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Factors related to stability following the surgical correction of skeletal open bite

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Objectives: If a skeletal anterior open bite malocclusion is treated by orthognathic surgery directed only at the mandible, the lower jaw is repositioned upward in a counter-clockwise rotation. However, this procedure has a high risk of relapse. In the present study, the key factors associated with post-surgical stability of corrected skeletal anterior open bite malocclusions were investigated.
Material and methods: Eighteen orthognathic patients were subjected to cephalometric analysis to assess the dental and skeletal changes following mandibular surgery for the correction of an anterior open bite. The patients were divided into two groups, determined by an increase or decrease in nasion-menton (N-Me) distance as a consequence of surgery. Changes in overbite, the displacements of molars and positional changes in Menton were evaluated immediately before and after surgery and after a minimum of one year post-operatively.
Results: The group with a decreased N-Me distance exhibited a significantly greater backward positioning of the mandible. The group with an increased N-Me distance experienced significantly greater dentoalveolar extrusion of the lower molars.
Conclusions: A sufficient mandibular backward repositioning is an effective technique in the prevention of open bite relapse. In addition, it is important not to induce molar extrusion during post-surgical orthodontic treatment to preserve stability of the surgical open bite correction.
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Introduction

The orthodontic treatment of an anterior open bite malocclusion is considered to be challenging. A valid reason for concern is that relapse is found in 38.1% of patients treated by conventional orthodontic mechanics.[1] An additional factor is that many anterior open bite cases have a vertical skeletal discrepancy which is managed orthodontically by the extrusion of anterior teeth and/or the intrusion of molars or, alternatively, corrected surgically.[2] Surgical correction has been established as a standard approach to treat a skeletal open bite malocclusion to restore facial harmony and provide a functional occlusion.[2] Orthognathic surgery planning usually requires the upward and forward repositioning of the mandible in a counter clockwise direction. Unfortunately, a percentage of cases experience significant relapse due to surgical factors related to the method of jaw repositioning, fixation and the subsequent alteration in muscle tension.[3-5] Proffit and Ozdemir reported that relapse was a result of surgical procedures to lengthen the ramus and move the mandibular symphysis away from the hyoid bone which produces stretching of the suprahyoid and the elevator muscles of the mandible.[6,7] It was also suggested that stretching of the enveloping soft tissues, as well as jaw muscle activity, might be additional complicating causes of relapse following mandibular setback surgery.[4,8] It has been shown that relapse is dependent on the amount of surgical repositioning of the mandible,[9] whereas orthodontic relapse may result in the reappearance of an open bite.[8] It is therefore concluded that open bite relapse can be due to surgical and dental changes which may ultimately affect the facial skeleton. However, the reason for treatment relapse has not been definitively identified.[10]

The aim of the present investigation was to assess skeletal and dento-alveolar stability after mandibular surgical correction of skeletal anterior open bite.

Materials and methods

The Hiroshima University Hospital's Ethical Committee approved this retrospective study. The subjects were selected because of the treatment received and consisted of 18 patients (5 males and 13 females with a mean age of 22.4 ± 4.2 years) diagnosed with a jaw dysplasia associated with an anterior open bite (Mean FMA = 29.8 ± 6.6°, Mean ANB = -1.43 ± 2.74°, including skeletal Class III patients and skeletal Class II patients). All patients underwent presurgical orthodontic treatment, followed by orthognathic surgery in the Orthodontic and Surgical Clinics of Hiroshima University Hospital. Patients who underwent additional procedures (genioplasty or had a cleft lip and palate repair) were not included in the study.

Over a period of eight years (1999 to 2007), the identified patients received a sagittal split ramus osteotomy (SSRO) involving a counter clockwise (closing rotation) of the distal mandibular fragment.

Cephalometric analysis

Four lateral cephalograms were taken of each patient: at first examination, immediately before surgery, immediately after surgery and one year after surgery. The lateral cephalograms were taken with the teeth in occlusion and lips in a relaxed state. One investigator identified the cephalometric landmarks and traced the cephalograms on acetate paper.

Evaluation of stability

To evaluate the stability of mandibular position after surgery, nasion-menton (N-Me) distance during the time from surgery to one-year review, was analysed. All subjects were placed into two groups determined by the changes noted in N-Me distance. One group exhibited an increase in N-Me length, whereas the other experienced a decrease or almost no change during the study period (Figure 1).

