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Clinical Observation of the Postoperative Stability of Bone Segments In Short Lingual Osteotomy without Fixation Using the New "Physiological Positioning Strategy"

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Abstract

The aim of this study was to evaluate the "Physiological Positioning Strategy (PPS)" as a new treatment modality for orthognathic surgery, which could manage the positioning of bone segments after osteotomy. In this study, 20 patients with skeletal mandibular prognathism were treated by surgery with PPS, jaw exercise was performed after one-day maxilla-mandibular fixation, and the process of bony healing was investigated for 1 year. Ramus and gonial angles were measured at various time points after surgery to examine the stability of the lateral aspect. As a result, the proximal bone segment was moved notably to clockwise rotation, but it then returned to the original position 3 months after surgery. The RAMUS was measured similarly in the frontal aspect; the bone segments were remarkably separated just after operation, but the gap diminished significantly with time. At 3 months post-surgery, the minute gap between bone segments was filled with new bone, and osseous healing was almost completely accomplished. These results show that PPS contributes to stability after surgical treatment with sufficient osseous healing and represents an effective new treatment modality for jaw deformities without complicated technique, mainly owing to the jaw exercise started soon after the surgery.

Keywords: Jaw exercise; Mandible; Physiological positioning strategy; Short lingual osteotomy

Introduction

There are various treatment modalities for jaw deformities. Sagittal Split Ramus Osteotomy (SSRO) is a well-established method for correcting mandibular deformities [1,2]. Because the contact surface between the bony segments after the split is wide, SSRO has a broad range of applications and is used frequently for cases with a relatively large amount of mandibular movement [3]. On the other hand, there are some difficulties in SSRO when there is a large amount of mandibular setback. Especially in mandibular asymmetry cases, the bony interference between the proximal and distal segments of the mandible causes outer displacement of the proximal segment. It is not easy to replace the proximal segment to precisely the same preoperative position in these cases, and we sometimes face difficulty in the fixation of bone segments. As a result, alterations in condylar position can occur, which lead to dysocclusion associated with the risk of relapse in the early stage and could also cause temporomandibular disorders (TMD) [4,5]. On the other hand, bone fixations are usually not used in intraoral vertical ramus osteotomy (IVRO) [6,7], so that the unrestricted proximal segment that includes the condyle can be repositioned physiologically by jaw exercise [8]. Thus, IVRO is adopted not only in orthognathic surgery but also in TMD treatment [7-9]. Nevertheless, IVRO requires a longer period of time for maxilla-mandibular fixation (MMF) than SSRO [10,11]. Furthermore, IVRO is not suitable for cases that require

a large amount of bone movement for collection [6,10,11]. A Short Lingual Osteotomy (SLO) is a modified SSRO technique wherein the mandibular osteotomy is cut further anteriorly to overcome these shortcomings of SSRO [3,12]. Based on the benefits and disadvantages of SSRO and IVRO, we performed an osteotomy with SLO and developed a new concept similar to the postoperative management of IVRO that does not require the fixation of bone segments after mandibular osteotomy. This treatment strategy is termed the "Physiological Positioning Strategy (PPS)". In PPS, jaw exercise is vital and started on the first day post-surgery in order to work the muscle for the movement of bone segments, especially the proximal bone segment, to the physiological position, and to minimize the patients' discomfort related to the longer period of time for rigid MMF. The authors have already reported the excellent postoperative dental and distal bone segment stability in PPS using IVRO [8] and SLO [13]. This study focused on the movement of the proximal bone segment to evaluate the efficacy of early jaw exercise in PPS on the proper healing of bone segments after surgical treatment.

Patients and Methods

Patients

Twenty Japanese adults, including 5 males and 15 females, were involved in this retrospective study. They presented with jaw deformities diagnosed as mandibular prognathism with and without mandibular asymmetry. Patients with past orthognathic surgery were excluded from this study. None of the patients had any kinds of medical or psychological syndromes or alcohol dependency. At the time of orthognathic surgery, the patients' ages ranged from 17 to 31 years, with a mean age of 22.7 years.

Asymmetry

The guideline for the selection of facial asymmetry was menton (Me) deviation from the mid-line over 4 mm, where the mid-line was defined as the line from the crista galli (Cg) through the Anterior Nasal Spine (ANS) [14,15]. The distance from the mid-line to the Me was from 5.6 to 10.7 mm, with a mean distance of 8.5 mm in the asymmetry cases. The distal bone segment was moved with rotation to correct mandibular prognathism and asymmetry in our operation.

