Original Contribution

Kurume Medical Journal, 64, 57-63, 2017

The Usefulness of Piezoelectric Surgery in Sagittal Split Ramus Osteotomy

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Received 5 June 2017, accepted 11 October 2017
J-STAGE advance publication 16 March 2018

Edited by KENSUKE KIYOKAWA

Summary: Mandibular osteotomy carries with it a risk of damaging blood vessels and nerves when using traditional surgical techniques. Piezosurgery®, is a new technique that uses ultrasonic vibration to enable bone-selective sectioning without damage to the surrounding soft tissues. However, paralysis may not be completely eliminated using Piezosurgery® for osteotomy. We investigated how piezoelectric surgery in bilateral sagittal splitting ramus osteotomy (BSSRO) affected the surrounding soft tissue. Forty-four patients with skeletal mandibular prognathism underwent mandibular setback with BSSRO. Patients were divided into two groups, those treated by the conventional chisel technique and those treated by Piezosurgery®. Osteotomy time, blood loss, and incidence of paresthesia were compared retrospectively. Osteotomy time and blood loss in the piezo group were significantly reduced compared to the chisel group. Interestingly, whereas paresthesia incidence immediately after the operation did not differ between the groups, paresthesia in the piezo group 3 months postoperatively was significantly less than in the chisel group. However, a few cases of paralysis did not recover even in the piezo group. Blood loss and osteotomy time did not correlate with the paralysis. This study demonstrates that while piezoelectric surgery does impact the nerve tissue, the use of piezoelectric surgery in BSSRO leads to significantly less long term paralysis compared to surgery done by chisel.

Key words paresthesia, Piezosurgery, sagittal split ramus osteotomy, short lingual osteotomy

INTRODUCTION

Sagittal split ramus osteotomy (SSRO) is the most common surgical procedure in orthognathic surgery for the mandible [1, 2]. Possible complications during SSRO include unfavorable fractures, neurovascular bundle damage, and bleeding. Among these, neurosensory disturbance affecting the inferior alveolar nerve (IAN) is one of the most frequent complications. To address this, various modifications of SSRO have been proposed to make surgical execution easier, safer, and more predictable [3, 4]. Mandibular osteotomy can be performed via vertical osteotomy in the outer cortical bone on the inside of the mandible ramus, as described by Trauner and Obwegeser [2], or via modified osteotomy [1], which is carried out after drilling the compact bone between the incisura along the anterior border of the mandible ramus. Sagittal splitting is often performed to separate the posterior border of the mandible ramus along the inside of the outer cortical bone using a chisel. Finally, complete separation is carried out using a separator. Bleeding [4] and/or paralysis [3] may occur due to the physical tissue damage caused by the chisel or the conventional bur.

The piezoelectric device (Piezosurgery®), is a unique ultrasonic bone-cutting instrument that has bone selectivity, and is thus inert against soft tissue. Reports of its use are found in both the orthopedic and neurosurgery literature [5, 6, 7]. In oral and maxillofacial surgery, Piezosurgery® has been reported in implant and

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Abbreviations: SLO, short lingual osteotomy; SSRO, sagittal split ramus osteotomy fracture operations [8, 9-11]. Conventional tools such as saws and burs generate a significant amount of heat in the cutting zone, and overheating of adjacent tissue may delay the healing process [12]. Piezosurgery® can precisely cut hard tissue and generates minimal heat during cutting, thus preventing injury to adjacent tissue [13]. Vercellotti et al reported that postoperative bone healing using Piezosurgery® was better than that using the conventional bur [14]. This suggests that minimizing the mechanical stress on the surrounding bone may promote bone regeneration. Landes et al. reported that piezoelectric surgery could reduce both blood loss and the occurrence of paresthesia, due to reduced trauma on the neurovascular tissues [15]. In orthognathic surgery, the piezoelectric device may one day replace conventional tools including the saw and chisel; however, piezoelectric orthognathic surgery, particularly SSRO, is not yet established. No reports in any surgical field demonstrate that it is possible to completely avoid paralysis by using Piezosurgery®, and it may not be possible to completely avoid soft tissue trauma using a piezoelectric device. Furthermore, while the use of Piezosurgery® for osteotomy has increased, methods vary widely. We herein investigate whether or not piezosurgery is effective as a minimally invasive tool that can lead to a decreased incidence of paresthesia after SSRO in comparison to conventional surgery.

