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Research Article

PIEZOSURGERY: AN INDESPENSABLE TOOL TO THE SURGICAL FIELD

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ABSTRACT

Piezosurgery is an excellent way of performing effective osteotomies, sparing the adjacent soft tissues as well as protecting the adjacent nerves and blood vessels. Improved wound healing and better bone formation have also been reportedusing piezosurgery through several experimental studies. This revolutionary tool preserves osteocyte cells, which in turn complement the whole bone healing process. The most wonderful features of piezosurgery is its soft tissue sparing capability, controlled blood loss and better patient comfort, which helped to make this technique an exceptional one in the surgical branches of medicine and dentistry.

INTRODUCTION

'Piezoelectric Bone Surgery' or simply 'Piezo surgery' is the method of utilizing piezoelectric vibrations for cutting the bony structures. The Piezoelectric effect was first described by Jacques and Pierre Curie in 1880s and involves the appearance of an electric charge across certain crystals when they are under mechanical pressure.[1] Inversely, when an electric current is applied across them, they deform. This phenomenon of deformation when under alternating current creates micro-vibrations or oscillations of ultrasonic frequency. The adjustment of the accurate frequency of the device makes it possible to cut the hard tissues while sparingall the soft tissues. The operating frequency ranges 10Hz to 30 or 60Hz and maximum up to 29 kHz unit. The lower range of frequency makes it possible to cut the hard bony structure, not soft tissue. Power can be adjusted from 2.8 to 16 W, although, different power settings are already made for different bone densities in this device. The tip of this unit vibrates within a range of 60–200 µm which further allows precise cutting along with meticulous incision lines. Initially, piezoelectric surgery was used by maxillofacial surgeons, but later on, this has been widely used in the field of neurosurgery as well as in orthopaedic procedures. It has emerged as a boon for these specialities as this tool not only lowers the chance of damage to adjacent vital soft-tissue structures such as nerves and vessels during osteotomies but also preserves the osteocytes, complementing the healing process.

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Fig 1 Piezoelectric Surgical Unit

Piezosurgery Unit

A Piezosurgery unit consists of a piezoelectric handpiece, a control unit to control the frequency of vibrations, power of cutting and the amount of irrigation, holders for the headpiece and irrigation fluids and a footswitch that activates the handpiece tips. Various types of handpiece tips including scalpel saw, cone compressor, bone harvester are available. They are available in different sizes and shapes with titanium or carbide coating. Piezosurgery requires light handpiece pressure and an integrated saline coolant spray to avoid overheating of the bone and increase the visibility of the surgical site. The frequency is usually set between 25 and

30 kHz producing micro-vibrations of 60–210 micrometer amplitude with power exceeding 5 W. Addition of a 50 kHz pulse every 10 ns to this basal frequency increases the device power allowing efficient bone cutting.[2] While cutting the deep layers of bone, cooling efficiency can be increased by interrupted cutting or cooling the solution to 4 °C.[3] The pressure applied, the speed of the tip in contact with bone and translation speed affects the cutting power. Piezosurgery devices require slight pressure to have precise cutting. The increased pressure limits the tip motion thus overheating the tip and causing bone necrosis.

Different Modes in Piezoelectric Device: Mainly three modes are used in the field of dentistry, which includes:

- Low mode,
- High mode &
- Boosted mode.

The "Low mode" is useful for the treatment of apical root canal and the "high mode" is for cleaning and smoothing purposes. The "Boosted mode" is used for the osteoplasty procedures and during osteotomy. The most often used mode in oral and maxillofacial surgery is boosted mode in which digital modulation of the oscillation pattern produces alternating high-frequency vibrations, with pauses at frequencies up to 30 Hz to avoid overheating, while maintaining optimal cutting capacity.[4]

Pros and Cons of Piezoelectric Surgery: Piezosurgery has various advantages compared to traditional methods of surgical instrumentation used for osteotomies or osteoplasty.

These are as follows:

- Soft tissue protection
- Mechanical as well as thermal injury can be avoided while performing osteotomy close to vital structures like nerves, blood vessels, Schneiderian membrane and dura mater
- Ideal visibility of the operative field[5]
- Lower level of vibration and noise prevents psychological stress and patient apprehension
- Tooth vitality can be protected[6,7]
- Minimal blood loss
- Higher patient comfort
- Minimal pressure is required for performing the osteotomy

Certainly, this device is also having certain negative aspects, these can be mentioned as:

- Expensive armamentarium
- Technique sensitive operation
- An inexperienced operator may induce damage to the adjacent soft tissues
- Extended duration of operation for simple osteotomy procedures
- Piezosurgery is relatively contraindicated for use in patients with pacemakers, although there is no evidence of electromagnetic interactions produced by piezoelectric devices according to one in vitro study.[8]

Piezosurgery in Different Spheres of Dentistry: The piezoelectric unit has a myriad of applications for bone surgeries in a variety of dental surgical specialities. One of the important advantages of using piezosurgery is that it can precisely cut the hard tissue while precluding any injury to the soft tissues.