Surgery

All 20 patients underwent SLO bilaterally, according to the previous report by Young et al. [3] to reduce the posterior mandible excess. In this operation, no stripping of either the pterygo-masseteric sling or the posterior border of the mandibular ramus was performed. Therefore, all masseter muscles, medial pterygoid muscles, and stylomandibular ligaments were intact. The anterior osteotomy line was made from the mandibular second molar to the mesial part of the masseter muscle insertion. After separation of the mandible, sufficient movement of the distal segment was confirmed, and then the maxilla and mandible were fixed by ligature wires with a splint in place on the maxillary arch. Here, it is notable that neither rigid nor non-rigid fixation between the bone segments was performed, so that the proximal segment was likely to be "floating".

Postoperative management

We have already reported the same postoperative management after IVRO with one-day MMF [12]. The postoperative management was performed as shown in figure 1. Briefly, after 1 day of MMF, elastic was placed to maintain the ideal occlusion, and jaw exercise was started with a splint in place at the same time. After the fourth week post-surgery, the time spent wearing the splint was reduced 2 hours every day. After the fifth week, the splint was worn for 12 hours (daytime) and removed for 12 hours (evening) for a week. After the sixth week, jaw exercise was continued with no splint for a week. If occlusal stability was confirmed during the seventh week, orthodontic treatment was resumed. If not, the patients continued to perform jaw exercise with a splint in place for another week. All cases started the postoperative orthodontic treatment by the ninth week at the latest. The amount of jaw opening was measured between the maxilla and mandibular central incisor edges by a bite gauge. TMD signs and symptoms such as Temporomandibular Joint (TMJ) noise, pain, and mal-movements were examined clinically before treatment and for 1 year after surgery.

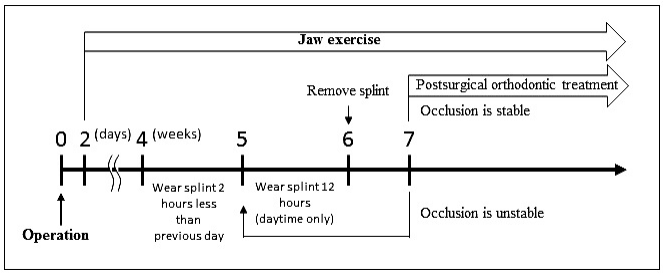

Figure 1: The treatment protocol based on the floating bone concept

Cephalometric analysis

To evaluate the post-surgical stability of the proximal bone segment, posteroanterior and lateral cephalometric radiographs were taken for all patients with the teeth in occlusion and lips in a relaxed position, looking straight ahead, the true vertical perpendicular to the floor and the true horizontal parallel to the floor, with the teeth in maximum intercuspation at the preoperative (T0), immediately postoperative (T1), 1 month postoperative (T2), 3 months postoperative (T3), 6 months postoperative (T4), and 12 months postoperative (T5) examinations. Skeletal changes were evaluated by ramus angle and gonial angle on the lateral cephalometric radiographs. The former is measured between FH plane and ramus plane, and the latter is measured between ramus plane and mandibular plane. On the posteroanterior cephalometric radiographs, RAMUS, which is the angle between the tangential lines of the lateral ramus and Lo-Lo' (Lo; right lateral orbitale, Lo'; left lateral orbitale) was investigated [16].

In the analysis of posteroanterior cephalometric radiographs, all 40 sides were divided into two groups, a symmetry group (8 patients, 16 sides) and an asymmetry group (12 patients, 24 sides). Furthermore, in the asymmetry group, the 24 sides were divided into deviated side and non-deviated side, and

they were analyzed separately.

Statistical analysis

Data were compared between the pre- and postoperative values, and also between the deviated and non-deviated side values. Differences among the time points and the groups were analyzed by non-paired comparisons using the Mann Whitney U-test. Time-dependent changes in cephalometric measurements were examined by analysis of variance (ANOVA). Differences were considered significant at $p < 0.05$.

