Assessment of skeletal stability of intraoral vertical ramus osteotomy with one-day maxilla-mandibular fixation followed by early jaw exercise

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Abstract

Purpose: Intraoral vertical ramus osteotomy (IVRO) is an effective surgical technique for cases of mandibular setback, and is simpler and has a lower incidence of mentalis paresthesia compared to sagittal split ramus osteotomy (SSRO), another well-known orthognathic surgical technique for the mandible. However, IVRO has a disadvantage in the prolonged duration of postoperative maxilla-mandibular fixation (MMF) required due to the absence of rigid bone fixation. To avoid an extended MMF period, we developed a postoperative management protocol for our IVRO patients, which includes jaw exercises with elastic bands starting on the second day after surgery.

Methods: We evaluated the cephalometric skeletal and dental stabilities of 16 IVRO patients as they followed our protocol.

Results: The stabilities were confirmed and were similar to those of previous reports.

Conclusion: One-day MMF and early initiation of jaw exercise after IVRO did not affect the jaw position stability. Moreover, our findings suggest that starting jaw exercise earlier after IVRO surgery is beneficial, as it allows patients to avoid a long period of rigid MMF so that they can resume their normal daily activities sooner.

Key words: intraoral vertical osteotomy (IVRO), maxilla-mandible fixation (MMF),

jaw exercise

Introduction

Sagittal split ramus osteotomy (SSRO) and intraoral vertical osteotomy (IVRO) are common strategies for the treatment of mandibular prognathism patients (*Chang et al.*, 2000). Both surgical techniques are well established, and each has risks and benefits. Compared with SSRO, IVRO has the advantage of a lower incidence of damage to the inferior alveolar neurovascular bundle (*Glabi and Sikes*, 2000), with a frequency of less than 1% (*Bell and Yamaguchi*, 1991). In contrast, SSRO reportedly has a strong association with alveolar nerve injury, with an incidence of more than 85% of cases. Moreover, 2-3.5% of cases with transected nerves never completely recover from paralysis (*Turvey*, 1985, *van Merkesteyn et al.*, 1987, *Nishioka et al.*, 1987, *Westemark et al.*, 1998). Therefore, it is important to confirm the anatomical position of the inferior alveolar nerve by CT imaging before surgery (*Yoshioka et al., 2012*). In addition to the lower incidence of nerve injuries, IVRO offers other advantages over SSRO, such as a reduced operating time and less bleeding, by virtue of its technical simplicity (*Bell and Yamaguchi*, 1991, *Westemark et al.*, 1998). Furthermore, IVRO is a more favorable osteotomy procedure for asymmetry cases, because the bony interference is reduced compared to that associated with SSRO (*Ueki et al.*, 2006).

On the other hand, some disadvantages of IVRO relative to SSRO have also been reported. First, only cases of mandibular prognathism are indicated for IVRO (*Ayoub et al.*, 2000). This is because the proximal and distal segments of the mandible after IVRO cannot contact each other after the mandible has been advanced to correct mandibular retrognathism. Some reports and textbooks show internal rigid fixation (IRF) with plates and/or screws after osteotomy with IVRO (*Troulis and Koban*, 2004, *Priffit et al.*, 2008, *Haerle et al.*, 2009). However, IRF with IVRO is still not a standard procedure. MMF is performed more often than IRF after IVRO.

The MMF period after IVRO is longer than that after SSRO (*Ueki et al.*, 2005, *Chen et al.*, 2011). While postoperative MMF is generally required for a period of couple of days to two weeks for SSRO (*Yoshioka et al.*, 2008, *Kitahara et al.*, 2009), IVRO requires two to six weeks, depending on the institution where it is performed (*Ueki et al.*, 2005, *Chen et al.*, 2011). There is no consensus thus far on what constitutes an adequate period of MMF after IVRO. Regarding the duration of MMF, SSRO was thought to be more beneficial for patients than IVRO because they could return to their daily lives sooner after surgery. Therefore, we developed a new postoperative management protocol employing two days of MMF, followed by jaw exercise, for IVRO patients. We then evaluated the postoperative skeletal and dental stabilities of patients who were treated using the new protocol.

Materials and Methods

This study was approved by the human research ethics committee of Nagasaki University Hospital.

Patients: The patients included eight males and eight females whose average age was 24.75 years (range: 19-38 years) and who were receiving orthodontic treatment and only IVRO surgery to correct skeletal mandibular prognathism at Nagasaki University Hospital. We followed the usual IVRO postoperative regimen (shown in Fig. 1). Any patient who did not agree to participate in this study or who was not followed up after surgery was excluded from the study. None of the patients had undergone a prior orthognathic surgery. IVRO was performed according to the surgical technique described by Hall et al. (*Hall and Mckenna*, 1987), and additional surgeries, including genioplasty, were not combined with the procedure. The surgery was considered complete after wired MMF with a splint on the maxillary arch was finished.

