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Educational Article

An overview on the art of piezosurgery in the maxillofacial practice

Naveen Nandagopal[1,*], Bobby John[2]

[1] Department of Oral and Maxillofacial Surgery, Government Dental College, Alappuzha, Kerala, India
[2] Department of Oral and Maxillofacial Surgery, Government Dental College, Kottayam, Kerala, India

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Abstract – Introduction: Piezosurgery is an emerging boom in the field of maxillofacial surgery for precise, safe and effective osteotomies sparing the adjacent vital structures compared to conventional surgery. **Corpus:** It works on the principle of piezoelectric effect in which crystals in the piezoelectric substances get deformed on the application of an electric field. Various studies gave the evidence of improved wound healing and bone formation compared to conventional approaches. The soft tissue sparing capability with improved patient comfort and decreased blood loss gave the utmost importance for this surgical technique in the present as well as future world of surgery. **Conclusion:** Piezosurgery has emerging as a promising surgical modality with a wide range of clinical applications throughout the whole field of surgery.

Introduction

Piezosurgery is a recently advanced surgical technique for sectioning the hard tissues sparing the adjacent soft tissues such as brain, neurovascular structures and mucosa. It works on the principle of ultrasonic microvibrations. The principle of piezoelectric effect was first described by the French physicists Jean and Marie Curie in 1880 [1,2]. Later in 2000 Italian oral surgeon Tomaso Vercellotti developed the new technique of piezosurgery to overcome the limits of traditional instrumentation in oral bone surgery by modifying the conventional ultrasound technology [3].

Various studies gave the evidence of improved wound healing and bone formation compared to conventional approaches. The application of this meticulous technology is increasing in various surgical fields like otorhinolaryngology, neurosurgery, maxillofacial surgery, ophthalmology, traumatology and orthopaedics. The soft tissue sparing capability with improved patient comfort and decreased blood loss gave the utmost importance for this surgical technique in the present as well as future world of surgery.

Principle

The piezosurgery works on the principle of piezoelectric effect which is based on cavitation effect and microvibration phenomenon. The crystals in the piezoelectric substances get deformed when it is placed in an electric field. The periodic changes in the polarity of field produces ultrasonic oscillations, which are amplified and transferred to a vibration tip to diverse solid, liquid or gaseous materials. The tip on the bone tissue with slight pressure generates a mechanical cutting effect called cavitation phenomenon. Usually it produces a functional frequency of 20 kHz as in ultrasonic scalers. The addition of a 50 kHz pulse every 10 ns to this basal frequency increases the power of the receiver device allowing the bone cutting without damaging soft tissues [2,4].

Mechanism

A piezosurgery unit consists of

- Piezoelectric headpiece.
- Control unit to control the frequency of vibrations, power of cutting and the amount of irrigation.
- Holders for the headpiece and irrigation fluids.
- Foot switch which activates the handpiece tips.

Various types of headpiece tips including scalpel, saw, cone compressor, bone harvester etch 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 mm amplitude with power exceeding 5 W.

* Correspondence: knavishri@gmail.com

Addition of a 50 kHz pulse every 10 ns to this basal frequency increases the device power allowing the bone cutting more effectively. While cutting the deep layers of bone cooling efficiency can be increased by interrupted cutting or cooling the solution to 4 °C [4]. The pressure applied, the speed of the tip in contact with bone and translation speed have an effect on the cutting power. Piezosurgery devices require slight pressure to have precise cutting. The increased pressure limits the tip motion producing overheat and thereby bone necrosis.

Modes of piezoelectric devices

Mainly three modes are used in the field of dentistry, which includes

- Low mode
- High mode
- Boosted mode.

Low mode is useful for apical root canal treatment and high mode is for cleaning and smoothing bone borders. Boosted mode is used for the osteoplasties and osteotomies. 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 [3].

Biological effects

The effects of piezoelectric devices on the bone structure and viability have an utmost importance in the success of regenerative surgery. Even though there have been various studies regarding the effects of piezoelectric surgery on bone structure and cellular viability, most of them showed that the gouge-shaped bone chisel, back action, enblock harvesting, rongeur pliers, and piezoelectric surgery offers the most efficient methods for harvesting the vital bone [2]. High pressure applied and high temperatures even for a short time may cause the necrosis of bony tissue. Recently, Stubinger *et al.* also showed that autologous bone harvested with a piezoelectric device offers stable and aesthetic placements of oral implants after a 5-month's healing [5]. In a histomorphological study Preti *et al.* reported that neo-osteogenesis was consistently more active in bony samples from implant sites that had been prepared using piezoelectric surgery, and there was an earlier increase in BMP-4 and TGF-β2 proteins, and fewer pro-inflammatory cytokines in bone around the implants [6].