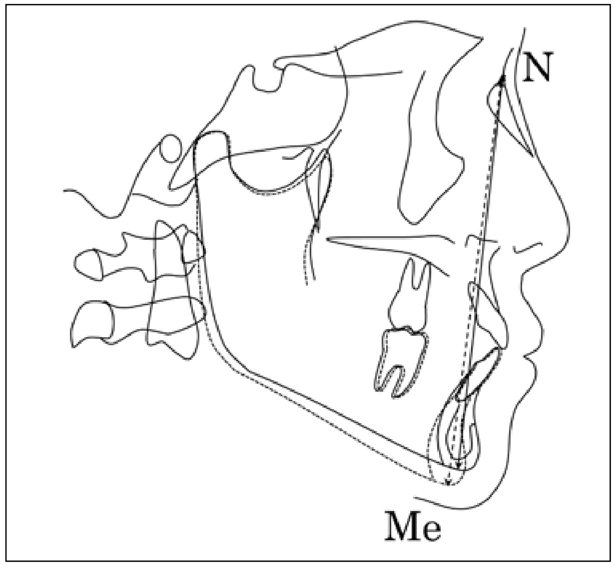

Figure 1. Evaluation of vertical relapse. To evaluate the vertical stability of the mandible, the length of N-Me was analysed from just after surgery (the solid line) to one year after surgery (the dotted line). All cases were classified into two groups: Group 1, with an increase in the length of N-Me, and Group 2, with a decrease or maintenance in the studied phase.

Group 1 consisted of three males and four females with a mean age of 19.8 ± 1.8, whose change in N-Me length was 1.22 ± 0.49 mm. Group 2 consisted of two males and nine females with a mean age of 23.8 ± 4.5, whose change in N-Me distance was -1.00 ± 0.72 mm.

Evaluation of skeletal and dentoalveolar changes

To determine cephalometric changes, sella-nasion (S-N) plane was used as a horizontal skeletal reference line and dentoalveolar changes were assessed using the occlusal plane as a baseline. The following measurements were taken: the position of Me and Frankfurt-mandibular plane angle (FMA) for skeletal changes (Figure 2) and the position of the upper and lower first molars and overbite for dental change assessment (Figure 3).

Statistical analysis

Statistical analysis was carried out using Microsoft Excel 2007 (Microsoft, Redmond, WA, USA). Statistical significance was examined using the Student's *t*-test at a significance level of $p < 0.05$ or 0.005.

Table I. The errors of the method (Se) $Se = \sqrt{\Sigma d^2/2n}$.

Dental changes in the phase of orthodontic treatment before surgery	Group 1	Group 2
Overbite (mm)	0.20	0.27
Vertical displacement of lower molar (mm)	0.25	0.06
Horizontal displacement of lower molar (mm)	0.25	0.13
Vertical displacement of upper molar (mm)	0.48	0.19
Horizontal displacement of upper molar (mm)	0.28	0.03
Skeletal changes of mandible position at surgical correction	**Group 1**	**Group 2**
Vertical position of Me (mm)	0.28	0.29
Horizontal position of Me (mm)	0.36	0.18
FMA (°)	0.20	0.13
Dental changes in the phase of orthodontic treatment after surgery	**Group 1**	**Group 2**
Vertical displacement of lower molar (mm)	0.21	0.10
Horizontal displacement of lower molar (mm)	0.25	0.13
Vertical displacement of upper molar (mm)	0.11	0.14
Horizontal displacement of upper molar (mm)	0.05	0.11

Table II. Dental changes in the phase of orthodontic treatment before surgery.

	Group 1	Group 2	*p*
Overbite (mm)	0.07 ± 1.36	1.28 ± 1.99	NS
Vertical displacement of lower molar (mm)	0.14 ± 0.62	0.40 ± 0.45	NS
Horizontal displacement of lower molar (mm)	0.12 ± 0.57	0.18 ± 1.92	NS
Vertical displacement of upper molar (mm)	0.44 ± 1.06	0.40 ± 0.56	NS
Horizontal displacement of upper molar (mm)	0.62 ± 1.10	0.57 ± 1.45	NS

NS, not significant

Table III. Skeletal changes of mandible position at surgical correction.

	Group 1	Group 2	*p*
Vertical position of Me (mm)	1.82 ± 1.61	2.91 ± 1.61	NS
Horizontal position of Me (mm)	-3.74 ± 4.21	-8.00 ± 4.04	< 0.05
FMA (°)	0.34 ± 2.21	0.68 ± 3.60	NS

NS, not significant

Table IV. Dental changes in the phase of orthodontic treatment after surgery.

