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Stress change on the temporomandibular joint in mandibular prognathism subjects with asymmetry after orthognathic surgery

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SUMMARY The purpose of this study was to evaluate changes in stress on the temporomandibular joint (TMJ) in 80 Japanese subjects (21 males and 59 females, mean age 23.7 years) with mandibular prognathism, with and without asymmetry after orthognathic surgery using the rigid bodies spring model (RBSM). The asymmetric group consisted of 40 subjects whose Mx–Md midline was more than 3 degrees. The remaining 40 subjects formed the symmetric group.

The geometry of the stress analysis model was based on frontal cephalograms of the subjects. Menton (Me), the centre point of occlusal force on a line connecting the bilateral buccal cusps of the second molars, and the most lateral, superior, and medial points on the condyle were plotted on a computer display and stress on the condyle was calculated with the two-dimensional RBSM program, Fortran. The degree (force partition) of the resultant force, the direction (angulation), and the displacement (X, Y) of each condyle were calculated and the horizontal displacement (u), the vertical displacement (v), and rotation displacement (θ) of the mandibular body at Me were calculated pre- and post-operatively. The data was analysed using paired and unpaired *t*-tests.

For the vertical (v) and rotational (θ) displacement, the post-operative value was smaller than the pre-operative value (v: $P < 0.001$, θ: $P = 0.0063$) in the asymmetric group. For angulation and the X-component, the post-operative value was smaller than that pre-operatively on the deviated (angulation: $P = 0.0074$, X-component: $P = 0.0003$) and non-deviated (angulation: $P = 0.0024$, X-component: $P = 0.001$) side in the asymmetric group. However, there was no significant difference between the pre- and post-operative value for any parameter in the symmetric group.

These findings suggest that surgical correction of mandibular prognathism, with and without asymmetry, could induce an improvement in stress balance on the TMJ in the frontal aspect.

Introduction

Temporomandibular joint (TMJ) internal derangement (ID) is widely reported to be associated with mandibular asymmetry. Schellhas *et al.* (1990) suggested that disc displacement, ID, or degenerative joint disease could be the main causes of mild and moderate mandibular asymmetry. On the other hand, various studies have investigated occlusal problems as a predisposing factor for TMJ ID. Occlusal instability, midline discrepancy, right–left differences in molar relationship, and inclination of the frontal occlusal plane have been considered to be important occlusal characteristics in patients with TMJ disorders (Solberg *et al.*, 1986; Fushima *et al.*, 1999). Differences in the heights of the right and left rami have also been suggested as important skeletal problems associated with TMJ pathology (Inui *et al.*, 1999; Trpkova *et al.*, 2000). A similar tendency has been recognized in mandibular prognathism with asymmetry (Ueki *et al.*, 2000), although the incidence of TMJ dysfunction in mandibular prognathism is lower than in mandibular retrognathism (Fernández Sanromán *et al.*, 1998).

Improvement in TMJ symptoms before and after orthognathic surgery has been investigated in several clinical investigations (Karabouta and Martis, 1985; Kerstens *et al.*, 1989; White and Dolwick, 1992; Hu *et al.*, 2000). In a previous study, it was found that sagittal split ramus osteotomy (SSRO) did not improve anterior disc displacement (ADD), while intraoral vertical ramus osteotomy (IVRO) improved ADD for a short post-operative period, and both procedures improved TMJ symptoms (Ueki *et al.*, 2002; 2007a,b). This suggests that TMJ symptoms are not always the result of disc displacement. In other words, biomechanical change from occlusal and skeletal change may induce improvement in the TMJ.

Most authors agree that the external and internal morphology of a given bone or joint in adults is determined by the biomechanical loads placed upon it during growth. Previous studies have suggested that mandibular asymmetry or occlusal plane inclination could induce TMJ ID due to disturbances in stress on the TMJ (Korioth *et al.*, 1992; Hylander and Johnson, 1997). Paradoxically, there is a theory that attempts to establish a flat occlusal plane or symmetry can induce a favourable stress balance on bilateral TMJs.

Regarding dynamic analysis, changes in stress on the TMJ after orthognathic surgery using a lateral cephalogram with the rigid bodies spring model (RBSM) have been investigated (Ueki *et al.*, 2005; 2006). However, when the asymmetry cases were analysed, it was found that a RBSM program for frontal cephalograms was necessary. Therefore, a program of RBSM for frontal cephalograms was developed and the stress on the TMJ in mandibular asymmetry subjects was investigated.