Clinical applications

Sinus lift

The Piezoelectric Internal Sinus Elevation (PISE) technique [7] is a surgical sinus augmentation technique in which an ultrasonic piezoelectric device with a specialized carbide tip is used instead of the surgical mallet and the hydraulic pressure from internally or externally irrigated saline to the sinus membrane makes its detachment from the sinus floor more easier. This carbide tip has an indicating line of bone depth while performing the osteotomy, thereby minimizing the membrane perforation risk.

After the sinus cortex perforation, bone grafts or substitutes mixed with platelet rich plasma or fibrin adhesives can be grafted into the prepared socket with amalgam carrier or small spoon shaped curette. Reduced incidence of Benign Positional Paroxystic Vertigo (BPPV) and membrane perforation makes this technique more attractive alternative for direct or indirect sinus lift procedures [7]. In Wallace *et al.* reported only 7 of 100 cases of schneiderian membrane perforation in their study of sinus lift procedures using piezosurgery, whereas Vercellotti *et al.* observed the membrane perforation in only 5% of patients [8,9]. The additional bone grafts can be placed to elevate the sinus floor for the required height. 0.5–1 cm^3 of bone graft is usually recommended to elevate the sinus floor upto 5 mm for placement of a single dental implant. It offers a better choice for sinus floor elevation in the condition where at least 3-mm residual bone is available under the maxillary sinus floor. Reduced surgical time and patient discomfort makes it more advantageous.

Surgical removal of impacted third molars

Conventionally, rotary handpieces and burs are used for removing the bone over impacted third molars and other impacted teeth as well. Piezosurgery has been suggested as an alternative for rotary instruments. The tool for removing the bone over impacted third molars are rotary handpieces. Recently, piezosurgery technique has gained popularity. Even though various studies suggested piezosurgery as an better alternative for rotary headpiece, several other studies reported a controversial thought due to its prolonged surgical period.

Arakji *et al.* and Al-Moraissi *et al.* reported the lower incidence of pain, swelling and truisms in peizosurgery groups [10,11]. Similar results were reported by Goyal *et al.* in a comparative prospective study on piezosurgical removal of 40 impacted mandibular third molars [12]. Barone *et al.* suggested that piezosurgery is more favorable than rotary instruments in view of reduced postoperative swelling and trismus [13]. Mantovani *et al.* and Menziletoglu *et al.* reported the prolonged time period for the piezosurgery in impacted tooth removal [14]. Even though it is a real time consuming technique compared to rotary instruments, selective cutting feature of mineralized structures, reduced temperature at surgical site and better visibility of the surgical site by constant irrigation system promote the bone healing and makes it ideal for osteotomies at the sites closer to the vital structures.

Bone harvesting

Bone can be harvested in the form of bone chips or blocks which act as a guide for bone regeneration via osteoconduction and a space maintainer for the growth factors to promote the bone healing [1,15,16]. Conventional methods of bone harvesting includes bone scrapers, rongeurs, gouge shaped chisels, trophies or enbloc harvesting. Recently piezosugical bone harvesting gains a paramount importance due to its wide range of benefits compared to conventional methods.

The piezoelectric device with osteoplasty No. 1 to osteoplasty No. 3 tips can be used with gentle scratching movements along the surface of the bone to obtain sufficient bone chip volume which is very difficult with conventional bone mills. The bone chips obtained via conventional bone mills have lower particle size which get easily resorbed without fulfilling its role as a space maker or guide for bone regeneration whereas piezosurgery provides significant amount of bone with particle size of 500 μm at lower complication rate and minimal resorption rate [4]. The structure of piezosurgically obtained bone margins are less impaired compared to conventional methods. Berengo *et al.* reported that piezosurgery retains a significant amount of viable osteocytes and osteoblasts [17]. Even though it is a time consuming technique, piezosurgery still remain as one of the most easier and safer method for bone harvesting.

Bone splitting/ridge expansion

Ridge splitting is indicated in cases with sufficient alveolar bone height and insufficient bone width especially prior to implant placement. Usually split thickness flap is used to prevent bone resorption. The most common complications encountered with conventional rotary instruments or chisel are pressure trauma and improperly maintained vertical dimension and width of alveolar bone, which can be overcome by the piezoelectric bone cut [4].

Distraction osteogenesis

Mandibular distraction osteogenesis considered to be a surgical option for Pierre Robin syndrome during the neonatal life. It offers a safe and effective option to relieve the airway obstruction and swallowing difficulty due to micrognathia and avoids the need of tracheotomy [18]. As the piezoelectric osteotomy during the distraction procedure permits a clear micrometric selective bone cut and thereby preserving the osteocytes and periosteal tissues, this technique promotes the new bone formation with early release of morphogenetic proteins.

Alveolar nerve decompression

Piezosurgery promotes the accuracy and precision of osteotomy for alveolar nerve decompression, thereby minimizing the thermal or mechanical damage of neurovascular structures [19].

