Piezoelectric osteoarthrectomy for management of ankylosis of the temporomandibular joint

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Abstract

We describe the use of a piezoelectric osteotome for removal of bone in patients with ankylosis of the temporomandibular joint (TMJ) and its advantages over conventional techniques. We studied 35 patients with ankylosis of 62 TMJ (27 bilateral and 8 unilateral, 2 recurrent) who were treated by gap arthroplasty between 1 January 2011 and 31 December 2012. We used a preauricular, with extended temporal, incision in all cases. The ankylosis was released with a piezoelectric scalpel. There were 23 men and 12 women, mean (SD) age 16 (9) years. We noticed a substantial reduction in bleeding with the piezoelectric bone cutter compared with the dental drill, though the operating time was longer. We noticed no bleeding from the maxillary artery or pterygoid plexus. Mean (SD) bleeding/ie was 43 (5) ml, and mean (SD) operating time was 77 (8) minutes for a single joint. At 6 months’ follow-up mean (SD) passive mouth opening was 35 (3) mm. Piezoelectric bone removal for the release of ankylosis of the TMJ is associated with minimal bleeding, few postoperative complications, and satisfactory mouth opening at 6 months’ follow up.

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Introduction

The development and success of piezoelectric bone cutting has revolutionised maxillofacial surgery. It uses ultrasonic vibrations and so has selective affinity for hard tissue, and as it causes no heat it avoids any damage to the soft tissue.\textsuperscript{1} Since its invention it has become one of the widely-practiced methods for creating osteotomies for distraction osteogenesis,\textsuperscript{2} implant dentistry,\textsuperscript{3} sinus grafting,\textsuperscript{3} and orthognathic surgery.\textsuperscript{4} Though there is a published consensus about the use of piezosurgery in these operations, little has been written about its use in the treatment of ankylosis of the temporomandibular joint (TMJ).

Ankylosis of the TMJ is disabling, and causes problems in mastication, digestion, speech, appearance, and hygiene. Among the various treatments described for it, gap arthroplasty is well-established. The operation consists of aggressive osteoarthrectomy of the ankylotic mass to create a gap of 1.5 cm, followed by aggressive physiotherapy.\textsuperscript{5} Creating such a gap is also the most important first step for
other interpositional treatments. Conventional methods for the release of ankylosis are associated with complications such as bleeding, damage to the facial nerve, and recurrence. Reankylosis is a problem for both the patient and the surgeon, and early healing of the cut ends of bone and aggressive physiotherapy are critical in its prevention.

In this paper we report the use of piezoelectric removal of bone in ankylosis of the TMJ, discuss its advantages over conventional techniques, and report initial results at 6 months’ follow-up. We intend to follow this group for 5 years to record any recurrence caused by regrowth.

**Patients and methods**

The institutional review board approved the protocol for a prospective observational descriptive study in patients with ankylosis of the TMJ (Figs. 1 and 2) who were operated on using the piezoelectric scalpel in our unit between January 2011 and 31 December 2012. Patients treated by gap arthroplasty were included, but those treated by interposition of a costochondral graft or temporalis fascia, or lateral arthroplasty, were excluded. Informed written consent was obtained from all patients. Osteoarthrectomy was done using the piezoelectric scalpel (Fig. 3) to create a gap of at least 1.5 cm (Fig. 4). Mouth opening was evaluated on the table after release of the ankylosis, and at 1 week, 12 weeks, and 6 months (Fig. 5). Mouth opening of less than 25 mm was classified as reankylosis. Intraoperative bleeding, duration of operation, and incidence of infection were also recorded. Bleeding was measured from suction and loss into the sponge. The amount of postoperative drainage from the suction drain at the surgical site was not included. All patients had the same hospital regimen of physiotherapy during the study period. Postoperative computed tomography (CT) was not done to avoid undue exposure, and information from plain radiographs was sufficient to see the adequacy of gap.

**Fig. 1.** Preoperative photograph showing no mouth opening.

**Fig. 2.** Coronal computed tomographic scan of the same patient as in Fig. 1 showing bilateral ankylosis of the temporomandibular joint.