Indications: Piezosurgery can be used in a range of surgical scenarios, these are:

1. Soft tissue debridement
2. Smoothening of root surfaces
3. Bone grafting
4. Implant site preparation
5. Implant retrieval
6. Sinus Lift Procedure
7. Retrograde root canal preparation
8. Apisectomy & cystectomy
9. Extraction of ankylosed teeth, and
10. Orthognathic surgeries.

Contraindications: Although there are no absolute contraindications of using piezoelectric devices, some conditions should be under consideration, these are:

1. Cardiopathy
2. patients with uncontrolled diabetes mellitus
3. patient receiving radiotherapy
4. patients with metal/ceramic crowns
5. patients with pacemakers

Sinus Lift: The chances of membrane perforation with conventional techniques of sinus lift procedure is reported to be 14–56%, while studies on the use of piezosurgery devices report it to be 5–7%.[9]The "PISE" technique or "Piezoelectric Internal Sinus Elevation" is a surgical sinus augmentation technique in which a specialized carbide tip of an ultrasonic piezoelectric device is used instead of using a conventional mallet.[10]A copious internal or external irrigation creates a hydraulic pressure which makes the detachment of the sinus membrane from the bony floor easier. Another feature of the carbide piezo tip is marking for bone depth which can indicate the depth of osteotomy in real-time. Thus, the risk of membrane perforation is minimized.

Buccal wall Osteoplasty: Piezoelectric saws make the osteoplasty extremely precise and easy, hence the bone fragments removed during osteoplasty can also be used as grafting material.

During osteotomy: The piezoelectric saw oscillates at predetermined frequencies which can abrade only the mineralized tissues, while the soft tissues can easily match this frequency and are thus spared.[11]

Schneiderian membrane separation: Special inserts require a minimal access port and the head separates the sinus membrane around the perimeter of the bony window and also decrease the chance of perforation.

Fig Sinus lift by piezosurgery

Mobilization of Inferior Alveolar Nerve: Bovi, in 2005, first reported a technique for IAN mobilization with simultaneous implant placement utilizing a piezoelectric device.[12] He confirmed that inferior alveolar nerve mobilization with a piezoelectric device minimizes the risk of irreversible damage to the nerve and it also enables the surgeon to make a smaller bony window, which, in turn, decreases overstretching of the mental nerve.

In another study, Metzger (2006) compared the mobilization of the inferior alveolar nerve using a piezoelectric device versus conventional burs. His findings also revealed a lower rate of nerve injury using piezoelectric devices.[13]

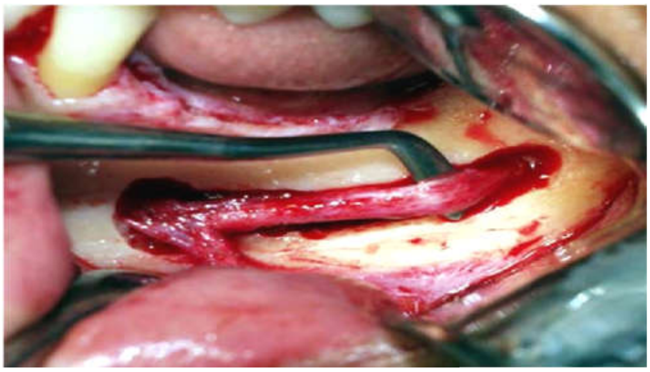

Fig Transposition of inferior alveolar nerve.

Orthognathic Surgery: A precise osteotomy and preservation of soft neurovascular tissues is a prerequisite for any aesthetic surgical procedure. Landes *et al*. performed a study on 90 patients undergoing orthognathic surgery by piezoelectric osteotomies. This study demonstrated a decreased blood loss compared to conventional surgery but no significant difference in the duration of surgery. Le-fort I osteotomy only required the use of chisels in about 33% of cases.[14,15,16] In the same study, patients who underwent bilateral sagittal split osteotomy (BSSO) using piezoelectric device retained the inferior alveolar nerve sensitivity in 98% of the cases after 3-month of the procedure, compared to 84% after conventional BSSO.

Distraction Osteogenesis: Distraction Osteogenesis (DO) is performed to augment the bone which is deficient in its skeletal dimension. The use of piezosurgery permits the initial osteotomy to be made delicately and accurately while minimizing injury to the soft-tissue flap and surrounding hard tissue, preserving the vascularity which is the prerequisite for successful new bone formation.[17]It also preserves the original bone structure, especially while performing surgeries on the cancellous bone, which promotes bone healing. Distraction Osteogenesis using piezoelectric osteotomy for Pierre Robin Sequence has shown improved results with precise placement of micro-distractors.[18]

TMJ Ankylosis: The surgical correction of ankylosed Temporomandibular Joint involves osteoplasty as well as ostectomies. Bone cutting at this region is meticulous and requires high precision due to proximity to critical structures like the Middle meningeal artery, the Maxillary artery, the Masseteric artery as well as the Facial and Auriculotemporal Nerves. Conventional bone cutting instruments such as burs and saws put these vital structures at significant risk of injury and permanent damage. Hence, using piezoelectric surgical devices can become torchbearers for surgeries involving these regions. This technique not only minimizes the postoperative complications; it also reduces the bleeding tendencies.[19]

Fig Piezoelectric arthroplasty for TMJ ankyloses.