Cyst removal

Odontogenic and nonodontogenic cysts of the jaws can be removed by using piezoelectric devices more effectively. Piezosurgery allows safe cystic removal without damaging adjacent vital structures and promotes the bone healing after the cystic removal [1,4].

Periodontic and endodontic surgery

Piezosurgery using ultrasonic oscillations were widely used for the removal of supragingival as well as subgingival plaque and to remove root canal fillings and fractured instruments from root canals [2]. Usually ultrasonic scalers work at the functional frequency of 20 kHz. Ultrasonic piezoelectric retrotips reduces the need for root sectioning, thereby reducing the number of exposed dentinal tubules and the risk of apical leakage. It also offers improved cleaning of cavity walls and reduced smear layer volume after root canal preparation [20].

Dental Implantology

In the present world piezosurgery is most widely accepted in the fields of implantology. The sufficient alveolar bone height and width is the most important requirement prior to the placement of dental implants. It can be achieved by various techniques like sinus lift, ridge splitting and bone harvesting, which can be performed by piezoelectric devices with greater precision and accuracy. Piezoelectric surgery offers more customized and minimally invasive osteotomies, which made the implant site preparation and lateralization of the inferior alveolar nerve more feasible [21]. da Silva Neto *et al.* in a prospective study illustrated the improved stability of implants placed using the piezoelectric method than that of implants placed using the conventional technique by evaluating the implant-stability quotient in sites prepared by either conventional drilling or piezoelectric tips via resonance-frequency analysis. In their study, they showed significant increases in quotient values for the piezosurgery group [22].

Orthognathic surgeries

The piezosurgical application in the field of orthognathic surgery is gaining interest especially for bilateral sagittal split osteotomy, Lefort I and II osteotomy and surgically assisted rapid maxillary expansion. Most of the previous studies on piezosugically assisted orthognathic surgeries emphasizes the safety and precision of the piezoelectric devices without thermal or mechanical damage to adjacent structures and bony necrosis and thereby reducing the postoperative swelling and hematoma [1,2].

In an *in vitro* study in 2019, Noetzal *et al.* histologically examined only a small layer of intratrabecular debris on the piezosurgically osteotomized bone surfaces, which was illustrated by toluidine blue staining on the cutting surfaces of all osteotomies. According to Noetzel *et al.* even though conventional rotatory saws were faster and created less heat compared to all tested piezoelectric systems, piezosurgery systems offer an increased safety and precision level than conventional methods. They also proved that straight tips offer faster osteotomy speed than angulated tips and thin insert tips have a positive relation with osteotomy time and performed faster than conventional microsaw [23].

Lefort I osteotomy can be performed using piezoelectric scalpel with slightly curved base and thinner and wider extremity at light pressure till the osteotomy of the maxillary cortex was completed. The pterygomaxillary disjunction was completed with a wider and thicker scalpel with cutting edge perpendicular to the long axis of handpiece. Even though the posterior most access of piezoelectric device is quite difficult during Lefort I osteotomy, tip of the piezoelectric scalpel can be palpated upto the level of hamular notch. Piezosurgical technique permits the surgeon to make a precise osteotomy cuts between the teeth while performing Lefort I osteotomy or surgically assisted rapid maxillary expansion, sparing the adjacent bone and tooth vitality.

Ueki *et al.* reported the use of ultrasonic bone curette for the pterygoid disjunction during Le Fort I osteotomies without damaging the surrounding tissues such as descending palatine artery like neurovascular structures [24].

Piezoelectric instruments can also be used for the osteotomy between two maxillary central incisors during the procedure of surgically assisted rapid maxillary expansion. It permits more precise osteotomy without damaging adjacent bone, tooth and neurovascular structures, thereby reducing the risk of bony necrosis.

Bilateral sagittal split osteotomy (BSSO) performed by piezosurgery facilitates improved protection of inferior alveolar neurovascular bundle, thereby reducing the postoperative complications like edema and hematoma. Landes *et al.* and Geha *et al.* reported improved retention and recovery of inferior alveolar nerve sensory functions after the procedure of bilateral sagittal split osteotomy performed by piezosurgery [25,26].

Craniofacial surgeries for craniosynostosis

More recently piezosurgery made a leading role for craniofaciostenosis surgeries protecting the adjacent vital structures like dura matter, brain, eye globe, neurovascular structures and other soft tissue structures. Gleizal *et al.* reported that piezosurgical osteotomies allows a safe effective and precise alternative for mechanical saws even though the duration of surgery and learning curve was lengthy [3]. It ensures more precise cutting in a blood free operative area with great intraoperative visibility control and safety in anatomically critical and difficult regions [27].

Reconstructive surgeries

The piezosurgery have a paramount importance during the reconstructive procedures. This technique minimizes the bony part of the flaps and the feeding neurovascular structures, there by improving the flap viability which is important for the further reconstructive options [1].