METHODS

Study Design and Patients

This study was approved by the institutional ethics committee of Kurume University School of Medicine. From January 2001 to December 2014, 44 patients with skeletal mandibular prognathism were surgically treated by bilateral sagittal split ramus osteotomy (BSSRO) alone. Cases that included genioplasty or osteotomy that were not SSRO were excluded from the study. Twenty-two patients (44 sides) underwent conventional osteotomy using the chisel for splitting the mandibular ramus (chisel group) and the remaining 22 patients (44 sides) were treated using piezosurgery (piezo group).

Total blood loss was recorded during surgery. Measured parameters included osteotomy time, incidence of postoperative IAN paralysis and other complications, and were examined on each operative side. Osteotomy time was measured from the start of the mucosal incision to the completion of separation of bone fragments.

Sensory disturbance of the lower lip and mental region on each side was evaluated subjectively immediately after the operation and 3 months postoperatively. The patients were classified as “with paralysis” or “without paralysis”. Attenuation or loss of sensation was classified as paralysis.

Total blood loss, osteotomy time, and incidence of paralysis were compared as retrospective data.

Operative technique of SSRO

After initial orthodontic therapy, all cases of SSRO were performed according to the short lingual technique proposed by Hunsuck [16]. All operations were performed by the same surgeon.

A mucosal incision on the external oblique line extending to the first molar region was made. After dividing the buccinators muscle, the anterior border of the ascending ramus was reflected superiorly, and the temporalis muscle attached to the coronoid process was stripped off using a notched ramus retractor and electrocautery. The medial aspect of the ramus was reflected posteriorly and the retractor was installed. The lateral aspect of the mandibular angle was reflected subperiosteally to the inferior border of the mandibular angle. When the bone thickness of the inner aspect of the anterior border of the ascending ramus was wide, the bone was shaved with a round bur. Then a horizontal bone groove from the medial cortex of the ramus to just posterior to the mandibular foramen was made with a Lindemann bur (2.3 × 22 mm). A groove was cut in the lateral cortical bone from the lateral-most aspect of the anterior border of the ascending ramus at the region of the second molar to the inferior border of the mandible angle with a Lindemann bur (2.3 × 22 mm). Following completion of the cortical bone cut, both cortical osteotomy lines were connected with a fissure bur along the anterior border of the ascending ramus. All of the bur cutting was performed under water injection.

In the chisel group, the outer cortical and the inner cancellous bone were separated carefully with the chisel. The chisel was used to force a fracture line along the lateral cortex in order to achieve a correct osteotomy, and the invasion depth of the chisel was adjusted so as not to reach the mandibular canal. We then pried open the osteotomy gap by chisel rotation or bone separator forceps resulting in a complete sagittal separation of the ramus.

In the piezo group, the Mectron Piezosurgery® device (Mectron Medical Technology, Carasco, Italy) was used. Piezosurgery® was used in the bone mode with the OT7 tip (Piezo-surgery, Mectron, Italy) (Fig. 1). The ultrasonic scalpel tip was inserted along the

