to some degree and others can not. Through investigating the relationship between mouth opening and CT features, we found D2 and D3 were independent factors affecting the mouth opening. According to the partial correlation coefficient of the regression equation, the effect of D3 on mouth opening was greater than that of D2. By analyzing the relationship between mouth opening and D3, we found that patients were completely unable to open their mouth as long as there was no radiolucent zone in the bony fusion area, regardless of the width of bony fusion area, and vice versa. The results showed that whether a radiolucent zone existed in the bony fusion area determined whether mouth opening was completely limited. The results also suggested that residual mouth opening in patients with complete bony ankylosis was probably not due to the elasticity of the mandible[8] or the movement within the cranial sutures,[10] but to the insufficient calcification of the bony fusion area which could not fully confine the motion of the ankylosed joint. However, further research is still needed to verify our view. Dynamic magnetic resonance imaging has an ability to provide almost real-time imaging and furnish information about bones and soft tissue with reasonable resolution,[18] without subjecting patients to ionizing radiation.[19] It may be an ideal tool to test this hypothesis.

Fully estimating the severity of bony ankylosis will contribute to evaluating the difficulty of surgery, making a precisely planned resection, and assessing the amounts of autogenous or alloplastic material to be used to fill the gap arthroplasty.[5] The results of this study indicate that the information about D2 and D3 are very important when assessing an ankylosed joint. Although CT plays a vital role in both diagnosis and evaluation of bony ankylosis, the high radiation dose, high cost, and limited availability have confined its use.[20] Recently, cone-beam computerized tomography (CBCT) has been adopted in clinical dental practice,[20-23] and it is also becoming the imaging modality of choice for bony imaging of the TMJ, including

ankylosis.[24-27] CBCT can provide relatively high isotropic spatial resolution of osseous structures with a reduced radiation dose compared with CT.[28,29] Therefore, evaluation the severity of bony ankylosis by CBCT will be a promising approach.

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*Reprint requests:*

Yi Zhang
Department of Oral and Maxillofacial Surgery
School and Hospital of Stomatology
Peking University
22 Zhongguancun Nandajie
Haidian District
Beijing 100081
P.R. China
zhangyi2000@263.net