Postoperative management (Fig. 1): The wires for MMF were replaced with elastic bands on the second postsurgical day. Then, each patient wore a splint and the elastic bands for 24 hours a day and started performing jaw exercise using them. The elastic bands were replaced with new ones every morning, and larger sizes were used as patients became able to open their mouths wider without symptoms. At the beginning of the fourth week after surgery, all patients started to reduce the amount of time they wore the splint by two hours progressively each day, and by the beginning of the fifth week, the patients wore a splint for only 12 hours during the night and removed it for 12 hours during the day. During the fifth week, the patients wore the elastic bands all the time except during meals and while brushing their teeth. At the beginning of the sixth week after surgery, the patient no longer wore the splint, but the jaw exercise with elastic bands was continued for one week. If occlusion was established during the seventh week, postoperative orthodontic treatment was begun. However, if occlusion was not established by that time, then the patient wore a splint for 12 hours a day for four days, then not at all for the following three days. In all cases, postoperative orthodontic treatment was started no later than the eighth week after surgery. Even after postoperative orthodontic treatment was started, patients continued to wear the elastic bands for jaw exercise for approximately six months after surgery until the occlusion stabilized and the jaw opening and closing paths were steady. This is because it takes approximately six months to develop functional and skeletal stability (*Ueki et al.*, 2008).

Jaw exercise: Each patient followed an oral surgeon's instructions for practicing the jaw exercise while looking in a mirror. Patients opened their mouths in the phonetic sign of "a" and closed their mouths in the phonetic sign of "i", and held their breath after each jaw movement. The jaw was led by the patients' own hands placed on the mental region in order to ensure that it moved symmetrically on a vertical movement path. During this exercise, special attention was paid to prevent the patients from using their hands to assist in jaw opening and closing. If any patient could not bite on a splint firmly or the fitting was unsecured, the mandible was guided by the patient's hands to fit the dentition into the splint completely. Each exercise was performed for approximately 15 minutes, four times a day.

Cephalometric measurement (Fig. 2): Cephalometric radiographs were taken pre-operatively (pre), immediately postoperatively (post), one month after surgery (1M), six months after surgery (6M), and 12 months after surgery (12M) for all patients. To evaluate the horizontal and vertical changes in the mandible, serial digital x-ray images were captured, landmarks were identified, and the images were digitized by using a cephalometric analysis software program (Winceph, version 9, Rise, Sendai, Japan). To evaluate the dental changes, the following were measured: U1-FH, the angle between the Frankfort horizontal (FH) plane and the long axis of the upper central incisor (U1); L1-MP, the angle between the mandibular plane (MP) and the long axis of the lower central incisor (L1); U1⊥PP, the perpendicular length from the maxillary incisor edge to the palatal plane (PP); and L1⊥MP, the perpendicular length from the mandibular incisor edge to the mandibular plane (MP). To evaluate the skeletal changes, the angle of the SNB was measured, as were the anterior-posterior and superior-inferior positions of the menton (Me). To determine the two-dimensional position of the Me, an x-y coordinate system was defined such that the SN line was used as the x-axis, and a perpendicular line to the SN from the sella turcica (S) was used as the y-axis. The ramus, the angle between the posterior border of the mandibular ramus (ramus plane) and the FH plane, was measured to evaluate the anterior-posterior movement of the proximal segment after surgery.

Electromyograms of masticatory muscles: Electromyograms of the masticatory muscles, specifically the temporalis, masseter, and digastric muscles, were examined by using a Neurotop device (Nihon Kohden, Tokyo, Japan) during the jaw opening and closing motions. The route along the edge of the lower incisor during jaw opening and closing motions, as well as during the chewing motion, were assessed by a jaw movement indicator, the MM-J2 (Shofu, Kyoto, Japan) at two time points: before the operation and after the positioners were set. The jaw opening width was measured at various intervals.

Statistical analysis: Student's *t*-test was used to compare the average cephalometric measurements to evaluate the treatment-related changes at different time points. A p-value ≤ 0.05 was considered to be significant.

Results

Among the 16 patients who underwent surgery, the mandible was moved posteriorly by an average of 6.43 mm (range: 0-11 mm) on the right and 7.00 mm (range: 3-11 mm) on the left side, respectively. The difference between the movement on the right and left sides was 1.17 mm (range: 0-5 mm) on average.

Dental changes

Changes in the incisor angles (Fig. 3): U1-FH was 112.41 degrees post-surgery, and 109.44 degrees at 1M. It changed by an average of -2.97 degrees, which was a statistically significant difference. From 1M to 6M, it moved by 0.72 degrees, and then by 0.57 degrees from 6M to 12M, demonstrating a tendency for there to be a slight proclination after 1M. Compared with pre-surgery, however, there were no significant differences at any of the time points (immediately post-procedure or at 1M, 6M, or 12M). L1-MP was 88.5 degrees post-surgery, and tended to move more lingually after 1M, 6M, and 12M. However, there were no significant differences at any of the time points.

