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Abstract

Purpose. The purpose of this study was to evaluate bone formation between the proximal and distal segments after a sagittal split ramus osteotomy (SSRO) with bent plate fixation.

Subjects and Methods. The subjects were 23 patients (46 sides) who underwent bilateral SSRO setback surgery. They were divided into titanium and absorbable plate groups. A 3-7 mm gap was made between the proximal and distal segments and a bent plate was fixed with 4 screws in each side of the mandible. The square of ramus (RmS), the antero-posterior length (RmA-RmP), and the medio-lateral width (RmM-RmL) of the ramus at the horizontal plane under the mandibular foramen were assessed preoperatively, immediately after surgery, and 1 year postoperatively by computed tomography (CT).

Results. There were no significant differences between the titanium and absorbable plate groups over time. RmS after 1 year was larger than pre-operatively in both groups ($P<0.0001$). RmA-RmP significantly increased immediately after surgery and significantly decreased after 1 year in both groups ($P<0.0001$). RmA-RmP after 1 year was significantly larger than the preoperative value in both groups ($P<0.0001$). RmM-RmL showed a similar tendency to the antero-posterior length, but was not significant.

Conclusion. The gap between the proximal and distal segments can fill with new bone after SSRO with both titanium and absorbable plates, even with few bony contacts between segments.

Key words:

Sagittal split ramus osteotomy

Bent plate

Bone formation

Computed tomography

Introduction

The sagittal split ramus osteotomy (SSRO) is the most common surgical method[1] for the correction of jaw deformities. One of the advantages of this osteotomy is that osseus union is facilitated by the large area of bony contact remaining after either advancement or retrusion of the distal segment. Alterations in condylar position after surgery can lead to malocclusion associated with the risk of early relapse,[2,3] and also favor the development of temporomandibular disorders (TMD).[4-6] Unfortunately, positioning devices do not generally improve long-term outcomes in either mandibular advancement or setback surgery.[7]

We previously used bent plates to secure fragments without a positioning device[8] and found that the bent plate increased the incidence of postoperative TMD and did not change skeletal or occlusal stability. In this method, the gap between the proximal and distal segment is created by a bent plate, preventing formation of a large bony contact. In setback surgery, especially with asymmetry, fixation between segments can be performed without bony contact to prevent large changes in condylar position and angle.

SSRO osteotomy sites in animals use wires filled with callus, which forms bone, but callus is not usually formed in rigidly fixed osteotomy sites, defined as rigid fixation using stainless steel bone screws with large amounts of bony contact. However, no studies have examined rigid fixation without bony contact. Furthermore, there are few clinical reports on bone formation between segments after SSRO for jaw deformity patients with computed tomography. It is also unclear whether bone forms in the gap between the proximal and distal segments in setback surgery cases using a bent titanium plate and absorbable plates.

The purpose of this study was to evaluate bone healing and bore regeneration between the proximal and distal segment after SSRO with bent plate fixation.

Patients and Methods

Patients

The 23 Japanese adults (men: 3, women: 20) in this study presented with jaw deformities diagnosed as mandibular prognathism with and without maxillary deformity. At the time of orthognathic surgery, the patients ranged in age from 16 to 42 years, with a mean age of 25.1 years (standard deviation, 7.3 years). Informed consent was obtained from the patients and the study was approved by Kanazawa University Hospital.

Surgery

The study group comprised 23 patients (46 sides) who had mandibular prognathism (12; 24 sides, the titanium group; 11; 22 sides, the PLLA group). The groups were randomized to show similar distribution in preoperative SNB. Before surgery, lateral, frontal, and S-V cephalograms were obtained as described previously[8]. All patients underwent BSSO setback by the Obwegeser method. At the time of fixation, the dental arch of the distal segment was secured to the maxillary arch with an interpositional splint and 0.4-mm wire. In the titanium group, a long miniplate (4 holes burr 8mm thickness 1.0mm) and 4 screws (2×14 mm and 2×5 mm) (Universal Mandible fixation module, Stryker Leibinger Co., Freiburg, Germany) were placed in the mandibular angle region. In the PLLA group, a mini-plate (28×4.5×1.5 mm) and 4 screws (2×8 mm) (Fixorb®-MX, Takiron Co., Osaka, Japan) were placed in the same region and manner.