	Group 1	Group 2	*p*
Vertical displacement of lower molar (mm)	0.65 ± 0.25	-0.31 ± 0.61	< 0.005
Horizontal displacement of lower molar (mm)	0.38 ± 0.48	-0.06 ± 0.54	NS
Vertical displacement of upper molar (mm)	-0.08 ± 0.32	-0.25 ± 0.39	NS
Horizontal displacement of upper molar (mm)	0.28 ± 0.60	0.41 ± 0.55	NS

NS, not significant

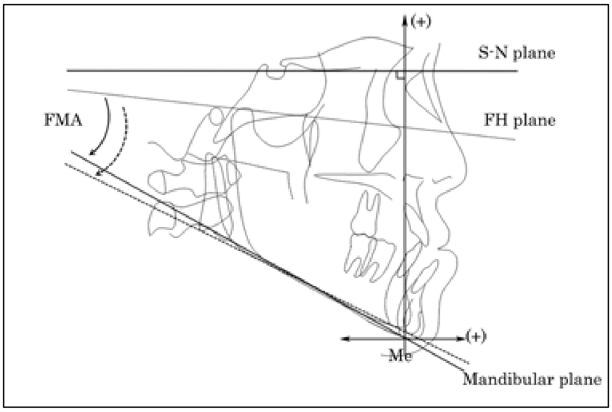

Figure 2. Evaluation of changes in FMA and Me position at surgical correction. To evaluate skeletal changes at surgery, FMA and the displacement of the Me position were analysed. The horizontal reference line is the S-N plane. The vertical reference line is a line perpendicular to the S-N plane through Me just before surgery. The dotted line indicates just after surgery and the solid line indicates just before surgery.

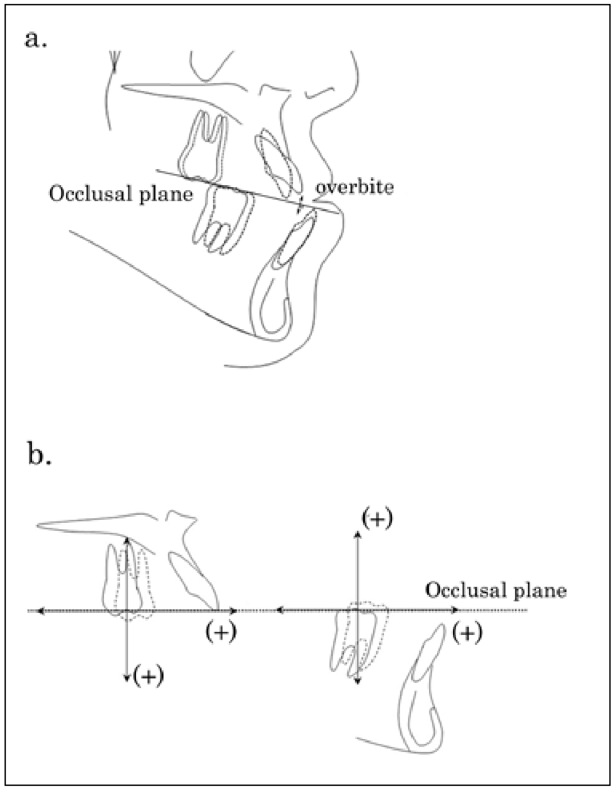

Figure 3. Evaluation of changes in overjet and Me position at surgical correction. a. To evaluate the changes in overjet before surgery, the perpendicular distance to the occlusal plane was analysed at first examination (the solid line) and just before surgery (the dotted line). b. To evaluate dental changes in orthodontic treatment, the displacement of the first molar position was analysed just before surgery and one year after surgery (the dotted line). The horizontal reference line is set as the occlusal plane. The vertical reference line is a line perpendicular to the occlusal plane through the first molar position at first examination or just after surgery (the solid line).

Error of the method

The error of the method was estimated by remeasuring all cephalograms at least one month following the initial analysis and applying Dahlberg's formula: $Se = \sqrt{\Sigma d^2 / 2n}$, in which Σd^2 is the sum of squares of the differences between the first and second measurements, and n is the number of measurements. The errors of the method (Se) for the evaluation of all measurement items were tabulated (Table I).

Results

Dentoalveolar changes during presurgical orthodontic treatment

To reduce the counter clockwise upward and forward rotation of the mandible required at surgery, the open bite was reduced by 0.07 ± 1.36 mm and 1.28 ± 1.99 mm in Groups 1 and 2, respectively, during the presurgical orthodontic treatment phase. The lower molars extruded 0.14 ± 0.62 mm and 0.40 ± 0.45 mm in Groups 1 and 2, respectively. The extrusion of the upper molars was 0.44 ± 1.06 mm in Group 1 and 0.40 ± 0.56 mm in Group 2. Lower molars were moved forward by 0.12 ± 0.57 mm in Group 1 and 0.18 ± 1.92 mm in Group 2. Upper molars were moved forward by 0.62 ± 1.10 mm and 0.57 ± 1.45 mm in Groups 1 and 2, respectively. For these minimal dento-alveolar changes, no significant differences were found between the two groups (Table II).