Vertical linear distance (Fig. 3): U1⊥PP changed by 0.97 mm between post-surgery and 1M, which showed significant U1 elongation; however, the amount of eruption was considered to be negligible. There were no significant differences between the pre-surgery value and any of the time points after surgery. L1⊥MP moved by -1.25 mm from pre-surgery to 1M, by 1.13 mm from post-surgery to 1M, by 0.94 mm from pre-surgery to 6M, and by 1.44 mm from post-surgery to 6M. The mandibular incisor showed a tendency to erupt after surgery, and the position was significantly different until six months after surgery. L1-MP changed vertically by 1.13 mm between post-surgery and 1M, and by 1.44 mm between post-surgery and 6M. There were significant differences between both periods. However, there was no statistically significant change in the lower incisor position (0.9 mm eruption) between post-surgery and 12M. Also, L1-MP changed by -0.15 mm between the pre-surgery and 12M examinations, by 0.54 mm from 6M to 12M, and by 0.9 mm from post-surgery to 12M. None of these differences was significant.

Skeletal changes

SNB (Fig. 4): All cases had skeletal mandibular prognathism and underwent a setback operation. Therefore, surgery significantly decreased the SNB (by -3.5 degrees from pre- to post-surgery). The SNB was also significantly decreased between pre-surgery and 12M. While the SNB changed by -0.93 degrees between post-surgery and 1M, which was a significant decrease, there were no significant differences at either 6M or 12M compared to immediately post-surgery. However, between 1M and 12M, the SNB changed by 0.73 degrees, demonstrating a significant increase. This means that point B had moved posteriorly immediately after surgery, but tended to move anteriorly later, although the amount of change was very small.

Me (Fig. 4): The antero-posterior movement of Me (Me(x)) decreased greatly, by -6.40 mm, as a result of surgery, but the difference was not significant, probably due to accidental error. However, the Me(x) was decreased significantly at 1M, 6M, and 12M compared to that measured pre-surgery (-9.96, -9.25 and -10.58 mm, respectively).

There were no significant differences between the pre-surgery value and any of the time points after surgery. Therefore, the Me(x) moved slightly posteriorly in the first month after surgery and was stable thereafter. The vertical movement of Me (Me(y)) from 1M to 6M was -1.09 mm, showing a significant decrease, but this decrease is considered to be negligible because it does not impact the patient outcome.

Ramus (Fig. 5): The measurement of the ramus was 89.20 degrees immediately post-surgery, 85.34 degrees at 1M, 84.56 degrees at 6M, and 84.00 degrees at 12M, showing significant increases during the periods from pre- to post-surgery, pre-surgery to 1M, and pre-surgery to 6M. However, there was no significant difference between pre-surgery and 12M. The ramus was significantly decreased after surgery at 1M (-3.86 degrees), 6M (-4.6 degrees), and 12M (-5.2 degrees) compared to that at post-surgery. No other time points showed significant changes. In the ramus measurements, the proximal segment showed clockwise rotation after surgery and seemed to return to its original position.

Masticatory function (Fig. 6): Figure 6 shows typical electromyograms of the masticatory muscles during the simple jaw opening and closing motion (A) and the routes along the edge of the lower incision during the single jaw opening and closing motion (B), as well as during the chewing motion (C) after the positioner was set. The electric potentials of the jaw-closing muscles, temporalis and masseter, were detected during jaw closing, and those of the digastric jaw-opening muscle were upregulated during the jaw-opening motion (A). The pathway was almost a single line during the simple jaw opening and closing motions (B). During the chewing motion, the routes were symmetrical in the axial and coronal views, and the sagittal view showed a sufficient chewing motion area (C). Few differences were observed between two time points, i.e., before the operation and after the positioner was set (data from before the operation is not shown). The width of the jaw opening after the setting of the positioner was almost the same as that before surgery (data not shown).

Discussion

SSRO and IVRO are frequently used during the surgical treatment of skeletal mandibular prognathic patients. There is reportedly no difference between the IVRO and SSRO procedures in terms of the postoperative long-term stability (*Yoshioka et al.*, 2008). Due to the higher incidence of inferior nerve injury during SSRO compared to IVRO, IVRO is thought to be the preferable treatment for skeletal mandibular prognathism. However, due to the absence of bony fixation between the segments, the duration of MMF after IVRO is longer than that after SSRO (*Ueki et al.*, 2005, *Chen et* *al.*, 2011). Following the new regimen, shown in Figure 1, to manage patients post-operatively, we released our patients from MMF on the second day after surgery and started jaw exercises using elastic bands and a splint.

Yoshioka et al. previously evaluated the horizontal and vertical positions of point B and the pogonion on the x-y coordinates of individual tracings of the cephalograms. Point B moved 0.21 mm posteriorly and the pogonion moved 0.23 mm posteriorly during the 12 months after IVRO, but the changes were very small. The stability of IVRO was shown to be the same as that of SSRO (*Yoshioka et al.*, 2008). Chen et al. (*Chen et al.*, 2011) evaluated the movement of Me by a method similar to ours using an x-y coordinate. In their study, the Me relapsed by only 1.3 mm on the x-axis, and SNB relapsed by only 0.6 degrees, thus demonstrating great skeletal stability after the IVRO procedure. However, those cases had MMF for 2 to 6 weeks. We think that the mandible rotated clockwise slightly with the supporting point at the Me, because the SNB tended to increase after surgery, whereas the Me maintained its position. The change between 6 months and 12 months after surgery was not significant. Moreover, the range of the SNB difference between immediately after surgery and 12 months after surgery was 0.2 degrees. These changes were similar to those reported in previous studies. Therefore, skeletal stability in the present study was confirmed.