To prevent intraoperative condylar axial rotation, model surgery was performed preoperatively with reference to the S-V projection.[8]

Before surgery, a S-V cephalogram was obtained for all patients followed by simulation. First, a distal segment including the lower dental arch was set back and rotated according to the position of the upper dental arch on the submental-vertical cephalometric trace. A cross point between the contours of the preoperative and postoperative mandible was mostly found on the deviation side (Fig. 1).

When the proximal and distal segments are fixed with straight plates after BSSO, proximal segments containing the condylar head cause internal rotation, and the posterior aspect of the distal segment on the deviated side sometimes interferes with the proximal segment (Fig. 2). This suggests that setting the osteotomy line at the cross point can reduce the size of the gap between the proximal and distal segments on the deviation side.

On the non-deviation side however, the cross point does not exist on the geometrical model in most cases of mandibular prognathism with asymmetry. In other words, the gap mostly occurs between the proximal and distal segments on the non-deviation side, wherever the osteotomy line is set. Osteotomy lines and bending angle were determined. As a result of this simulation, it was found that the osteotomy line on the deviation side should be set at the posterior area of the mandibular body to prevent interference between the proximal segment and the distal segment in patients with mandibular asymmetry. It was assumed that the use of bent plates was the most efficient and simple method to prevent internal rotation of the proximal segments (Fig. 3)[8].

After approximately 1 week of inter-maxillary fixation, elastic was placed to maintain ideal occlusion. All patients received orthodontic treatment before and after surgery. CT was taken for all patients preoperatively, immediately after surgery and 1 year after surgery.

The patients were placed in the gantry with the tragacanthal line perpendicular to the ground for CT scanning. They were instructed to breathe normally and to avoid swallowing during the scanning process. CT scans were obtained in the radiology department by skilled radiology technicians using a high-speed, advantage-type CT generator (Light Speed Plus; GE Healthcare, Milwaukee, WI, USA) with each sequence taken 1.25 mm apart for 3D reconstruction (120 kV, average 150 mA, 0.7 sec/rotation, helical pitch 0.75). The resulting images were stored in the attached workstation computer (Advantage workstation version 4.2; GE Healthcare, Milwaukee, WI, USA) and the 3D reconstruction was performed using the volume rendering method. ExaVision LITE version 1.10 medical imaging software (Ziosoft, Inc, Tokyo, Japan) was used for 3D morphologic measurements.

Measurements of ramus using CT

The RL line was determined as the line between the most anterior points of the bilateral auricles. The horizontal plane under the mandibular foramen parallel to the FH plane was identified, and ramus area was measured pre- and postoperatively and bilaterally (Fig 4).

1, Square of ramus (RmS): the square showed total area of the proximal plus distal segments, when the image immediately after surgery was measured (Fig.5).

2, Antero-posterior length (RmA-RmP): the distance between the most anterior point (RmA) and most posterior point (RmP) of ramus (Fig. 6).

3, Medio-lateral width (RmM-RmL): the distance between the most medial point (RmM) and the cross point (RmL) between the lateral outline of ramus and the line through the most medial point parallel to the RL line (Fig. 6).

All CT images were measured by an author. Fifteen patients were selected randomly and CT images were measured again 10 days later. A paired t test was applied to the first and second measurements. The difference between the first and second CT measurements was insignificant ($p>.05$).

Statistical analysis

Data were statistically analyzed with StatView software, version 4.5 (ABACUS Concepts, Inc., Berkeley, CA, USA) and Dr. SPSSII (SPSS Japan Inc., Tokyo, Japan). Total time-course changes from pre-operation to 1 year after surgery were examined by analysis of variance (ANOVA). Comparisons between the titanium group and the absorbable group in each time period were performed and adjusted using Bonferroni correction. . The differences were considered significant at $p<0.05$.

Results

No patients had post-surgical wound infection or dehiscence, bone instability or non-union, or long-term malocclusion. The mean setback amount was 7.2 ± 3.8 mm on the right side and 7.8 ± 3.3 mm on the left side in the titanium group, and 6.6 ± 2.4 mm on the right side and 7.2 ± 2.8 mm on the left side in the absorbable group. These differences were not significant.

The gap between the proximal and distal segments could fill with new bone after SSRO with titanium or absorbable plates after 1year, although a concave outline at the anterior part of ramus was observed in some cases.