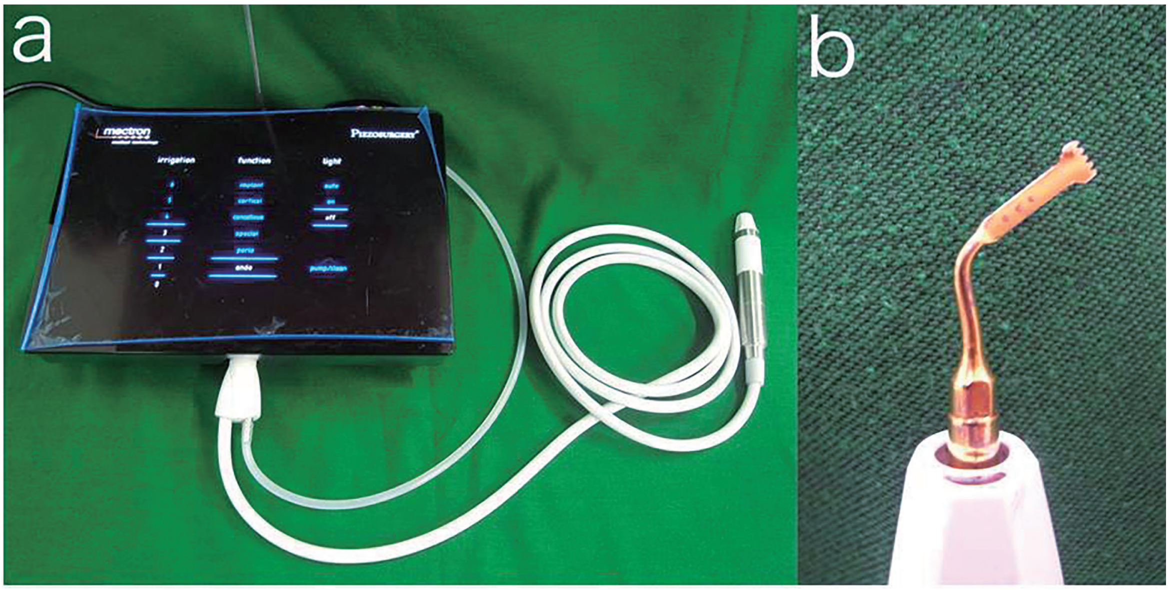

Fig. 1. The Mectron Piezosurgery® device and the OT7 piezoelectric microsaw.
a) Piezosurgery® was performed using the bone mode. b) The tip used was OT7.

inner surface of the lateral cortex to cut the cancellous bone under water injection. After bone cutting by piezosurgery, the ramus was completely split using a bone separator. In both groups, there was no exposure of IAN in the distal segment after splitting, and no case of accidental resection of IAN.

After completion of the osteotomy, the occlusion was moved and fixed at a prearranged position. Excess bone on the proximal segment was removed, if necessary. The proximal and the distal bone segments were fixed with a mini-plate and screws placed transorally on each side. The wound was closed primarily in layers following installment of a continuous drainage catheter.

Intermaxillary fixation was performed after 7 days. All cases were administered intravenous antibiotics preoperatively and postoperatively for 3 days, with oral antibiotics thereafter if necessary. Suppositories were administrated for analgesia until oral intake was resumed. Patients who complained of symptoms of peripheral nerve paralysis were administrated vitamin B12 supplementation upon the start of symptoms.

Statistical analysis

Statistical analysis was carried out by Student's *t*-test and Pearson's chi-square test. A-value of P less 0.05 was considered statistically significant. Results were presented as mean ± standard error unless otherwise specified. Correlation of items with significant difference was examined.

RESULTS

Patient Groups

Table 1 summarizes the chisel and piezo groups undergoing BSSRO. The chisel group included 22 patients (5 males, 17 females) who had a mean age of 27.9 ± 9.6 years, ranging from 17 to 54 years. The piezo group included 22 patients (8 males, 14 females) who had a mean age of 28.4 ± 9.5 years, ranging from 18 to 46 years. Mean amount of mandibular setback per side was 5.9 ± 2.4 mm, ranging from 0 to 10 mm, in the chisel group, and 5.0 ± 2.7 mm, ranging from 0 to 10 mm, in the piezo group. There was no significant difference between the groups in regards to either age or amount of setback (Table. 1).

Osteotomy time and blood loss

Osteotomy time, total operation time, and blood loss all differed significantly between the groups. While the mean time for osteotomy was 24.7 ± 6.8 minutes in the chisel group, it was 16.1 ± 4.7 minutes in the piezo group. The mean total blood loss was 127.7 ± 99.2 g in the chisel group and 41.6 ± 44.4 g in the piezo group ($p < 0.01$, $p = 0.0006$) (Table. 1).

Paralysis and complications

Paresthesia of IAN was evaluated immediately after the operation, and again at 3 months after the operation. The paresthesia incidence immediately postoperative was 38.6% (17/44) in the chisel group and

TABLE 1.
Comparison between Piezosurgery and conventional method in BSSRO.

	Chisel group	Piezosurgery group	*P*-value
Number of patients	22	22	NS
Site	44	44	
Age (years)	27.9 ± 9.6	28.4 ± 9.5	NS
Range	17 – 54	18 – 46	
Gender			NS
Male/female	5/17	8/14	
Amounts of mandibular movement by site (mm)	5.9 ± 2.4	5.0 ± 2.7	NS
Range	0 – 10	0 – 10	
Time for osteotomy by site (min)	24.7 ± 6.8	16.1 ± 4.7	<0.0001
Range	12.6 – 39.0	9.6 – 27.0	
Total blood loss (g)	127.7 ± 99.2	41.6 ± 44.4	0.0006
Range	20.0 – 320.0	0.0 – 150.0	

36.4% (16/44) in the piezo group. There was no significant difference between the groups. On the other hand, the paresthesia incidence three months after surgery was 22.7% (10/44) in the chisel group and 6.8% (3/44) in the piezosurgery group. The improvement incidence after three months in the chisel group was 41.2%, while that in the piezo group was 81.3%. This was statistically significant ($p < 0.05$, $p = 0.0314$) (Fig. 2).