In the evaluation of the movement of the proximal segment, this segment was noted to have shifted posteriorly at first and then moved back to its original position after one year. During IVRO, the pterygomasseteric sling is detached. For this reason, the proximal segment is often retracted anteriorly by the external pterygoid muscle and lateral ligament at the condylar process. On the other hand, the lower part of the mandibular ramus is moved posteriorly by the stylomandibular ligament. Since the condylar processes were within the temporomandibular fossa in all cases, this seemed to lead to the posterior rotation of the proximal segment, with a supported point at the condylar process. Therefore, the proximal segment frequently showed a posterior position immediately after surgery. This jumping of the proximal segment is considered to recover its original position after masticatory balance is established by the jaw exercise. No patients complained of jaw movement impairment or temporomandibular joint disorders. Vigorous jaw exercise seemed to lead the proximal segment to an ideal site for the newly established jaw movement, and consequently, the condylar head was physiologically led into the fossa. There have been few reports on the change in the proximal segment after surgery (*Ueki et al.*, 2009). Therefore, further research is needed.

The dental changes were evaluated based on the inclinations and eruptions of the maxillary and mandibular incisors. The incisor inclinations of both the maxilla and mandible were stable. The mandibular incisor retroclined lingually, but this was not significant. This may have compensated for the slight forward rotation of the mandible. In addition, the mandibular incisors showed a tendency toward slight eruption. It is considered that the elastic bands used for the jaw exercise exerted a vertical eruption force on the incisors. The amount of tooth eruption was small, less than 1 mm; however, considering this reciprocal reaction, an anchor for the elastic force should be placed in the bone instead of on the teeth.

As shown in Figure 6, the function of the mastication muscles was maintained, and the jaw motion was stable after the positioner was set. We also calculated the jaw opening width, and the value after the positioner was set remained unchanged from the preoperative position (data not shown). These results suggest that early jaw exercise can restore the jaw function after IVRO surgery.

Conclusion

We developed a new regimen for the postoperative care after IVRO (Fig. 1), which initiates jaw exercise using elastic bands on the second day after surgery. In this regimen, favorable postoperative skeletal and dental stabilities were found, which were similar to the cases in previous studies. This suggests that the early removal of MMF is possible, and patients can return to their daily routines sooner. We will continue to study how initial jaw exercise after IVRO surgery affects the masticatory system.

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Captions to illustrations

Figure 1: The postoperative time schedule. The time the splint was worn was reduced by two hours every day for a week at the beginning of the fourth week after surgery. All patients had resumed orthodontic treatment within eight weeks after surgery.

Figure 2: Cephalometric measurements: ① SNB angle: the angle between the SN line and NB line. ② Me(x, y): the perpendicular length from the menton to the x- or y-axis. ③ Ramus: the angle between the posterior border of the mandible and the Frankfort horizontal (FH) plane. ④ U1-FH: the angle between the long axis of the upper central incisor and the FH plane. ⑤ L1-MP: the angle between the long axis of the lower central incisor and the mandibular plane (MP). ⑥ U1⊥PP: the perpendicular length from the edge of the upper central incisor to the palatal plane. ⑦ L1⊥MP: the perpendicular length from the edge of the lower central incisor to the mandibular plane.