The time-course of changes were not significantly different in the two groups, but there were significant differences within subjects in RmS ($F=57.219$; $df=2$; $P<0.0001$), RmA-RmP ($F=168.162$; $df=2$; $P<0.0001$), and RmM-RmL ($F=47.379$; $df=2$; $P<0.0001$). The square of ramus after 1 year was larger than pre-operatively and immediately after surgery in both groups ($P<0.0001$). RmA-RmP significantly increased immediately after surgery, and significantly decreased after 1 year in both groups ($P<0.0001$). RmA-RmP after 1 year was significantly larger than preoperative values in both groups ($P<0.0001$). RmM-RmL showed a similar tendency to the antero-posterior length, but was not significant between pre-operation and 1 year (Table 1).

Discussion

Performing a fixation between segments in SSRO can cause postoperative TMD. In our previous studies, the horizontal condyle long axis increased significantly on the right side in the SSRO alone group.[9] However, the pre and postoperative angle of the condylar long axis was not different, and we found no medio-lateral or antero-posterior displacement. This result suggests that even without the condylar repositioning device, the condylar position and angle would not change significantly even without effort to maintain the preoperative condylar position. The condylar position data were widely dispersed, which may have prevented statistical significance. The most favorable postoperative condylar angle may not match the preoperative one, but would not be dramatically different except for cases with TMD or asymmetry. The dynamic stable position in TMJ is the most favorable based on our previous study.[8]

SSRO improved TMJ symptoms despite being unable to change preoperative disc position or correct anterior disc displacement.[9] In our previous study using CT, we also did not observe significant changes in condylar position or angle, but the gap between the proximal and distal segment created by the bent plate might reduce stress on the TMJ.[10]

It is unclear whether bone healing could complete without bony contact between the proximal and distal segments. For fracture surgery, Perren and other members of the ASIF/AO School[11,12] state that compression of the fragments is essential to primary bone healing. If bone healing was the only consideration, fixation with maximum bony contact would be best. However, modern plate and screw systems can prevent bony contact between segments but allow rigid fixation. Long-term stability and function require careful positioning of the proximal segment for optimal bone healing.

Classic bone healing is characterized by impaction, inflammation, soft callus formation leading to hard callus, and finally remodeling of woven bone to form mature lamellar bone.[13] The great majority of fractures are allowed to heal by secondary intention. The fractured fragments are aligned in a reasonable position and the jaws are immobilized by wiring the teeth together. This process, called secondary bone repair, is commonly seen when fractures are allowed to heal while fixed in a semi-rigid manner. The first four stages of healing can be entirely subverted if rigid internal fixation is used and the fragments are in firm contact.[14] This is called primary bone union and is characterized by remodeling only. It can occur only if the gap between fragments is less than 0.1 mm and there is no interfragmentary movement.

Gap healing is intermediate between primary and secondary bone healing.[15] In the mandible, gap healing is characterized by a plug of healing lamellar bone oriented at a right angle to the long axis of the jaw and derived from the endosteum. A periosteal reaction (external callus) is entirely absent if the bones are rigidly fixed and increases in proportion to the degree of the interfragmentary mobility. Gap healing occurs in cortical and cancellous bone when rigid fixation is used and a very small defect exists. Gap healing with endosteal bone proved consistently stronger than secondary bone healing with considerable quantities of periosteal bone. Although no differences could be detected histologically in the quality of the callus, the density of the new bone and the directional orientation of the collagen fibers provide a clue to the differences found in biometric strengths of the healing sites.[16] Cortex-to-cortex healing after mandibular osteotomy could be improved by decorticating the fragments, minimizing the area of bony apposition, and using rigid fixation.[17]

Here, the gap between proximal and distal segments could fill with new bone after SSRO with both titanium and absorbable plates, even if there were few bony contacts between segments. The gap between segments might be larger than in previous studies, and reflects bone regeneration more than bone healing because of the intentional 3-7 mm gap and the increased square of ramus. Guided bone regeneration is a surgical procedure that uses barrier membranes to direct growth of new bone at sites having insufficient volumes or dimensions for function or prosthesis placement.[18] If healing of the periosteal membrane at the incision area is complete, it can prevent invasion of mucosal endothelial cells into the gap between segments. 'The PASS Principle' published by Wang & Boyapati[19] is an acronym outlining the fundamental rationale and stages of successful regeneration, both for bone and other tissues, and is a guide to the physiological processes central in tissue regeneration. 1) PRIMARY CLOSURE of the wound to promote undisturbed and uninterrupted healing. 2) ANGIOGENESIS to provide the necessary blood supply and undifferentiated mesenchymal cells. 3) SPACE creation and maintenance to facilitate space for bone in-growth. 4) STABILITY of the wound to induce blood clot formation and allow uneventful healing. In SSRO, the ramus region fulfils these requirements for bone regeneration. Use of titanium or absorbable plates might promote the PASS principle. If the osteotomy line is adjusted, facial contour can also be adjusted without bone graft. If a membrane is used in the anterior site of the gap between segments, more exact bone regeneration can be obtained. In fact, a concave outline was observed in some cases in this study, although the square of ramus increased significantly.