Results

Process of postoperative osseous healing

Figure 2 shows the process of osseous healing using PPS. In the 3-dimensional assessment on CT images taken at the 3 days, 3 months, and 6 months postoperative examinations, the gap between the proximal and distal segments of the mandible gradually became narrower and was completely closed at the 6-month postoperative examination.

Change of the range of jaw opening

The average jaw opening range was 47.1 mm pre-surgery and 1.8 mm on the second day post-surgery when jaw exercises were just started. The amount of jaw opening increased gradually and was 45.2 mm at 6 months post-surgery, showing recovery almost to the pre-surgery level. The amount of jaw opening finally recovered to 48.5 mm at 1 year post-surgery (Figure. 3).

Skeletal changes

Lateral cephalometric radiographs: Ramus angle: In the analysis of all cases, the ramus angle increased significantly by 4.06º ($p < 0.05$) for T0-T1, and decreased significantly by 4.32º, 4.73º, and 4.77º ($p < 0.05$) for T1-T3, T1-T4, and T1-T5, respectively. There were no significant differences between T0 and T2-5 (Figure. 4).

Gonial angle: In the analysis of all cases, the gonial angle increased significantly by 6.06º, 6.65º, and 6.71º ($p < 0.05$) for T1-T3, T1-T4, and T1-T5, respectively. There were no significant differences between T0 and T1-5 (Figure. 5).

Posteroanterior cephalometric radiographs: RAMUS: In the symmetry group, the RAMUS increased significantly by 3.70º($p < 0.05$) for T0-T1, and decreased significantly by 2.73º($p < 0.05$) for T1-T2. There was no significant difference

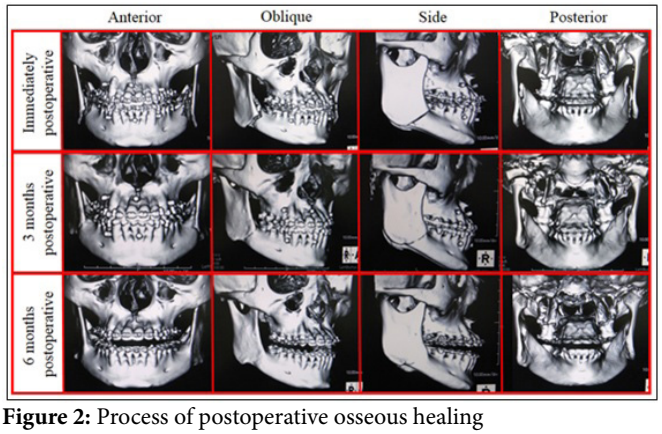

Figure 2: Process of postoperative osseous healing
In the 3-dimensional assessment on CT images taken immediately postoperatively and at the 3 months and 6 months postoperative examinations, the gap between the proximal and distal segments of the mandible gradually becomes narrower and is completely closed at the 6 months postoperative examination.

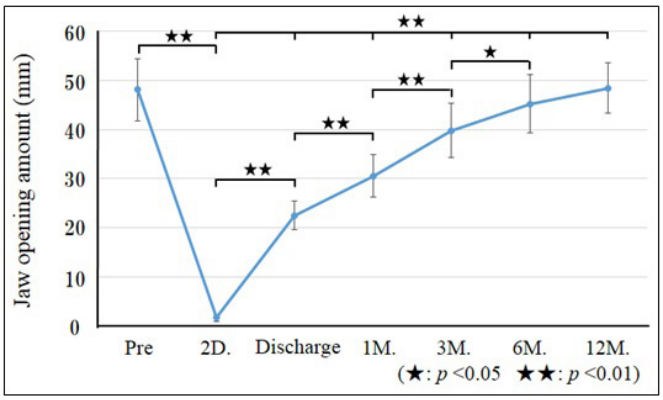

Figure 3: Change of the amount of jaw opening
The average jaw opening is 47.1 mm preoperatively and 1.8 mm on the second postoperative day (2D) when jaw exercises just started. The amount of jaw opening increases gradually and is 45.2 mm at 6 months postoperatively (6M), showing recovery almost to the preoperative level. The amount of jaw opening has finally recovered to 48.5 mm at 12 months postoperatively (12M.). (*: p <0.05; **: p <0.01)