There were significant differences in only three items: paralysis improvement rate, osteotomy time, and blood loss. However, the intraoperative blood loss and the operation time in patients with paralysis at 3 months after the operation were various. There were no correlations between blood loss and osteotomy time in the 13 patients from both groups who experienced unresolved paresthesia (Fig. 3).

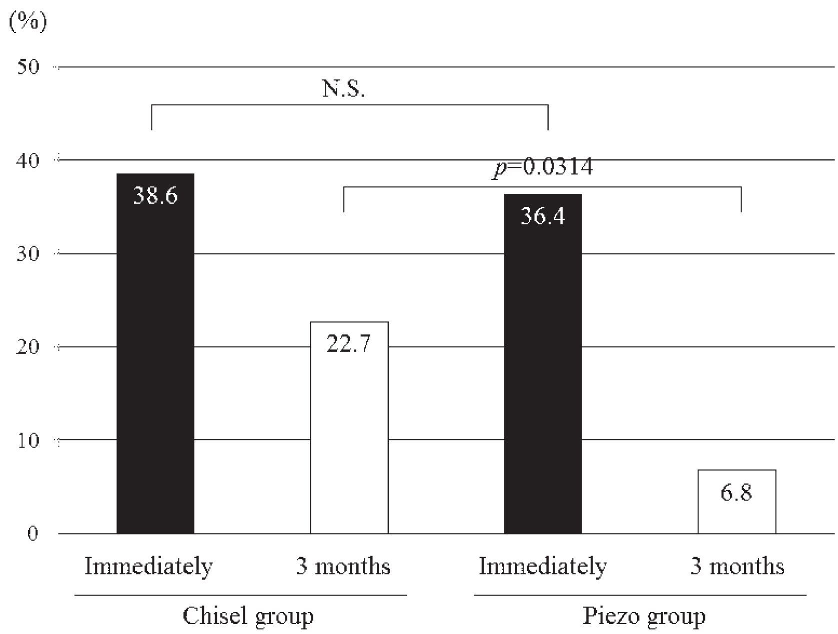

Fig. 2. Improvement of paresthesia after osteotomy using Piezosurgery®. The paresthesia incidence after 3 months was 22.7% in the chisel group and 6.8% in the piezo group. This difference was statistically significant.

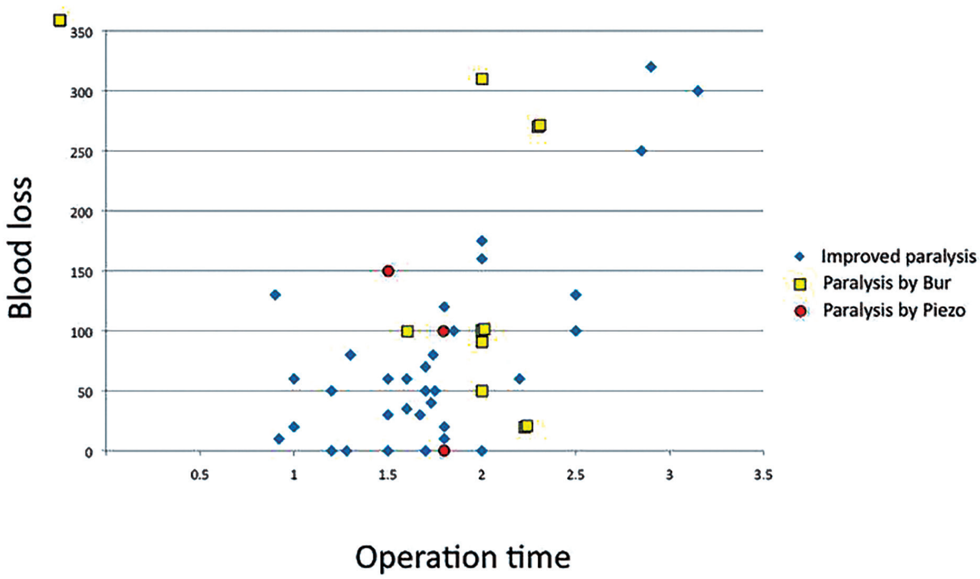

Fig. 3. Correlation of paralysis, blood loss and osteotomy time.
No correlation between the intraoperative blood loss and osteotomy time in patients with paralysis at 3 months after the piezo operation existed. And the blood loss in patients with paralysis at 3 months after the piezo and chisel operation was various. There were no correlations between blood loss and osteotomy time in all SSRO patients.