In conclusion, this study showed that the gap between the proximal and distal segments could fill with new bone after SSRO with titanium or absorbable plates, even if there were few bony contacts between segments. Furthermore, bone volume and facial contour can be adjusted without bone grafts, preventing postoperative TMD.

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Legends

Fig 1. Model surgery using submental-vertical cephalograms. Osteotomy lines and bending angle were determined after the distal segment, including the lower dental arch, was set back and rotated according to the upper dental arch.

Fig 2. Use of straight plates. When the proximal and distal segments are fixed with straight plates after SSRO, proximal segments containing the condylar head cause internal rotation, and the posterior aspect of the distal segment on the deviated side sometimes interferes with the proximal segment.

Fig 3. Simulation of plate bending. The plates were bent to prevent the proximal segments from rotating internally. Note the gap between the osteotomy surfaces on both sides.

Fig 4. Horizontal CT image at the level under the mandibular foramen.

Fig 5. Measurement of the square of ramus (RmS) on a horizontal CT image. A) Pre-operation, RmS shows r1. B) Immediately after surgery, RmS shows r1 and r2. C) After 1year, RmS shows r1.

Fig 6. Measurements of antero-posterior length (RmA-RmL) and medio-lateral width (RmM-RmL) on a horizontal CT image. RmA-RmP shows m2. RmM-RmL shows m1. A) Pre-operation, B) Immediately after surgery, C) After 1year.

Table 1. Results of the titanium and absorbable groups. SD indicates standard deviation.