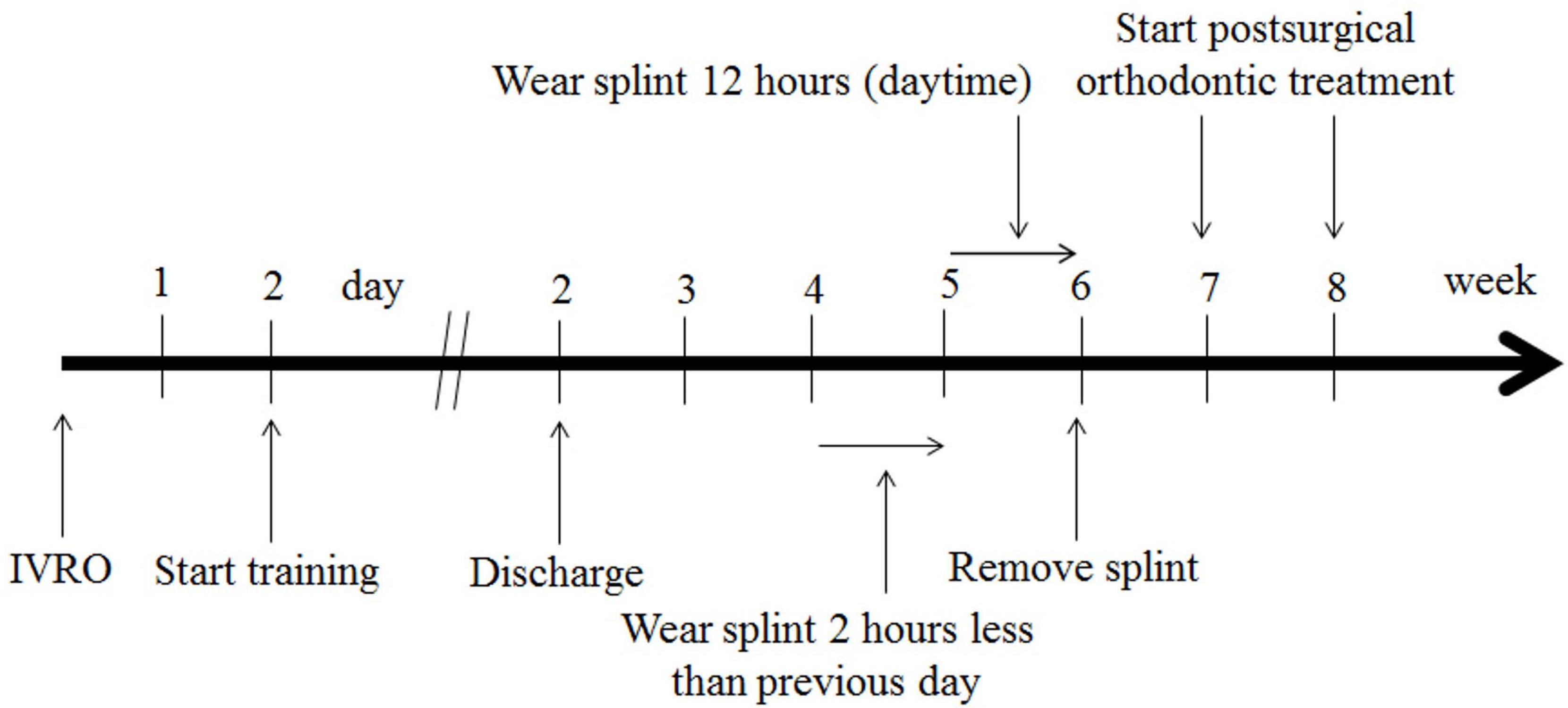
Figure 3: Dental changes after IVRO: U1-FH, L1-MP, U1⊥PP, L1⊥P.

Figure 4: Skeletal changes after IVRO: SNB and Me(x, y).

Figure 5: Movement of the proximal segment.

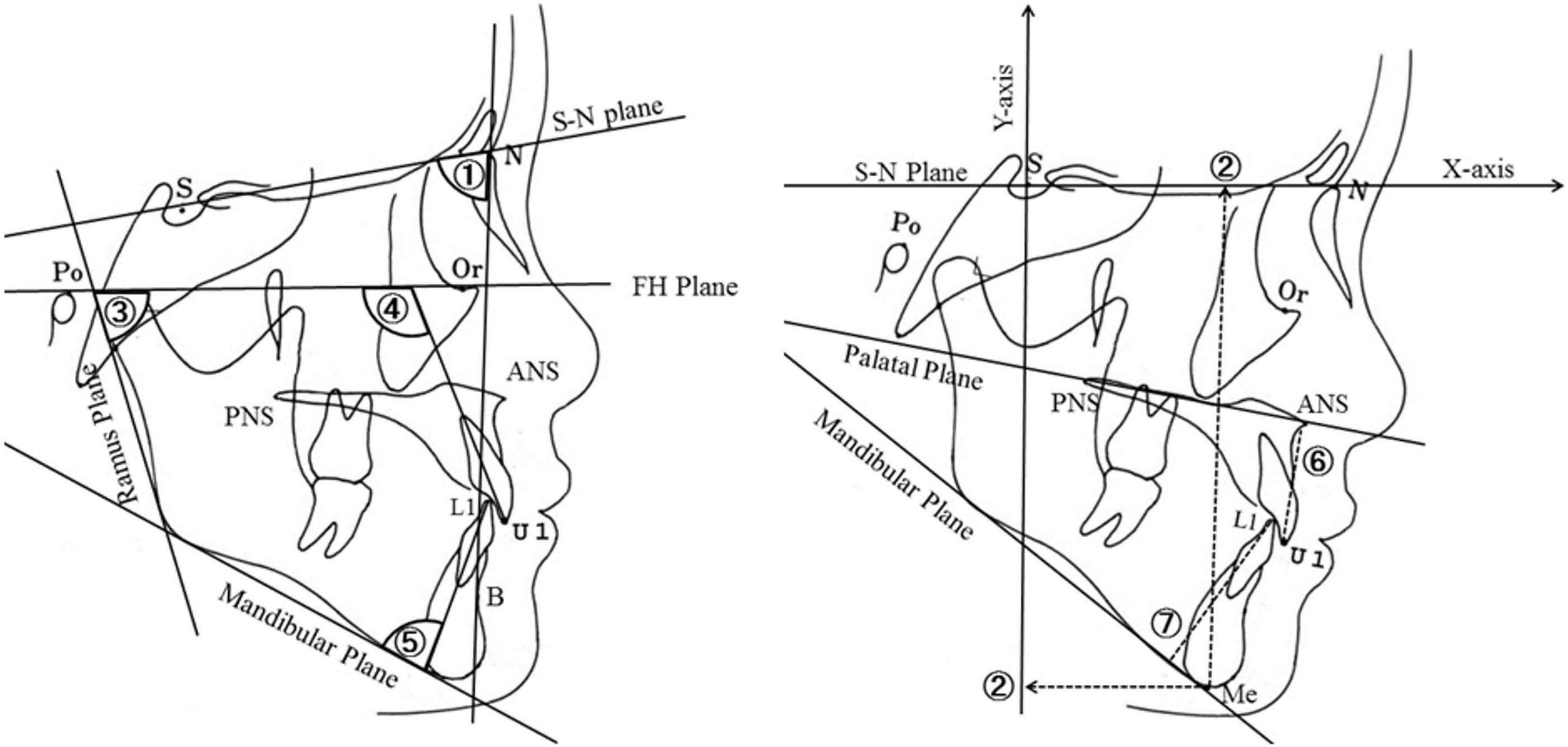
Figure 6: Typical electromyograms of the masticatory muscles (temporalis, masseter, and digastric) during the simple jaw opening and closing motion (A). The routes along the edge of the lower incisor during the jaw opening and closing motion (B) and a chewing motion (C) after surgery were assayed. All patterns after the positioners were set were similar to those prior to the operation.