One surgery related complication (an undesirable fracture in the chisel group) occurred in one of the 44 patients; however, this had no influence on the postoperative course. No patients in the piezo group had an undesirable fracture.

DISCUSSION

The conventional splitting technique of the mandibular ramus involves separating the cortical and cancellous bone slowly using a chisel. To avoid injury to IAN and vessels, the chisel is kept in contact with the lateral cortex at a height below the mandibular canal. In piezoelectric osteotomy, the piezoelectric bone saw is used in the same manner as a chisel. The only difference in the SSRO operation is the use of the piezoelectric device instead of the chisel to separate the cortical and cancellous bone. We found that piezoelectric osteotomy had several advantages compared to conventional chisel osteotomy.

The microvibrations created by the piezoelectric device permit the selective cutting of bone without damaging the soft tissues, and ensure precise cutting in a bloodless fashion by the cavitation effect. In this study, piezosurgery reduced osteotomy time by 30% on each side. The reduction of osteotomy time may be due not only to improvement of surgical skills acquired with a learning curve, but also to the less invasive nature of piezoelectric surgery as regards IAN and vessels. Bleeding during the piezoelectric osteotomy decreased by approximately one third compared to conventional osteotomy, attributable to less damage to the blood vessels. Additionally, swelling in the piezo group was less than that in the chisel group (data not shown).

Piezosurgery has a similar advantage for protection of the nerves. In this study, there was no significant difference between the groups in the incidence of sensory paralysis immediately after the operation. The incidence of paralysis per side was approximately 40% in both groups. However, more than 80% of the cases in the piezo group completely recovered within 3 months, whereas only 41.2% recovered in the conventional osteotomy group. The piezoelectric osteotomy group thus showed a significantly better recovery from nerve damage than the conventional chisel osteotomy group ($p < 0.05$, $p = 0.0314$) (Fig. 2). Geha et al reported an 80% complete neurosensory recuperation 2 months after BSSRO [17]. Brockmeyer et al also showed less somatosensory impairment and faster recovery of somatosensory function using piezosurgery [18].

Seddon's classification is the most well known classification of nerve injury [19]. With damage to only the axial nerve fibers (neuropraxia or axonotmesis), recovery should be expected, albeit slowly. Nerve damage after piezoelectric osteotomy is not as severe as after conventional surgery, and can be classified as neurotmesis.

Piezosurgery is known to be less traumatic to the surrounding soft tissues. It is unclear, however, if the paresthesia noted in this study was due to direct damage to the nerve by the piezoelectric device or to other causes, such as nerve compression by bone segments at the osteotomy site, or retraction of the medial soft tissue around the mandibular foramen. Panula et al suggested that the early intraoperative neurosensory function deficits might be caused by dissection trauma to the IAN around the mandibular foramen [20]. More than 90% of the sides operated on using piezosurgery had no paresthesia 3 months after osteotomy. There was no significant difference in the amount of mandibular setback between the groups. Because the paresthesia that occurred in the piezo group significantly improved after 3 months, whereas there was no significant difference in the incidence of the paralysis immediately after surgery in both groups, we consider that the physical damage to the nerves by piezosurgery is minimal and reversible. There were some cases in which remission of paralysis did not occur even in the piezo group in this study, and there were cases in both groups where paralysis was not cured despite the fact that blood loss was small. In this study, no correlation was observed between paralysis, blood loss and osteotomy time. The most common intraoperative problem during osteotomy is massive bleeding, and such bleeding can be life threatening. The most common postoperative problem is paresthesia, which can negatively affect the patient's quality of life. For surgeons, minimizing complications after minimally invasive operations is of utmost importance. Although the degree of physical damage that piezosurgery exerts on soft tissues is certainly small, when it is used in a region where hard tissue, blood vessels and nerves exist in a complicated arrangement, as is the case with SSRO, a low level of soft tissue invasion must be expected. However, piezosurgery minimizes its risk. We hope that this study will be useful in improving operative treatment in the oral region.

In conclusion, our study demonstrates that surgery using a piezoelectric device for sagittal split ramus osteotomy is minimally invasive, and is associated with significantly shorter operating times, significantly less blood loss, and significantly less long term paralysis of the IAN compared to surgery using a chisel.

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