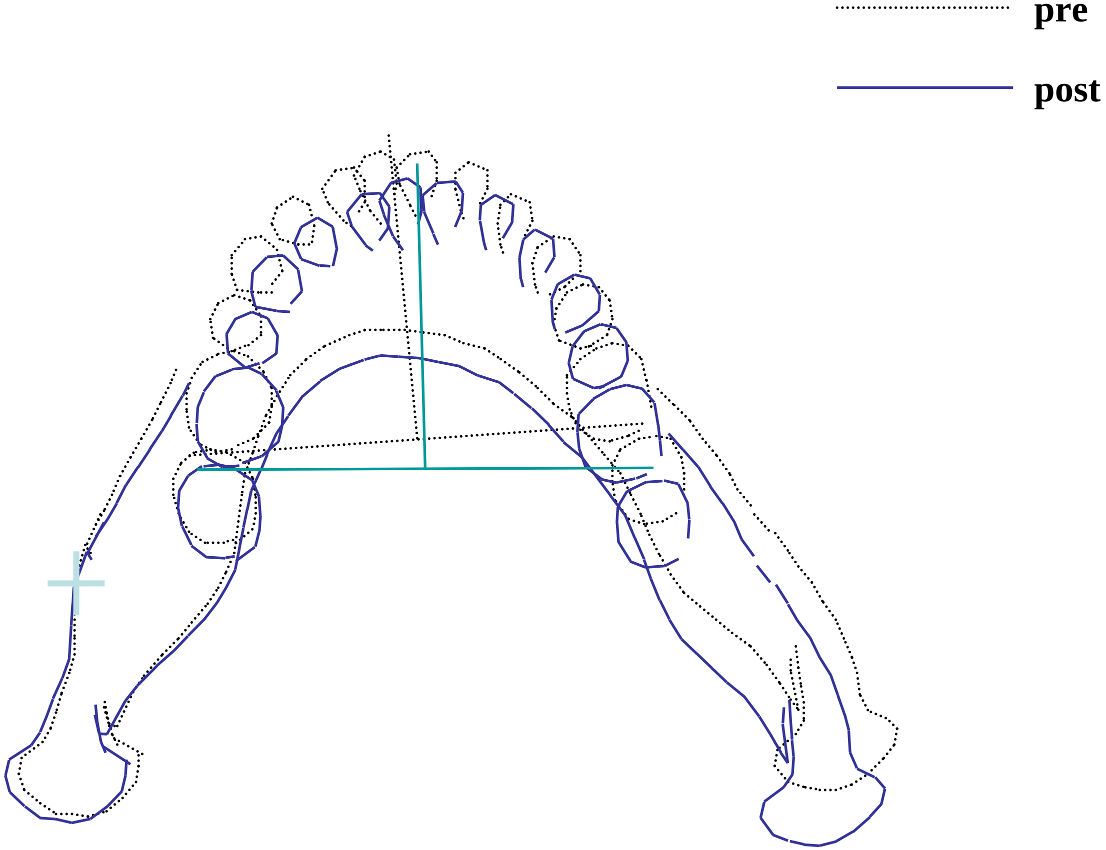


Fig. 1.

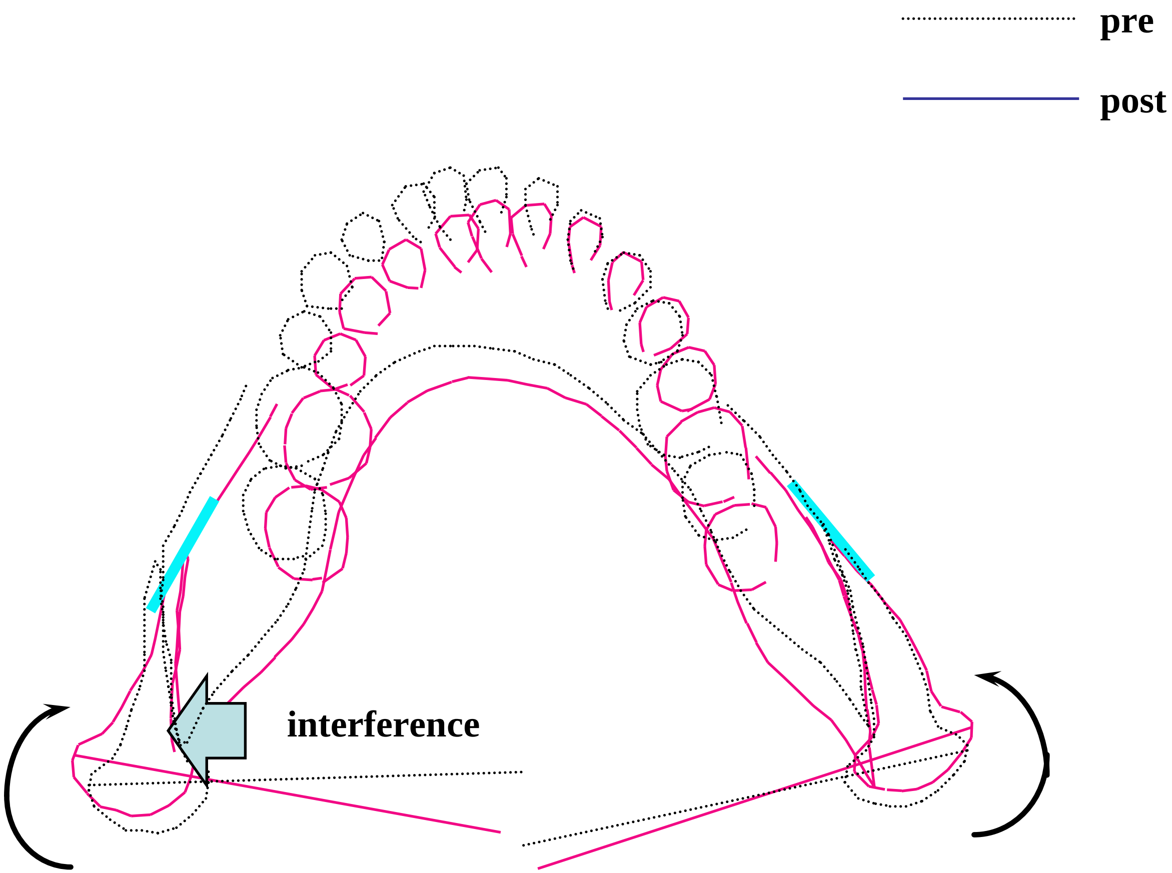


Fig.2.