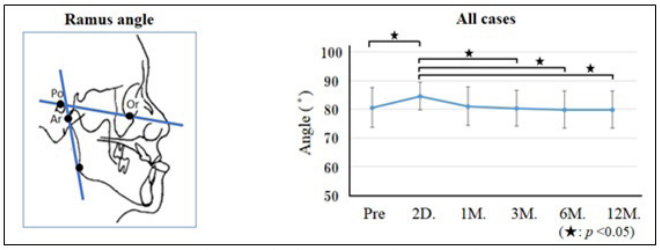

Figure 4: Ramus angle (angle between the FH plane and the ramus plane)
In the analysis of all cases, the ramus angle increases significantly by 4.06° ($p < 0.05$) for T0-T1, and decreases significantly by 4.32°, 4.73°, and 4.77° ($p < 0.05$) for T1-T3, T1-T4, and T1-T5, respectively. There are no significant differences between T0 and T2-5.
(T0: preoperative, T1: 2 days postoperative, T2: 1 month postoperative, T3: 3 months postoperative, T4: 6 months postoperative, T5: 12 months postoperative)

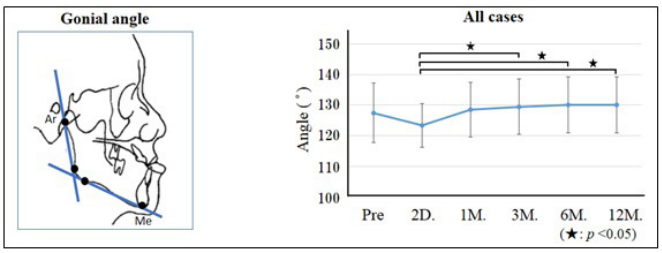

Figure 5: Gonial angle (angle between mandibular plane and ramus plane)
In the analysis of all cases, the gonial angle increases significantly by 6.06°, 6.65°, and 6.71° ($p < 0.05$) for T1-T3, T1-T4, and T1-T5, respectively. There are no significant differences between T0 and T1-5.
(T0: preoperative, T1: 2 days postoperative, T2: 1 month postoperative, T3: 3 months postoperative, T4: 6 months postoperative, T5: 12 months postoperative)

between T0 and T2, and for T2-T5. In the asymmetry group, the RAMUS increased significantly by 5.33º ($p < 0.05$) for T0-T1 and decreased significantly by 3.83º ($p < 0.05$) for T1-T2 at the deviated side. There was no significant difference between T0 and T2, and for T2-T5. On the other hand, on the non-deviated side, there was no significant difference for T0-T5 (Figure. 6).

TMD symptoms

There was TMD symptom which was clicking without pain at 6 (15.0%) of 40 TMJs before surgery. No patients complained of pain and tenderness at their TMJ regions. A TMJ click was maintained in 1 (2.5%) of 40 TMJs after surgery, even though that patient did not complain of trismus or pain.

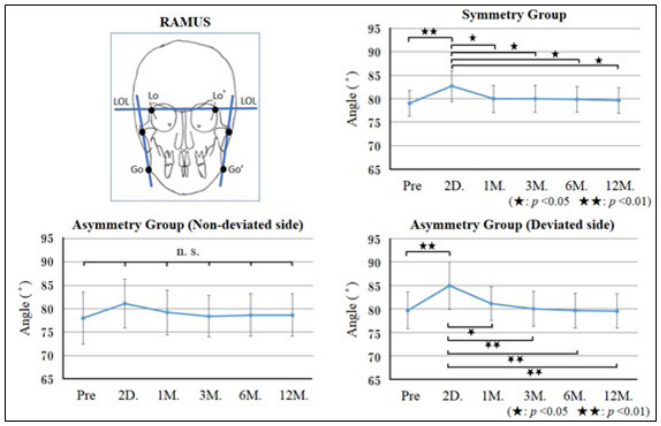

Figure 6: RAMUS (the angle between the tangential lines of the lateral ramus and Lo-Lo')
In the symmetry group, the RAMUS increased significantly by 3.70º($p < 0.05$) for T0-T1, and decreased significantly by 2.73º ($p < 0.05$) for T1-T2. There was no significant difference between T0 and T2, and for T2-T5. In the asymmetry group, the RAMUS increased significantly by 5.33º ($p < 0.05$) for T0-T1 and decreased significantly by 3.83º ($p < 0.05$) for T1-T2 at the deviated side. There was no significant difference between T0 and T2, and for T2-T5. On the other hand, on the non-deviated side, there was no significant difference for T0-T5
(T0: preoperative, T1: 2 days postoperative, T2: 1 month postoperative, T3: 3 months postoperative, T4: 6 months postoperative, T5: 12 months postoperative)