Skeletal changes in mandibular position at surgical correction

The vertical displacement of Me exhibited no significant differences between the two groups at surgical correction. Me was positioned 1.82 ± 1.61 mm upward in Group 1 and 2.91 ± 1.61 mm in Group 2. However horizontally, Me was repositioned significantly more distally in Group 2 than in Group 1 ($p < 0.05$). The mandible was repositioned backward by 3.74 ± 4.21 mm in Group 1 and 8.00 ± 4.04 mm in Group 2. The mandibular plane exhibited 0.34 ± 2.21 degrees of rotation in a clockwise direction in Group 1 and 0.68 ± 3.60 degrees of clockwise rotation in Group 2. However, no significant differences were found in FMA between the two groups (Table III).

Dental changes during post-surgical orthodontic treatment

The lower molars in Group 1 patients moved forward by 0.38 ± 0.48 mm, and the upper molars moved backward by 0.08 ± 0.32 mm and intruded by 0.28 ± 0.60 mm. In Group 2, the lower molars moved backward by 0.06 ± 0.54 mm, and the upper molars moved backward by 0.25 ± 0.39 mm and intruded by 0.41 ± 0.55 mm. These extremely minor changes were not significantly different between the two groups.

However, the extrusion of the lower molars was 0.65 ± 0.25 mm in Group 1, whereas Group 2 exhibited intrusion of 0.31 ± 0.61 mm. These changes represented a significant difference between the two groups (Table IV).

Discussion

The post-operative relapse of open bite malocclusions after surgical correction is considered to be multifactorial.[10,11] Ellis and McNamara stated that a basic treatment principle is to correct the deformity rather than camouflage the existing problem and so, the orthodontic extrusion of the incisors should be reduced to a minimum.[12] By contrast, in the present study, orthodontic extrusion of the incisors did not appear to affect the post-operative vertical position of the mandible. It was therefore concluded that, to reduce the amount of mandibular counter clockwise rotation during surgery, slight extrusion of the incisors does not have any negative effect on vertical skeletal relapse. In addition, the present study indicated that molar movement during presurgical treatment did not have any bearing on vertical skeletal relapse. However, the extrusion of lower molars during post-surgical treatment caused vertical instability of mandibular position. This result is contrary to a previous report which suggested that a moderate amount of preoperative molar extrusion exhibited long-term stability.[13] The overwhelming recommendation is the minimisation of preoperative molar extrusion[12] and overall, it is beneficial for clinicians to minimise molar extrusion for the consistently successful correction of open bite malocclusions.

During the surgical correction of an open bite, the mandible should generally not be rotated in a counter clockwise downward and backward direction, because this change is highly associated with relapse.[3,8] However, in the present study, vertical movement of Me at the time of surgical correction exerted no influence on mandibular vertical relapse. Significantly, mandibular surgical backward repositioning was greater in the group with a stable Me position compared with the unstable group following surgical correction. Previous reports have stated that a decrease in oral cavity volume, caused by a mandibular backward repositioning, negatively affects the stability of tooth position, occlusion, and dentofacial morphology.[14,15] This finding may be interpreted as a reduction in the horizontal stability of the mandible, as the amount of mandibular backward repositioning increases. Therefore, it is possible that an increasingly greater mandibular backward repositioning reduces vertical stability.

Confusingly, there were conflicting findings as the position of the mandible was stable in the vertical direction when the level of mandibular backward repositioning was increased. This may be explained by the reduced tension in the mandibular muscles as a result of the backward repositioning. The hyoid muscles might become more stretched as the mandible is rotated in the counter clockwise direction by surgery.[3,5,8] Importantly, vertical relapse is known to be related to the stretch induced in the infrahyoid and suprahyoid muscles at surgery. When the infrahyroid muscles become tense, the hyoid bone is pulled down and as a result, the mandible is rotated in a clockwise direction.[16] The mylohyoid, geniohyoid and anterior belly of the digastric muscles connect the mandible and the hyoid bone[17] and induce mandibular depression and hyoid elevation. The suprahyoid muscles have also been considered to be relevant in the relapse of open bite malocclusions because they become more tense when the mandible is rotated in a counter clockwise direction during surgery.[3,8] In the present study, the patients who displayed consistency of vertical Me position exhibited mandibular rotation in a counter clockwise direction during surgery to the same extent as the group that experienced relapse of Me vertical position. However, the mandible in the former group was repositioned backward more than in the group exhibiting relapse. This perhaps led to sufficient stability in the vertical dimension and indicated that if the mandible is repositioned backward more substantially during the surgical correction of an open bite, the mandibular muscles become less strained. For validation of this hypothesis, the nature of muscle activity in jaw dysplasia patients before and after orthognathic surgery requires examination.

Conclusions

It is concluded that significant mandibular backward repositioning is essential for skeletal stability after orthognathic surgery to correct an anterior open bite malocclusion. In addition, it is important to reduce molar extrusion during post-surgical orthodontic treatment to avoid downward displacement of the mandible, leading to relapse of the open bite.

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