Figure 1.



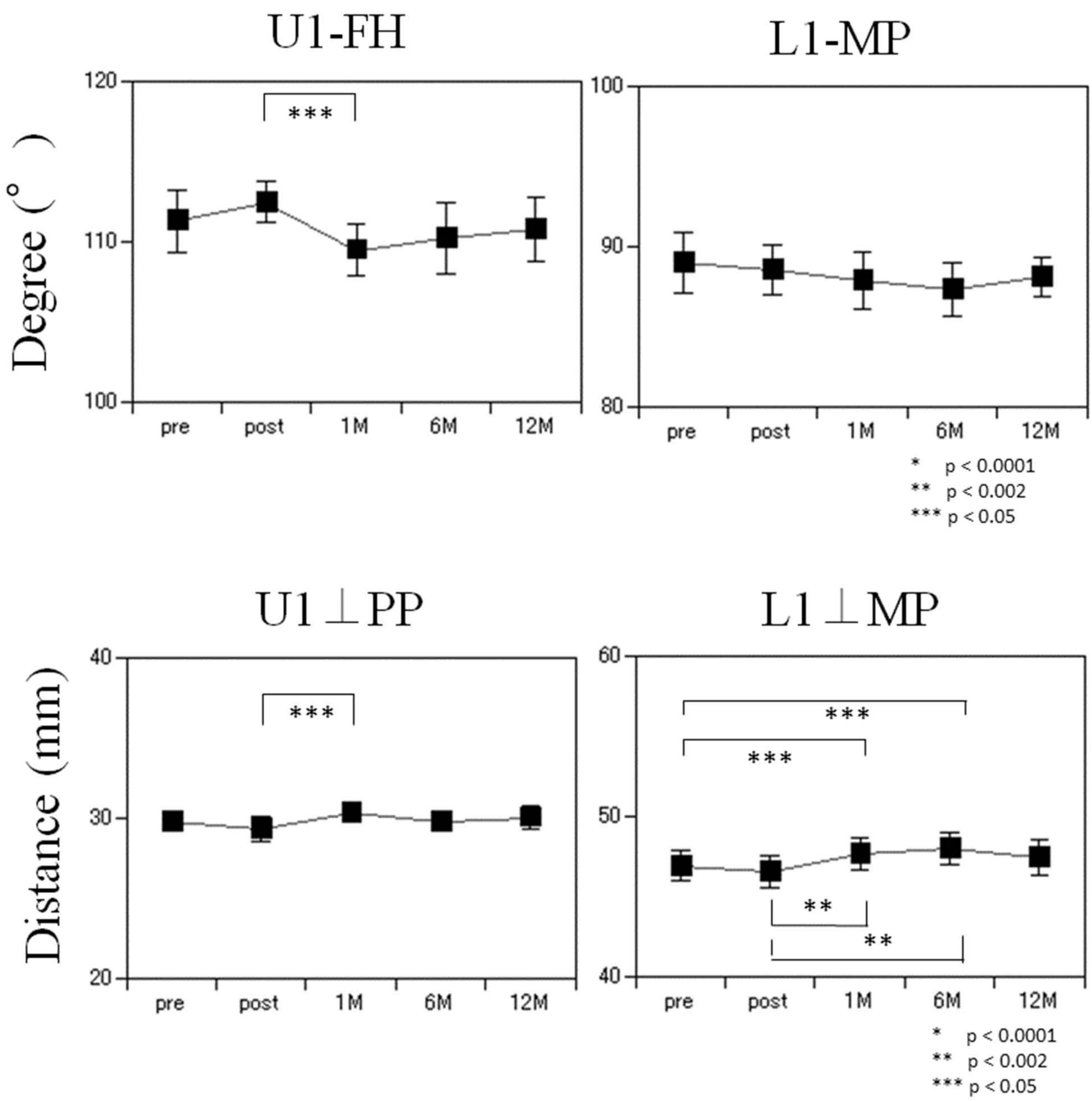
Start postsurgical
orthodontic treatment
Wear splint 12 hours (daytime)
1
2
day
2
3
4
5
6
7
8
week
IVRO
Start training
Discharge
Wear splint 2 hours less
than previous day
Remove splint

Figure 2.