The purpose of this study was to evaluate changes in stress on TMJ in mandibular prognathism subjects with asymmetry after orthognathic surgery using RBSM for frontal cephalograms.

Subjects and methods

Eighty Japanese adults (21 males and 59 females) were included in the study with jaw deformities diagnosed as mandibular prognathism, with and without asymmetry. The patients ranged in age from 15 to 39 years (mean age 23.7 years, standard deviation 5.5 years). Informed consent was obtained from the patients and the study was approved by Kanazawa University Hospital.

Lateral and frontal cephalograms were obtained of all patients. The cephalograms were taken before surgery (after pre-operative orthodontic treatment) and 3–6 months after surgery. The cephalograms were entered into a computer and analysed using appropriate software (Cephalometric Ato Z, Yasunaga Labo Com, Fukui, Japan). All patients were objectively diagnosed as skeletal Class III from the cephalometric measurements. On the frontal cephalogram, the angle between the ANS–Menton (Me) line and a line perpendicular to the bilateral zygomatic frontal suture line was defined as the Mx–Md midline angle. A positive value for this angle represented mandibular deviation to the left and a negative value mandibular deviation to the right. The Mx–Md midline angles of all cases were then given a positive value, so that all consecutive measurements could be attributed to either a deviated or non-deviated side (Ueki *et al.*, 2000). The subjects were divided into a symmetric or asymmetric group according to the Mx–Md midline. The asymmetric group consisted of 40 subjects (10 males and 30 females) whose Mx–Md midline was more than 3 degrees and the remaining 40 (11 males and 29 females) as the symmetric group.

Twenty-two of the 40 patients in the asymmetric group underwent a Le Fort I osteotomy and IVRO, nine a SSRO, seven an IVRO, and two a Le Fort I osteotomy and SSRO. Twenty-four of the 40 patients in the symmetric group underwent SSRO, 11 a Le Fort I osteotomy and SSRO, and 5 IVRO.

Determination of the occlusal force centre

A system comprising a pressure-sensitive sheet (Dental Prescale; Fuji Photo Film Co., Tokyo, Japan) and its analysing apparatus (Dental Occlusion Pressuregraph FPD-705; Fuji Photo Film Co.) connected to a personal computer was used in this study. Data on the reproducibility and the method of calibration have been reported (Maness *et al.*, 1987; Hattori *et al.*, 1994; Harada *et al.*, 2000; Nagai *et al.*, 2001). Each patient was seated with his/her head in an unsupported natural position, looking forward. The pressure-sensitive sheet was placed between the maxillary and mandibular teeth and the patient was instructed to bite as forcefully as possible for approximately 3 seconds. The sheet was read and analysed using the Dental Occlusion Pressuregraph and the results were transferred to the computer and visualized on the display screen. The occlusal force centre (only value on the X-co-ordinate) was determined on the basis of the occlusal balance. The examination was carried out before surgery (after pre-operative orthodontic treatment) and 3–6 months after surgery.

Input data for calculations

The most lateral point of the buccal cusp of the lower second molar, Me, and the most medial, superior, and lateral points on the bilateral condyles on the computer display were plotted, using the frontal cephalogram, and the co-ordinates of the occlusal force centre point was added to the occlusal plane. The mandibular two-dimensional RBSM using the frontal cephalometric data and the occlusal force data were analysed pre- and post-operatively with the Fortran program written according to a previously reported method (Ueki *et al.*, 2005; 2006).

When defining the numerical model, the geometry of the model was based on a frontal cephalogram of each subject (Figure 1). The entire mandible can be considered as a single rigid element. For the numerical model of the TMJ, the integral points for calculating the contact stress were defined along the contours of the uppermost face of the condyle. The glenoid fossa was assumed to be a rigid element, and the displacement of this rigid element was set to 0, so it may be treated as a supported element (Figure 2). The occlusal force and its action position were determined using the pressure-sensitive system. Only compressive force is transmitted in a contact surface. Redistribution of negative contact pressure was calculated, according to the following procedure:

Step 1: The contact pressure generated on integration points relative to the initially given muscular force is obtained.