Discussion

Recently, both SSRO and IVRO have been widely adopted for the correction of mandibular prognathism. The stability of these osteotomies is influenced by many factors, such as the amount of retrusion, asymmetry, clockwise rotation of the distal segment of the mandible, the orientation of the proximal segment, and the fixation method [17]. Especially in SSRO with rigid fixation, improper positioning of the proximal segment may cause various problems, including relapse and TMJ dysfunction [18,19]. It is sometimes technically difficult to reproduce the positioning of the proximal segment to the pre-surgical position in SSRO with rigid fixation. It is also possible that it might create non-physiological situations for the newly established occlusion and jaw movement, even if the segment is repositioned to the pre-surgical position, because the pre-surgical position may not be physiological after the pre-surgical orthodontic treatment. Consequently, the non-physiologically adapted condyle may cause TMD or PCR [4,5,20]. Several techniques and appliances have been developed to maintain the position of the proximal segment to overcome this problem, but they are not necessarily suitable solutions, and, in fact, they are not widely employed. Repositioning of the condyle is mainly dependent on the operator's experience and skills at present. Since there were no TMJ symptoms after IVRO in our previous study [8], we thought that SLO was also adoptable for the PPS technique to induce the physiological position of the condyle.

First, the ramus and gonial angles were analyzed on lateral cephalometric radiographs to examine the positional changes of the bone segments, especially the proximal bone segment, for 1 year after PPS. A special focus was placed on the transition of the proximal segment in the early postoperative stage with jaw exercise. The results showed that the proximal bone segment rotated clockwise immediately after surgery, but it returned to the original position within 3 months postoperatively. There was no significant difference in ramus angle preoperatively and 3 months postoperatively. Then, the gonial angle was analyzed in order to evaluate skeletal stability between the proximal and distal bone segments. The results showed that postoperative skeletal stability had been acquired at 3 months postoperatively, and no relapse was observed for 1 year.

In the analysis of RAMUS on posteroanterior cephalometric radiographs in the symmetry group, the gap between the bone segments opened remarkably immediately after surgery, but it decreased significantly as the proximal bone segment gravitated toward the distal bone segment with time. Finally, there was no significant difference in RAMUS preoperatively and 1 month postoperatively. After 3 months post-surgery, the minute gap between bone segments was filled with new bone, and osseous healing was almost accomplished. The RAMUS of the deviated side in the asymmetry group was larger than that of the symmetry group at T1, though there was no significant difference in the non-deviated side at each time point. This is because the interference between bone segments was more excessive on the deviated side [15]. Nevertheless, the leaped up proximal segment was returned close to the pre-operative position within 1 month.

Taken together with these cephalometric analyses, the proximal segment rotates clockwise and swings outside immediately after surgery, but it returns to the proper position within almost 1 month. The early jaw exercise seems to contribute to this phenomenon. Taking into account that bony healing has started within 3 months, as shown in Figure. 2, the jaw exercise soon after surgery is essential for the proper positioning of the condyle.

It is noteworthy that TMD symptoms decreased from 15.0% of TMJs before surgery to 2.5% of TMJs after surgery. This could be one piece of evidence showing that PPS leads to the physiological condylar position. Not only the early jaw exercise but also SLO might play an important role in PPS, because the preservation of the intact pterygo-masseteric sling and stylomandibular ligament might be critical for the movement of the proximal segment to the physiological position. We consider

that the superior-anterior traction force is applied to the proximal segment by the pterygoid and masseter muscles, which are activated by jaw exercise.

In conclusion, this study showed that our strategy, PPS, led to excellent postoperative skeletal stability in mandibular osteotomy as a result of jaw exercise started soon after surgery. It also led to the avoidance and improvement of TMD symptoms, because the bone segments moved to the physiological position. Further studies are required to validate this new treatment approach for other conditions, such as mandibular retrusion, open bite, and severe distortion, which need maxilla-mandibular osteotomies.

Disclosure

The authors have no financial interest to declare in relation to the content of this article.

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