Enucleation of Large Cysts/ Benign Tumours: While removing benign tumours from the mandibular region or even during enucleation procedure of any larger sized cyst, the Inferior Alveolar Nerve might be at risk of any unwanted injury during the surgery. Dr. Kagan D.*et al* (2009) introduced the "BONE LID TECHNIQUE,"[20,21] which employed piezosurgery devices to perform a precise osteotomy to expose intraosseous lesions from the buccal aspect, sparing the crestal region. This manoeuvre preserves the crestal bone and prevents damage to the inferior alveolar nerve.

Trauma and Post Traumatic Deformity Correction: Emergency surgical interventions for trauma cases may benefit greatly from the introduction of piezoelectric devices. For example, in the delayed reconstruction of comminuted frontal bone fractures, a piezo saw can perform excellent osteotomy of the malunited bone fragments to facilitate reconstruction. In Reconstructive surgeries involving inner table fracture of the frontal bone, cutting and re-shaping the inner table using piezosurgery will preserve iatrogenic Brain injury. Using a Piezoelectric unit to osteotomize a healing fracture reduces the chance of adjacent tissue injury, provides the best possible post-operative bone preservation, protects the adjacent soft tissues, prevents blood loss, improves visibility as well as ensures a better overall prognosis.[22]

Rhinoplasty: Lateral osteotomy during rhinoplasty is usually performed with a chisel which transmits a great deal of force to the underlying bone, cartilage and other soft tissues. The blind and unguarded use of the chisel may damage the adjacent soft nasal tissues and the underlying blood vessels, resulting in severe intraoperative bleeding and periorbital ecchymosis.

Fig Rhinoplasty by Piezo-electric devices.

All these probable postoperative complications can be minimized by the precise and safer piezo-surgical osteotomy technique, as reported by Robiony *et al.*[23] New piezoelectric inserts specifically designed for rhinoplasty preserve the soft tissues and thereby improve the stability of the position of the bone fragments after the osteotomy.

Implant Osseointegration: While performing osteotomy for implant placement, conventional drilling of bone generates a tremendous amount of heat. This may cause disturbances in the healing process and thus delaying osseointegration. A recent randomized controlled clinical trial by Da Silva Neto *et al*. in 2014 compared implant stability at various times postoperatively in osteotomies performed by conventional rotary instruments versus Piezosurgery devices. The overall implant stability was found to be much better with Piezosurgery devices.[24].

Fig Piezo-electric implant placement.

For Alveolar Augmentation Procedure: Ridge splitting for bone augmentation in implant surgeries traditionally was done using chisel and mallet, rotary bone-cutting burs or saws. The osteotomy thus created was uneven, and the high-speed rotary instrument/ saws generated a lot of heat. Also, there was a high risk for iatrogenic ridge fracture, undesired propagation of osteotomy, bone necrosis and injury to the neurovascular sturctures. The implant placement was usually carried out as a second stage surgery. Vercellotti (2000) described a new Ridge split technique using modulated-frequency piezoelectric energy scalpels, which involved the separation of the vestibular osseous flap from the palatal flap and the immediate positioning of the implant between the 2 cortical walls. The osteotomy gap thus created, was filled with bioactive glass synthetic bone graft material as an osteoconductive factor and autogenous platelet-rich plasma as an osteoinductive factor.[25] Thus this technique reduced the chances of damage to the critical anatomic structures during the osteotomy as well as can reduce the risk of bone thermo-necrosis, while simultaneously providing better control of the propagation of the ridge split osteotomy procedure.

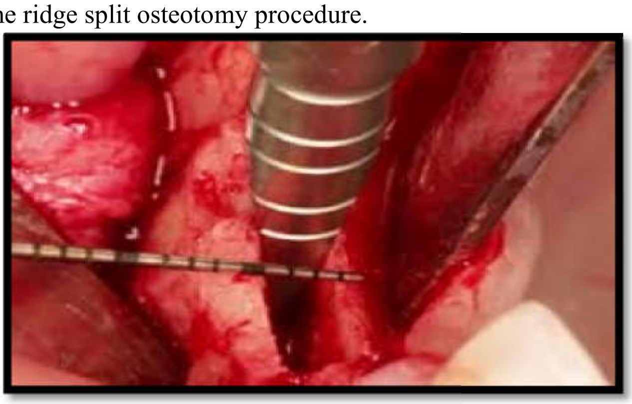

Fig Ridge-split technique by Piezosurgery.

CONCLUSION

Piezosurgery is one of the safest ways of cutting bones where one can expect precision and predict the outcome of the surgery as well. The best features of using Piezo-electric devices are minimal blood loss, clean surgical field during surgery, protecting the soft tissues from iatrogenic injuries, minimal production of sound and providing good patient comfort. Despite certain limitations viz. technique sensitivity and longer duration of operation, it has transformed highly demanding procedures into very feasible ones. Post-operative recovery and healing of the surgical site are extremely favourable following piezoelectric surgeries which further allow achieving the required regenerative potential of that bony region.

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