**Fig. 3.** Piezoelectric removal of bone for ankylosis of the temporomandibular joint.

**Fig. 4.** Panoramic radiograph (Panorex™) after bilateral gap arthroplasty.
Surgical technique

A standard preauricular, extended temporal, incision was used in all cases. After exposure of the ankyloitic mass, a gap of 1.5 cm was created by cutting the bone perpendicular to the cortical surface from the lateral to the medial side. It is possible to measure the mediolateral thickness of ankylosis on the CT scan (Fig. 2) and use the gradation marks on the piezoscapel to measure the working depth. Special attention was given to the medial side to avoid any tapering of the cut. The inferior cut was made at the narrowest part of the mandibular ramus, which corresponded to the condylar neck. This decreased the cross-sectional area that was cut and reduced the likelihood of recurrence. A minimum of 35 mm mouth opening was achieved in each case. In cases with massive ankylosis we used an incremental technique for removal of the bone. After the ostearthrectomy had been finished there was an adequate gap between the ramus and the glenoid fossa. Bony spicules that projected at the cut ends were smoothed and haemostasis achieved. The wound was irrigated with saline, a suction drain placed to prevent formation of a haematoma, and the incision closed in layers.

Results

A total of 35 patients (27 bilateral and 8 unilateral joints that comprised 62 sides) were studied. Of these, two were recurrent. There were 23 male and 12 female patients, whose ages ranged from 5 to 28 years (mean (SD) 14 (6) years). There was no bleeding from the maxillary artery or the pterygoid plexus. Mean (SD) blood loss was 43 (5) ml/side. We had no data about the blood loss from the dental drill or saw osteotomy to compare with this group, but thought that there was a substantial reduction with the use of the piezoscapel.

The mean (SD) operating time for a single joint was 77 (8) minutes and there was no evidence of infection in any of the cases operated on. At the 6 months’ follow-up the mean (SD) passive mouth opening was 35 (3) mm.

Discussion

Operations for ankylosis of the TMJ are known to be complicated by recurrence. Over a period of 100 years various treatments have been proposed including gap arthroplasty, interposition arthroplasty, reconstruction of the ramal condylar unit with a costochondral graft, and total reconstruction of the joint. In addition to recurrence, any intervention used to treat ankylosis is complicated by the presence of the facial nerve, the maxillary artery, the pterygoid plexus, and the deranged anatomy of the joint itself. It is therefore crucial to select a technique that allows completion of the osteotomy safely with minimal risk to the surrounding structures. Traditional methods of cutting bone using a chisel-mallet and bur necessitate greater exposure of the ankyloitic mass so that a guard can be placed underneath the medial surface to protect the soft tissues and the vessels. This requires considerable retraction or myotomy, or both, of the masseter muscle, which result in increased inflammation, increased postoperative pain, and swelling around the joint. This is critical in operations on the TMJ when immediate postoperative mobilisation is essential.

Traditional rotary cutting instruments work on macrorotation and macrovibration principle, which generates sufficient heat to cause severe damage to the bone as a result of marginal osteonecrosis. Other drawbacks of traditional procedures include an irregular, rough osteotomy, increased bleeding, increased vibration of the handpiece, limitation of dexterity of the surgeon, and, rarely, a trigeminocardiac reflex as a result of stimulation of the mandibular branch of the trigeminal nerve.

Piezosurgery is a relatively new technique that uses ultrasonic vibrations to make clean and safe osteotomies, and it overcomes several drawbacks of conventional methods. In our series of piezosurgery we obtained maximal cutting precision with minimal damage to the soft tissues and adja-cent vital structures. The main advantage of piezosurgery is its selectivity for hard tissues, as it works only on mineralised structures. Damage to soft tissues, blood vessels, and nerves is therefore minimised. There is little bleeding from the osteotomy site because of the cavitation effect of the ultrasonic vibration. The linear vibrations of the piezoelectric scalpel are practically imperceptible to the surgeon and do not affect dexterity when working in an anatomically delicate area. When bone is being cut, microcuts allow the bone to be burnished off and left smooth with uniform cut ends. The safety of the osteotomy is further facilitated by the presence of the gradation marks on the piezoelectric scalpel.

Fig. 5. Postoperative photograph showing adequate mouth opening.
which give an estimate of the working depth. The system is also equipped with an irrigation system that uses normal saline and undergoes ultrasonic vibrations. Cavitations energy generated as a result of these vibrations removes all cut debris and ensures a clean surgical field. Recently Olate et al described a piezosurgical technique for condylectomy, and discussed its advantages.

It is of particular interest that, unlike other rotating conventional tools, this one minimises the undesirable seeding of cortical bone chips into the surrounding area. This effect can be attributed to its linear microvibration pattern and the cavitational energy that flushes out all the microparticles and cut debris. These bone chips contain large amounts of bone morphogenetic proteins (BMP), and have the potential to increase the local concentration of calcium ions. It is well-known that osteotomy sites should be copiously irrigated with saline to wash out all BMP that could possibly stimulate mesenchymal differentiation and subsequent heterotopic bony formation.