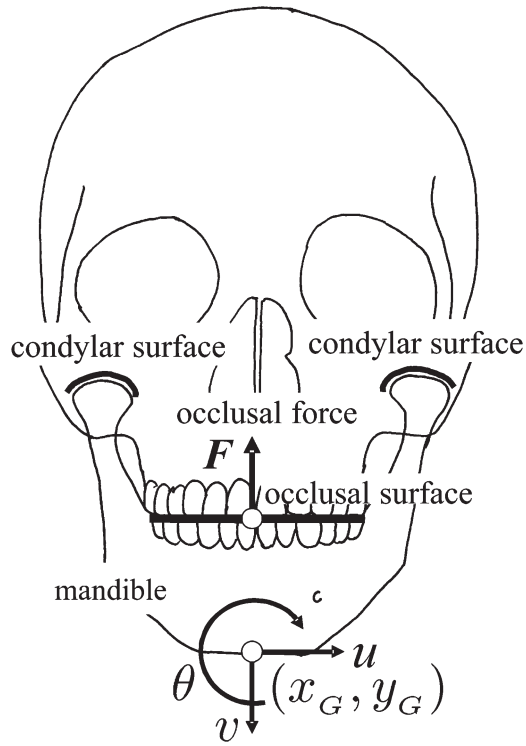


Figure 1 Rigid bodies spring model (numerical model). The geometry of the model is based on a frontal cephalogram of each subject.

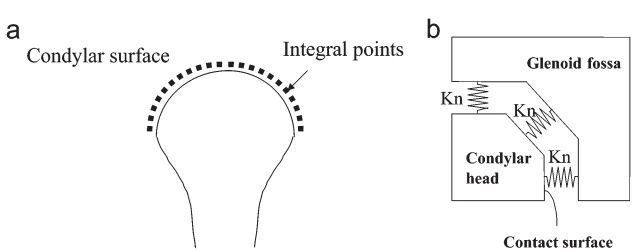


Figure 2 (a) Integral points on the codylar surface. (b) Spring model between the condylar surface and glenoid fossa. The integral points for calculating the contact stress are defined along the contours of the uppermost face of the condyle. The glenoid fossa is assumed to be a rigid element. Kn shows spring coefficient in the calculation in the rigid bodies spring model.

Step 2: If negative contact pressure is found for some integral points, it is temporarily removed and a constraint force is added to maintain the balance.

Step 3: As this constraint force does not actually exist, a force equal to this is added in a reverse direction.

Steps 1 and 2 are repeated until the negative contact pressure reduces to a negligible value. The contact pressure distribution without negative contact force can then be obtained.

Finally, as output data, the degree (force partition) of the resultant force, the direction (angulation) and the displacement (X, Y) of each condyle, the horizontal displacement vector (u), the vertical displacement vector (v), and the rotation angle (θ) of the mandibular body at Me were calculated (Figure 3).

Analysis was based on the definition that a stable condylar position is one in which the stress is distributed equally over the condylar surface. Once the final calculation had been performed and contact pressure was distributed equally over the condylar surface, any slight mandibular displacement may be disregarded. The displacement from vectors in the initial mandibular position to vectors in the final mandibular position after the calculations can be obtained by conversion calculations from the displacement vector. This means that the higher the displacement vector, the less clinically stable the mandible and TMJ.

Magnetic resonance imaging assessment

A detailed magnetic resonance imaging (MRI) assessment of each pair of TMJs was performed using a 1.5-Tesla MRI system (Signa Scanner, General Electric Medical Systems, Milwaukee, Wisconsin, USA), with bilateral 3 inch dual surface coils with the jaw in the closed, resting, and maximally opened position. An initial axial localizer was introduced to obtain exact midcondylar sections perpendicular and parallel to the long axis of each condyle. Images of the bilateral orthogonal sagittal planes and coronal planes of the TMJs in the closed jaw position were acquired first with a repetition pulse (T_R) of 2000 milliseconds, echo times (T_Es) of 20 milliseconds, a 3 mm image slice thickness, and a field of view of 10 cm. Images of the bilateral sagittal planes of the TMJs in the open mouth position were then obtained with a T_R of 1000 milliseconds and T_Es of 20 milliseconds. The incidence of ADD with (ADDwR) and without (ADDwoR) reduction was examined pre- and post-operatively.