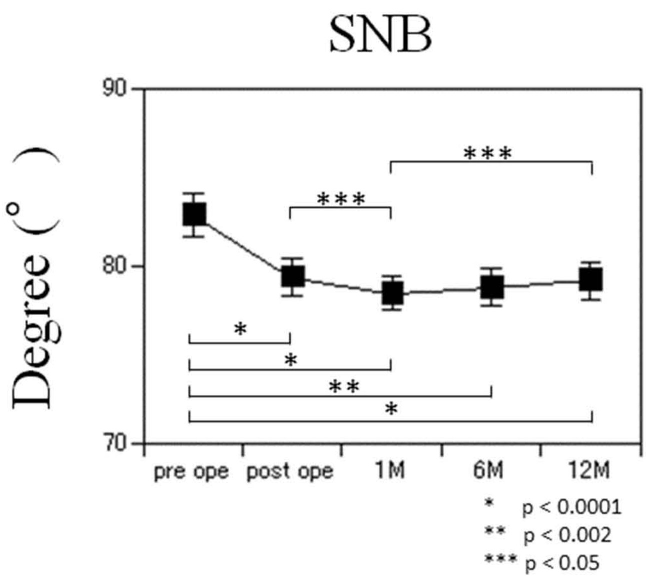
S-N plane
N
S
Po
Or
FH Plane
ANS
PNS
Ramus Plane
L1
U1
B
Mandibular Plane
Y-axis
S-N Plane
X-axis
Palatal Plane
Me

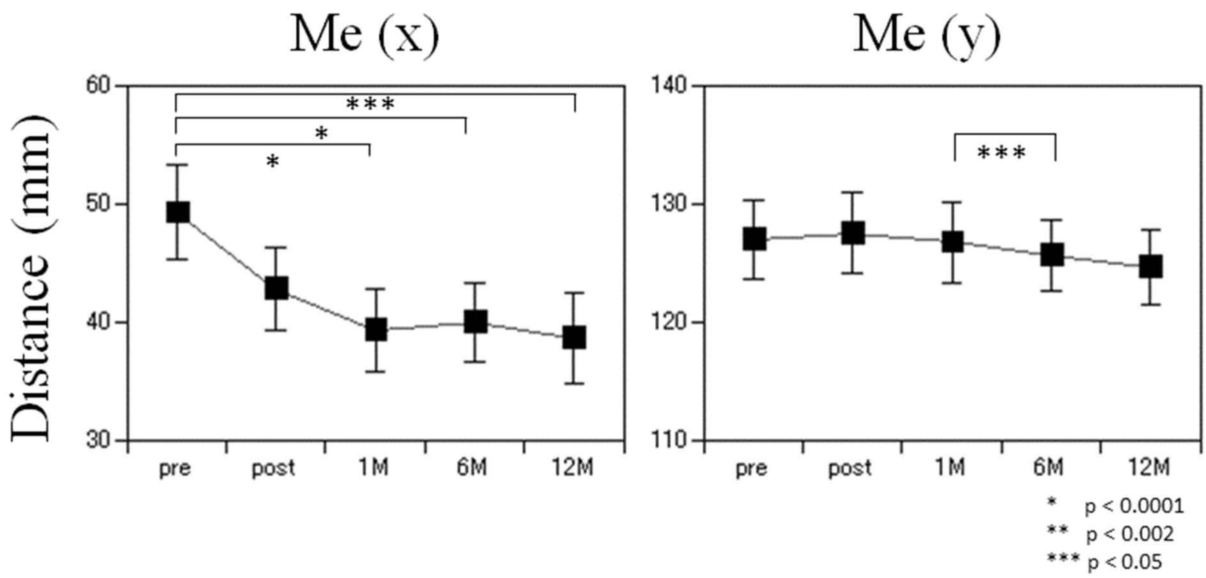
Figure 3.



	pre	post	1M	6M	12M
U1-FH (°) (S.E.)	111.27 (1.99)	112.41 (1.29)	109.44 (1.66)	110.16 (2.19)	110.73 (1.99)
L1-MP (°) (S.E.)	88.94 (1.88)	88.5 (1.56)	87.81 (1.77)	87.28 (1.65)	88.06 (1.26)
U1⊥PP (mm) (S.E.)	29.69 (0.57)	29.28 (0.74)	30.25 (0.56)	29.76 (0.54)	30.00 (0.69)
L1⊥MP (mm) (S.E.)	48.88 (0.97)	46.50 (1.03)	47.63 (1.01)	47.94 (0.99)	47.40 (1.14)