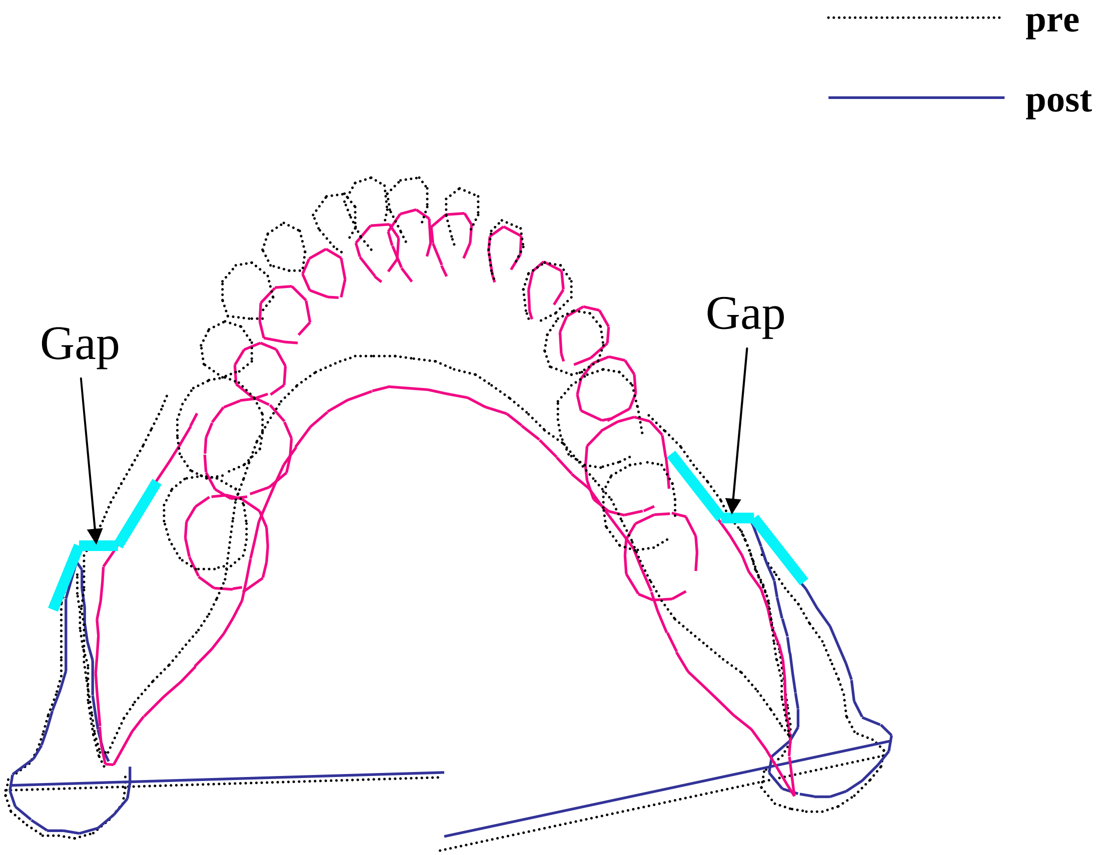


Fig. 3.