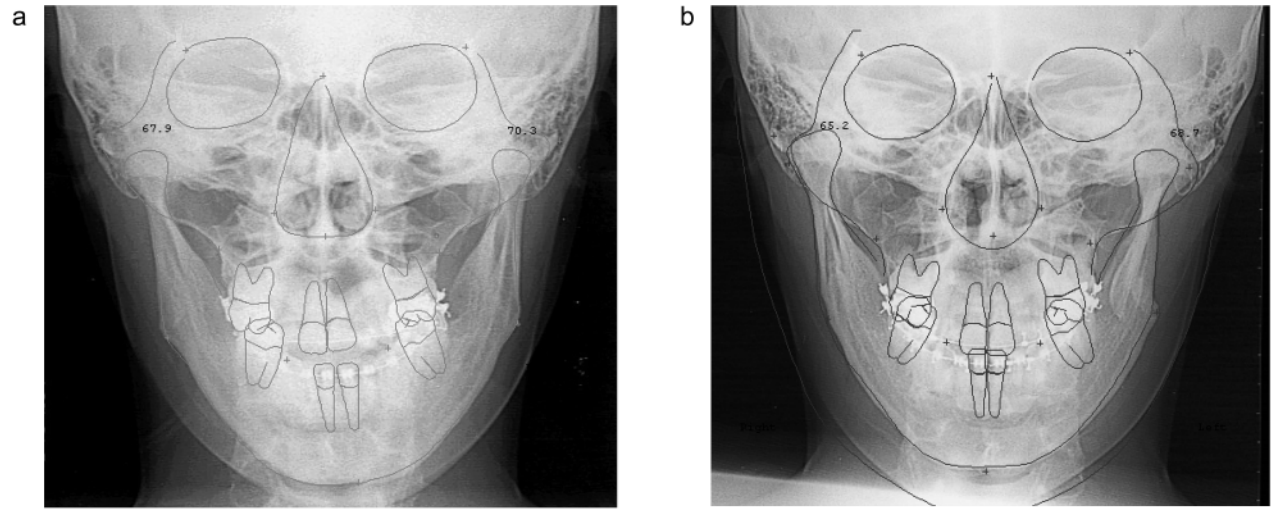
Statistical analysis

Data were compared between the groups with unpaired *t*-tests and between the pre- and post-operative value with paired *t*-tests using the Stat View™ version 4.5 software program (Abacus Concepts, Inc., Berkeley, California, USA). The differences were considered significant at $P < 0.05$.

Results

There were significant differences post-operatively compared with pre-operatively in the asymmetric group in the Mx–Md midline ($P < 0.001$) and occlusal cant ($P < 0.001$) but not in the symmetric group.

For vertical (v) and rotational (θ) displacement, post-operative values were smaller than pre-operative values (v: $P < 0.001$, θ: $P = 0.0063$) in the asymmetric group. For angulation and the X-component, the post-operative value



Displacement of mandible	(u)	0.01287		
	(v)	0.00983		
	(θ)	0.00003		
Force on condyle	Deviated side		Non-deviated side	
	Resultant force	0.296	Resultant force	0.705
	Angulation	3.864	Angulation	9.617
	X-component	0.020	X-component	0.118
	Y-component	0.296	Y-component	0.695

Displacement of mandible	(u)	-0.00288		
	(v)	0.01292		
	(θ)	-0.00001		
Force on condyle	Deviated side		Non-deviated side	
	Resultant force	0.528	Resultant force	0.472
	Angulation	-0.980	Angulation	1.730
	X-component	-0.009	X-component	0.014
	Y-component	0.528	Y-component	0.472

Figure 3 Results of rigid bodies spring model calculation. (a) Pre-operative; (b) post-operative. The degree (force partition) of the resultant force, the direction (angulation) and the displacement (X, Y) of each condyle, the horizontal displacement vector (u), the vertical displacement vector (v), and the rotation angle (θ) of the mandibular body at Menton were calculated.

was smaller than the pre-operative value at the deviated (angulation: $P = 0.0074$, X-component: $P = 0.0003$) and non-deviated (angulation: $P = 0.0024$, X-component: $P = 0.001$) sides in the asymmetric group. However, there was no significant difference between the pre- and post-operative values in any parameter in the symmetric group (Tables 1 and 2).