Removal of osteosynthetic materials

The formation of callus that covers miniplates and screws limit its removal more difficult in maxillofacial surgery as well as orthopedic procedures. Piezosurgery allows quick and safe removal of callus from titanium miniplates as this technique avoids the screw heads damage for subsequent screwdriver use [1,9].

Osteonecrosis

Piezoelectric device can be used to remove the necrotic bone residues in Antiresorptive agent-induced osteonecrosis of the jaw (ARONJ). In 2009, Crosetti *et al.* observed in a cohort study that piezosurgery can prevent further necrosis of bone after its removal [28]. Bilimoria *et al.* explores the role of L-PRF (an autologous blood product rich in cytokines and growth factors) in conjunction with piezoelectric debridement as a minimally invasive management technique in osteoradionecrosis by accelerating the hard and soft tissue wound healing [29]. Recent evidences shown that minimally invasive surgical approach with flapless piezoelectric surgery offers a positive response in the treatment of stage 1 and 2 osteonecrosis of the jaw. It is difficult to remove the bone precisely using conventional instruments such as rotating burs and oscillating saws in close vicinity to the neurovascular structures, whereas the piezosurgery could precisely remove the bone adjacent to inferior alveolar nerve and perform transposition of the IAN, even in the irradiated mandible, which was reported by Yoshimura *et al.* [30].

Mental nerve transposition

Piezosurgery offers a safe and effective technique to transpose the mental nerve that had hyperaesthesia by a dental prosthesis, which was reported by Sakkas *et al.* in their cross-over study in 2008 [31].

Rhinoplasty

In rhinoplasty, lateral osteotomy was usually performed with chisel which transmit a great deal of force to the underlying bone, cartilage and other soft tissues. The blind unguarded use of chisel may cause damage to soft nasal tissue and underlying vessels such as the nasal angular artery resulting in bleeding and periorbital ecchymosis [2]. These postoperative complications can be minimized by the precise and safer piezosurgical osteotomy, which was reported by Robiony *et al.* [32] and Lagunas [33]. New piezoelectric inserts were specifically designed for rhinoplasty which preserves the soft tissues and thereby improves the stability of the position of the bone fragments after the osteotomy [33].

Osteotomies in the TMJ (temporomandibular joint) area

The piezoelectric scalpel was introduced for osteotomy in TMJ area in 2006 [34]. It allows a safe and precise bony cut in the medial aspect of the condyle and the medial aspect of the articular eminence, thereby reducing the risk of internal maxillary artery and meningeal vessels injury. It is one of the greatest advantage during the condylectomy procedures in cases of condylar hyperplasia and TMJ ankylosis [33].

Other indications

Piezosurgery can be applicable for other surgical procedures like otological surgeries including stapedotomy, antrotomy, mastoidectomy, tympanotomy and facial nerve decompression, rhinological procedures including endoscopic dacryocystorhinostomy, neurosurgical procedures including craniotomy, orbitotomy and spinal laminotomy, orthopedic surgeries and osteosynthetic materials removal [1,2,28]. It offers more precise bone cutting while protecting adjacent vital structures like neurovascular structures dura matter and soft tissues.

Advantages [1,2,35–37]

- Improved soft tissue protection.
- Mechanical and thermal injury can be avoided while performing osteotomy close to vital structures like nerves, blood vessels, schneiderian membrane and dura matter.
- Ideal visibility of the operative field by voiding the blood of cutting area by cavitation and microvibration effects of piezosurgery.
- Less vibration and noise thereby reducing the psychological stress and fear of the patient.
- Protect the tooth vitality.
- Reduced blood loss.
- Increased patient comfort.
- Can be performed with small amount of pressure.
- Eliminates the need for the availability of chisel.
- Reduce the incidence of coagulation necrosis of osteotomized fragments.
- Produce micrometric bone cuts with greater precision.

Disadvantages [1,2,27,35,36]

- Expensive.
- Technique sensitive.
- If surgeon is less experienced, it may induce damage of soft tissues like nerves and blood vessels.
- Decreased experience with piezoelectric instruments may increase the duration of surgery.
- Difficult to learn.
- High level surgical control is required.

Conclusion

Piezosurgery is an emerging boom in the field of maxillofacial surgery for precise, safe and effective osteotomies sparing the adjacent vital structures. It facilitates the bone healing by inducing early increase in bone morphogenetic proteins and reduce the inflammatory process. Even though it is a time consuming technique with a large learning curve, its clinical advantages overrules its drawbacks. Recently it was emerging as a promising surgical modality with a wide range of clinical applications throughout the whole field of surgery.

Conflicts of interests

The authors had no conflict of interests.

Informed consent

The authors declare that informed consent not required.

Ethical committee approval

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