Heterotopic ossification can occur in the temporomandibular joint and surrounding tissues in 50% of patients after operations or trauma, and is the main cause of recurrence after operations for ankylosis of the TMJ. Factors such as prostaglandin E2, hypoxia, abnormal nerve activity, activation of mast cells, and immobilisation, are responsible for heterotopic bony formation. One study of an experimental piezosurgical osteotomy showed viable osteocytes with normal morphology and differentiation at the marginal osteotomy site. This viability of the cut ends and minimal trauma to the adjacent structures with less inflammation results in early formation of cortical bone at the osteotomy site, which leads to rapid and uneventful healing. Less inflammation also causes less pain and swelling and increases patients' compliance with physiotherapy.

Gulnahar et al compared the expression of heat shock protein 70 (a molecular marker of trauma, stress, and inflammation) during piezosurgery and conventional surgery and found that in both mRNA and protein it was twice as high in the conventional group than in the piezosurgery group. The damaged tissues and necrotic cut ends of the osteotomy site together with the postoperative inflammatory oedema substantially reduce local perfusion and lead to hypoxia, which is one of the most important independent risk factors for heterotopic bone formation and is attributed to trauma, formation of haematomas, and postoperative inflammation. Hypoxia decreases the function of osteoblasts and induces a reversible state of quiescence in their metabolism. It also increases the activity of osteoclasts that in turn resorb bone. Massive amounts of BMP and insulin like growth factor 1 (IGF-1) are released during bone resorption, which bind to the local and the circulating stem cells and induce their differentiation into osteoblasts, which are later stimulated to secrete osteoid. The stem cells that develop into osteoblasts after trauma may originate from the bone marrow or muscle. Osteotomy in patients with ankylosis may allow the chips of bone marrow that are capable of forming bone to spread into well-vascularised muscle tissues. This, combined with growth factors released from damaged tissues and BMP, may lead to heterotopic ossification. Abnormal homeostasis of BMP signalling, and activation of macrophages in response to injury to tissue, may also stimulate bony differentiation.

Studies have shown that bony ankylosis expresses more BMP-2 and BMP-4. By reducing surgical trauma and inflammation, piezosurgery may reduce hypoxia at the local site and reduce those factors that ultimately lead to excessive formation of bone.

Recurrence of ankylosis is thought to be the result of heterotopic bony formation. This is the rationale behind the use of low dose radiation and indomethacin to prevent it. Non-steroidal anti-inflammatory drugs and radiotherapy may also work, by suppressing the migration and proliferation of inducible mesenchymal cells. It is difficult to explain recurrence, however, after a meticulous operation that has created a gap of 1.5 cm, inserted vacuum suction to evacuate any haematoma, and followed them up with aggressive postoperative physiotherapy. We think that the synergistic effect of BMP and other contributing factors such as hypoxia mediated by postoperative inflammation have a considerable role in recurrence. In bilateral operations on the TMJ, the activity of the pterygomasseteric sling reduces the potential space between the roof of the fossa and the ramal stump. This reduced space, together with other factors such as irregular and bleeding cut ends; cortical bone particles seeded in soft tissues; postoperative inflammation; reduced pH; local hypoxia; and relative immobilisation of the joint by pain, may all contribute to recurrent bony formation. Except for the reduced space between the ramal stump and the base of the skull, the effect of all the other factors can be reduced if not eliminated by the use of piezosurgery.

In about 400 cases operated on in our unit during the last 20 years, the senior author (ARC) has on a few occasions encountered the inferior alveolar artery within the bone while creating the 1.5 cm gap. We have not encountered any instance of the maxillary artery traversing the ankylosis, as recently reported by Susarla et al who used preoperative angiography and selective embolisation in 5 patients with ankylosis. We think that embolisation may not be necessary despite the proximity of the vessels. Preoperative evaluation with CT, adequate access, sound surgical technique, and now the use of the piezoscalpel, ensures the safety of the nearby vessels.

Increased operating time, a learning curve, and the cost of the equipment are 3 of the drawbacks of piezosurgery. Flexural fatigue and breakage of the scalpel can happen if it is in contact with other metallic retractors as a result of interference with ultrasonic vibrations. However, these flaws are minor compared with the safety and assurance it provides during operation, and the benefits it offers because of the minimal surgical trauma.

Although the present descriptive study has results that support the new technique as well as giving sound theoretical physiological support, it has the limitations inherent in any observational study. Operative blood loss and duration of
operation could not be compared with those of the conventional technique. Future trials or cohort studies with larger samples would give us a clearer picture of the comparison. We have presented the initial results of piezosurgery with 6 months’ follow up. We will, however, monitor them for 5 years to comment on the recurrence rate.

References