Comparison between the deviated and non-deviated side showed no significant differences in resultant force ($P = 0.0054$), angulation ($P = 0.0095$), X-component ($P = 0.001$), or Y-component ($P = 0.0043$) in the asymmetric group pre-operatively. There were significant differences in resultant force ($P = 0.0372$), X-component ($P < 0.001$), and Y-component ($P = 0.0354$) in the symmetric group pre-operatively. However, in the symmetric group, no significant differences were found for any parameters post-operatively. On the other hand, in the asymmetric group, significant differences remained in angulation ($P < 0.001$) and X-component ($P = 0.0004$) post-operatively (Tables 1 and 3).

In the symmetric group, two joints with pre-operative ADDwoR did not change post-operatively. On the deviated side in the asymmetric group, 22 joints with pre-operative ADDwoR and eight with pre-operative ADD changed to 16 joints with ADDwoR and 10 joints with ADDwR post-operatively. On the non-deviated side in the asymmetric group, three joints with pre-operative ADDwoR and two with pre-operative ADDwR changed to three joints with ADDwoR; no joint showed ADD post-operatively.

Discussion

ADD has been observed mostly at the deviated side in patients with mandibular deviation (Link and Nickerson, 1992; Kobayashi *et al.*, 1999). Other authors have shown that in mandibular prognathism with asymmetry, there is a higher incidence of disc displacement on both sides (56 and 66.7 per cent, respectively; Ueki *et al.*, 2000; Yamada *et al.*, 2001), whereas minimal displacement is seen in patients with simple mandibular prognathism (18.2 per cent; Ueki *et al.*, 2000). TMD is associated with disturbed facial skeletal growth such as mandibular deviation in rabbits or humans (Schelhas *et al.*, 1993; Isberg and Legrell, 2000; Trpkova *et al.*, 2000). Some authors have reported TMJ ID as a primary cause of growth disturbance, including mandibular asymmetry (Hans *et al.*, 1992; Schelhas *et al.*, 1993). *In vivo* experiments of disc displacement in rabbits have also verified that permanent articular disc displacement is one causal factor in the development of mandibular midline asymmetry (Legrell and Isberg, 1999). However, some studies have suggested that disc displacement does not always induce mandibular asymmetry. Occlusal instability,

Table 1 Results for the parameters (u: horizontal displacement, v: vertical displacement, and θ: rotational displacement).

						Deviated side				Non-deviated side					
			u	v	θ	Resultant force	Angulation	X-component	Y-component	Resultant force	Angulation	X-component	Y-component	Mx–Md midline	Occlusal cant
Symmetric group	Pre-operative	Mean	−0.0007	0.0107	−3.4E-06	0.5317	−1.3774	−0.0137	0.5309	0.4699	2.4372	0.0207	0.4684	1.5473	−0.5765
		SD	0.0047	0.0013	1.46E-05	0.0908	2.9148	0.0264	0.0908	0.0905	4.1511	0.0313	0.0907	1.3753	2.1074
	Post-operative	Mean	−0.0023	0.0127	−1.1E-05	0.5034	−0.7218	−0.0078	0.4981	0.5072	0.8842	0.0095	0.5016	0.9823	−0.3218
		SD	0.0158	0.0097	6.92E-05	0.0624	7.7137	0.0783	0.0561	0.0604	7.9991	0.0788	0.0561	1.6569	2.4631
Asymmetric group	Pre-operative	Mean	−0.0015	0.0117	−1.1E-05	0.5682	10.9476	0.0138	0.5661	0.4344	6.0741	0.0506	0.4286	6.8570	−2.5080
		SD	0.0064	0.0016	2E-05	0.1438	38.3450	0.0455	0.1442	0.1430	8.0671	0.0517	0.1423	3.5046	2.5800
	Pre-operative	Mean	−0.0002	0.0089	−9.8E-07	0.5170	−2.7586	−0.0228	0.5154	0.4855	1.7315	0.0148	0.4841	0.6477	0.8867
		SD	0.0024	0.0017	7.23E-06	0.0866	3.7466	0.0331	0.0869	0.0869	4.2991	0.0343	0.0872	2.6956	3.1915

Table 2 Comparisons between pre- and post-operative value in the symmetric and asymmetric groups.