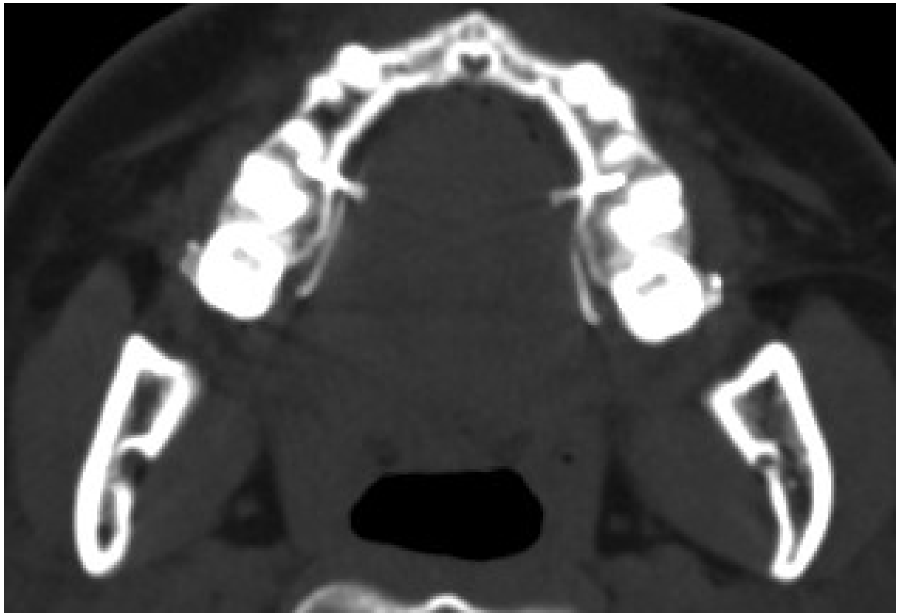
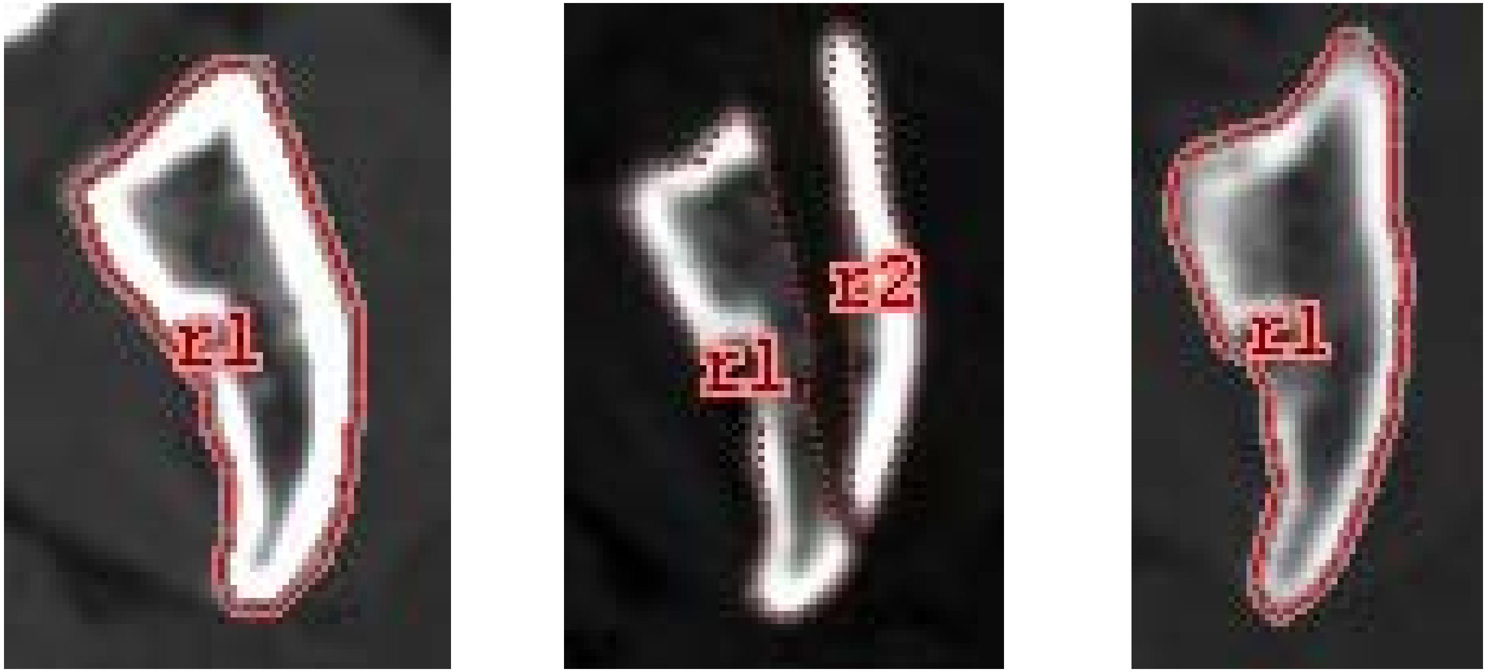


Fig. 4



A B C

Fig. 5

A B C

Fig. 6

	Pre-operation Mean	SD	Immidiarely after Mean	SD	After1 year Mean	SD
(Titanium group)						
RmS	2.3	0.5	2.6	0.5	2.8	0.6
RmA-RmP	12.0	1.8	15.8	2.1	14.5	1.9
RmM-RmL	33.2	3.1	37.0	4.7	33.0	4.2
(Absorbable group)						
RmS	2.0	0.3	2.2	0.3	2.4	0.4
RmA-RmP	11.7	2.2	15.7	2.7	14.2	2.1
RmM-RmL	31.1	2.9	35.0	4.6	31.5	4.8

Table 1.