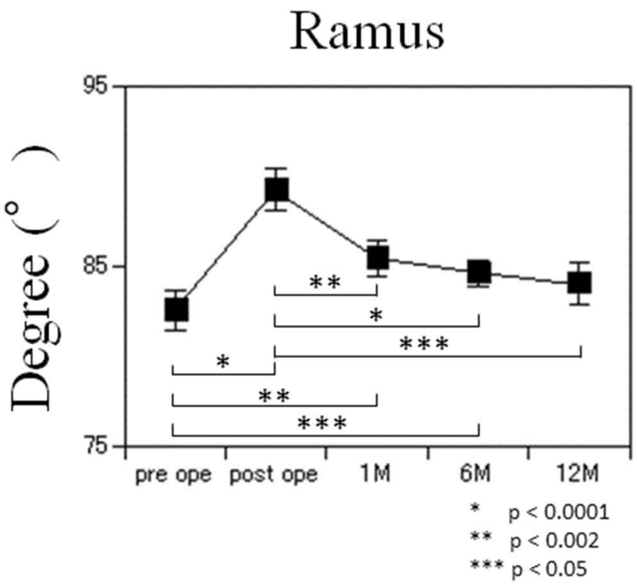
Figure 4.





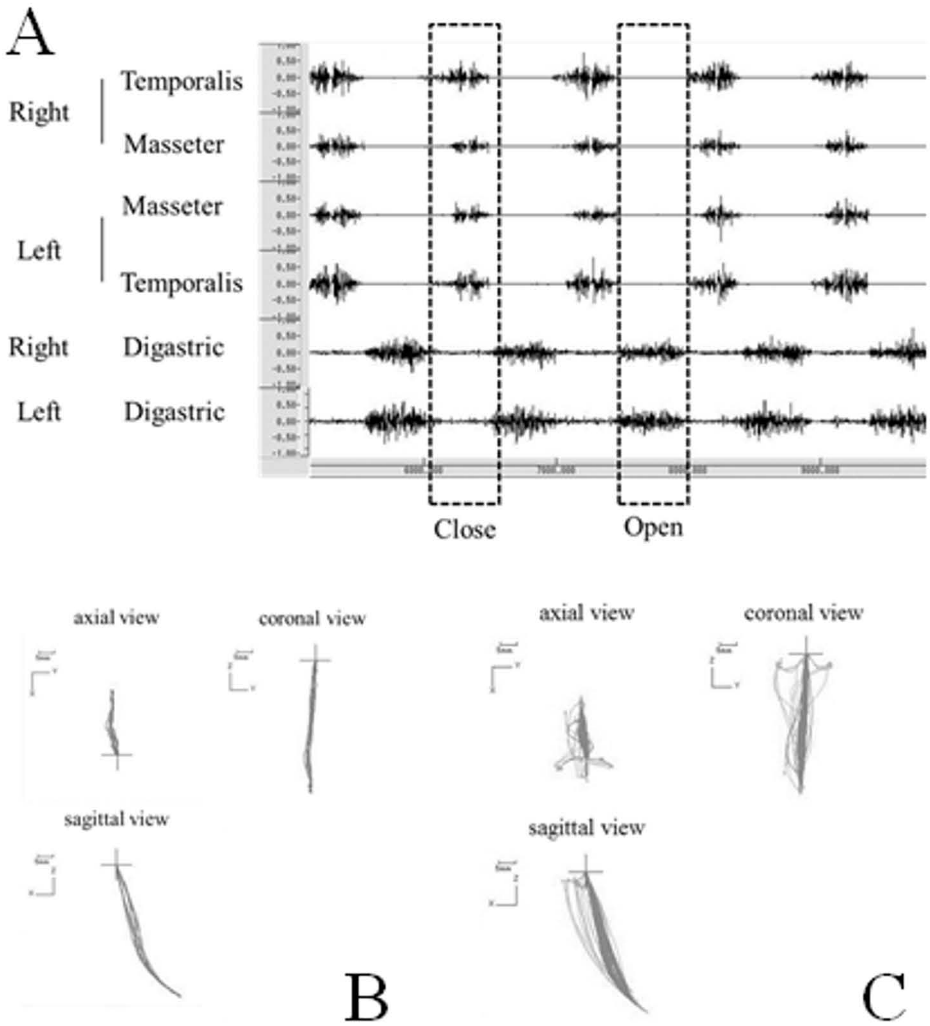
	pre	post	1M	6M	12M
SNB (°) (S.E.)	82.83 (1.25)	79.33 (1.00)	78.40 (0.96)	78.77 (1.03)	79.13 (1.05)
Me (x) (mm) (S.E.)	49.17 (4.00)	42.77 (3.46)	39.21 (3.47)	39.92 (3.31)	38.59 (3.81)
Me (y) (mm) (S.E.)	126.88 (3.30)	127.46 (3.39)	126.67 (3.37)	125.58 (3.07)	124.55 (3.14)

Figure 5.



	pre	post	1M	6M	12M
Ramus (°) (S.E.)	82.50 (1.09)	89.20 (1.14)	85.34 (1.01)	84.56 (0.74)	84.00 (1.14)

Figure 6.


A
Right
Temporalis
Masseter
Left
Masseter
Temporalis
Right
Digastric
Left
Digastric
Close
Open
axial view
coronal view
sagittal view
B
axial view
coronal view
sagittal view
C