				Deviated side				Non-deviated side			
	u	v	θ	Resultant force	Angulation	X-component	Y-component	Resultant force	Angulation	X-component	Y-component
Symmetric (pre) versus asymmetric (pre)	0.5380	0.0035*	0.0669	0.1795	0.5170	0.0014*	0.1952	0.1881	0.5546	0.0024*	0.1400
Symmetric (post) versus asymmetric (post)	0.4234	0.0171*	0.3665	0.3692	0.0132*	0.2551	0.2487	0.1650	0.5608	0.7016	0.2444
Symmetric (pre) versus symmetric (post)	0.5414	0.2132	0.5164	0.1289	0.5170	0.6461	0.0701*	0.0441*	0.2846	0.4243	0.0664
Asymmetric (pre) versus asymmetric (post)	0.2753	<0.0001*	0.0063*	0.0719	0.0074*	0.0003*	0.0746	0.0718	0.0024*	0.0001*	0.0500

*$P < 0.05$.

Table 3 Comparisons between the deviated and non-deviated sides.

	Resultant force	Angulation	X-component	Y-component
Deviated side versus non-deviated side				
Symmetric (pre)	0.0372*	0.2846	<0.0001*	0.0354*
Symmetric (post)	0.8328	0.5170	0.4842	0.8455
Asymmetric (pre)	0.0054*	0.0095*	0.0001*	0.0043*
Asymmetric (post)	0.2640	<0.0001*	0.0004*	0.2679

*$P < 0.05$.

midline discrepancy, right–left differences in molar relationship, and inclination of the frontal occlusal plane have been considered to be important occlusal characteristics in patients with TMJ disorders (Solberg *et al.*, 1986; Fushima *et al.*, 1999; Inui *et al.*, 1999; Trpkova *et al.*, 2000).

Improvement in TMJ symptoms after orthognathic surgery has been reported in several clinical investigations. Kerstens *et al.* (1989) observed post-operative improvement in 66 per cent of patients who underwent orthognathic surgery and White and Dolwick (1992) in 89.1 per cent. Similar data were found by Karabouta and Martis (1985). Hu *et al.* (2000) reported post-operative improvement in only 30 per cent of patients who had undergone SSRO but in 75 per cent who had undergone IVRO. Previous studies (Ueki *et al.*, 2002; 2007a) have also suggested that SSRO, either with or without a Le Fort I osteotomy, cannot alter the pre-operative disc position, including ADD, although these procedures can improve the symptoms of TMJ dysfunction. IVRO, with or without a Le Fort I osteotomy, could improve ADD and TMJ symptoms along with condylar position and angular change. However, it is difficult to predict the amount of improvement in ADD (Ueki *et al.*, 2002; 2007b).

This study investigated dynamic calculations using geometric information from frontal cephalograms, so that comparison between surgical procedures could not be taken into account. The purpose was to clarify the theoretical contact stress on the TMJ on the basis of geometric information alone, using a single calculation technique. Therefore, although differences in surgical procedure, fixation method, and the amount of setback would influence stress on the TMJ, the overall skeletal morphology analysed in this study was considered to be geometric information that included these factors.

Some finite element models (FEMs) of the TMJ have been developed to simulate condylar motion or stress change (Koolstra *et al.*, 1988; Korioth and Hannam, 1990; Korioth *et al.*, 1992; Chen and Xu, 1994; Tanaka *et al.*, 1994; Devocht *et al.*, 1996; Tanne *et al.*, 1996; Hylander and Johnson, 1997). However, in FEM, data on many material properties are necessary. FEMs are suitable for calculating stress within elements, while the RBSM method is used for calculating the surface force between elements. This theory has been used to analyse stress on the knee, hip, and wrist in the field of orthopaedic surgery (Genda *et al.*, 1995; Schuind *et al.*, 1995). For this reason, RBSM was employed because many individual images had to be analysed to provide a more comprehensive biomechanical description of loading and the results had to be suitable for statistical analysis. Finally, as the amount of data collected was large, simple analysis was required.

From the results of FEMs, Buranastidporn *et al.* (2006) 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 of symptoms on the ipsilateral and an increase on the contralateral sides. In their asymmetric–mandibular models, both TMJs were fixed in the same position and remained symmetric in shape. Ten asymmetric models were created with the frontal occlusal plane and frontal mandibular plane inclined by 1–10 degrees in 1 degree increments ascending to the left side (Buranastidporn *et al.*, 2006).

However, the TMJ structure in jaw deformity patients is different from that in subjects with normal TMJs. An asymmetric mandible has two different TMJs (Ueki *et al.*, 2000). It was not realistic that in an asymmetric–mandibular model, both TMJs remain symmetrical in shape. Therefore, when TMJ stress analysis is performed, outline data derived from more realistic morphology of TMJs are more appropriate to calculate the contact stress.

A previous study (Ueki *et al.*, 2005) using RBSM for sagittal tomography demonstrated that TMJ stress was associated with TMJ morphology in Class III patients, whether or not they were asymmetric. There was also a significant correlation between disc position and stress angulation. In the asymmetric group, regression analysis indicated a significant correlation between the difference in stress angulation (between the deviated side and non-deviated side) and the degree of asymmetry (measured by the angle of asymmetry). These results proved that TMJ morphological adaptation was strongly associated with occlusion and skeletal morphology.

Ueki *et al.* (2006), using RBSM for lateral cephalograms before and after setback surgery, and when muscular power was assumed to be 1, found that the post-operative degree of the force vector was higher than the pre-operative value. The X-co-ordinate u and rotation θ of the displacement vector in the pre-operative patients with mandibular prognathism were significantly greater than those in the control subjects. However, there were still significant differences between the displacement values of the post-operative patients and those of the control subjects. The results suggested that the condyles of subjects with normal skeletal relationships and occlusions were dynamically more stable than those of subjects with mandibular prognathism.

When the frontal occlusal plane increased in the FEM using frontal cephalograms, the distribution on the ipsilateral side showed a marked shift in direction, and the medial portions were loaded least, with the stress to the lateral part gradually increasing. For the contralateral disc, the medial borders were additionally loaded. The mean stress values on the ipsilateral (shifted) disc were smaller than those in the standard model and those on the contralateral side (Buranastidporn *et al.*, 2006).

In contrast, in this study using RBSM, the resultant force on the deviated side was found to be larger than that on the non-deviated side, in both groups. There was a significant difference in stress angulation between the deviated and non-deviated side but only in the asymmetric group. Although there was no significant difference in stress angulation between either side in the symmetric group, that on the deviated side was significantly larger than that on the non-deviated side. Furthermore, although stress angulation on the bilateral condyles tended to incline to the opposite side in the symmetric group, in the asymmetric group, it tended to incline to the same (deviated) side. This tendency in stress angulation might promote mandibular asymmetry. Vertical displacement in the asymmetric group was larger than in the symmetric group. This suggests that the symmetric mandible was more stable as an element in the vertical dimension of the asymmetric group. On the other hand, the X-component of the symmetric group was significantly smaller than that of the asymmetric group. This could imply that both condyles in the symmetric group were more dynamically stable than those in the asymmetric group in the horizontal dimension.

A comparison of the pre- and post-operative values revealed no significant changes in the symmetric group. In contrast, the post-operative values became smaller than the pre-operative value, during vertical (v) and rotational (θ) displacement of the mandible and angulation and X-component in both TMJs. This suggests that the direction of the inclined force was upwards on both sides following surgical correction and both condyles were more dynamically stable in the asymmetric group in the horizontal dimension. The pre-operative significant differences in three parameters between the deviated and non-deviated sides in the symmetric group were not found post-operatively. On the other hand, although there were significant differences in all four parameters between the deviated and non-deviated sides in the asymmetric group pre-operatively, significant differences in angulation and the X-component remained post-operatively. This suggests that the difference between the right and left sides could also improve after surgery in the symmetric group but not in the asymmetric group. Frontal cephalograms 3–6 months post-operatively were used in this study. Therefore, it was considered that the shapes of the bilateral condylar surface that adapted the pre-operative mandibular asymmetry did not change immediately after surgery and was not dynamically stable within that period. Since the purpose of this study was to examine the change following surgery, there was only one registration after surgery. However, more information including the remodelling process would have been gained if the registrations had been undertaken, e.g. 1, 3, and 12 months after surgery and even after a longer period of follow-up.

Conclusions

The findings on frontal cephalograms suggest that surgical correction of mandibular prognathism, with and without asymmetry, could induce improvement in stress balance on bilateral TMJs.

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