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Review Article

Piezoelectric surgery - Gaining popularity in modern periodontics: A review

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ABSTRACT

In this modern era of dentistry, piezoelectric surgery is one of the novel innovations invented by T. Vercelloti to perform various osseous surgeries. The piezoelectric device increases treatment effectiveness and ease of using the instrument during the surgery. Minor bleeding, accuracy in cutting, and magnificent tissue healing make it best to enhance surgical results despite being used in the most complex anatomical cases. The piezoelectric device produces ultrasonic vibration (25-29KHz frequency), an oscillation (60-120μm), and power up to 50W. Piezoelectric surgery devices allow for adequate bone-cutting without damaging the soft tissue. The present review emphasizes its discovery, ideology, components, and wide application in dentistry.

1. Introduction

Periodontal diseases are multifactorial infections caused by many bacterial species that interact with host tissues and cells, leading to the extensive release of inflammatory cytokines, chemokines, and mediators, which destroys the periodontal structures, including teeth supporting bone, leading to bony deformities.[1] This alteration in the normal physiologic bone pattern are corrected by various periodontal regenerative and reconstructive procedures.[1] Deformities in bone are corrected by osseous surgery for re-contouring the bone patterns. For many decades osseous surgery ware conventionally performed using hand and various rotary instruments. Using these conventional instruments, inappropriate force and heat generation during osseous surgery leads to fracture of the brittle bone, ultimately leading to alteration in standard physiologic bone patterns.[2,3] In the recent past, innovative surgical techniques using piezoelectric device machines with regulated frequency, restrained tip vibration has been introduced in Periodontology and Oral Implantology assuring precise and productive methods in comparison to the conventional technique. It has gained popularity in very short duration due to wide variety of applications in both medical and dental surgeries. It has made the surgical procedures like bone incising (osteotomy) and bone shaping (osteoplasty) easier.[4]

2. Historical Aspects and Physics Involved in Piezosurgery

The word ‘‘Piezo” originates from the greek word Piezein (to press tight, squeeze). Piezosurgery is basically based on the theory of "piezo-effect" i.e., changing the electrical field on crystalline structure.

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The change of electrical field strength in the crystalline structure results in the production of ultrasonic vibrations. In 1880, Jacques Curie and Pierre Curie discovered piezoelectric while working as laboratory assistants at the faculty of science in Paris. They generated electrical charges by applying pressure to the crystals like tourmaline, quartz and Rochelle salts.[4,5] In 1881, Gabriel Lippmann predicted the converse piezoelectric effect i.e. application of an electric field to the crystal materials causes the internal generation of a mechanical strain with the help of mathematical deduction from thermodynamic principles. In 1953, Catuna MC developed a drill with ultrasonic properties for cavity preparation on human teeth.[6] In 1957, Richman reported apicoectomies using an ultrasonic chisel for surgery without using slurry.[7] Demonstration to dissect the bone precisely using an ultrasonic blade was given by Mazzarow in 1960.[8] Mcfall et al., in 1961 compared healing with rotating instruments and an oscillating scalpel blade and concluded that there was no severe complications and wound healing was comparatively slower in the oscillating scalpel blade group.[9]

In 1980, Horton et al., conducted a study on alveolar bone in dogs comparing bone regeneration with rotating instruments and ultrasounds and concluded that regeneration of bone was better in ultrasonic group as compared to rotating instrument group, however smoother surface was appeared in rotating instrument group.[3] Torella et al., in 1998 reported the osteotomy procedures to lift the maxillary sinus was done by ultrasonic piezoelectric instruments.[10] Vercelloti T, in 1999, in collaboration with Mectron Spa invented piezoelectric bone surgery. Vercelloti T in 2000, published the first human clinical study using "piezoelectric bone surgery" maintaining the integrity of bone.[7,11] In 2001, after bringing together (ultrasound and the piezo effect), the Piezosurgery® was introduced as a surgical tool.[8] This device was commercially approved in Germany in the year 2002.[4] In 2003, Vercelloti fabricated the optimal frequency methods for performing surgical procedures.[12,13] In 2005, ultrasonics in the field of dentistry to perform different bone surgery was continued by the US Food and Drug Administration.[14]

3. Ideology of Piezoelectric Surgery

The doctrine behind the piezoelectric bone surgery is mostly based on two underlying concepts:[15–19]

3.1. Minimally invasive surgery

Improving the tissue healing and reducing the discomfort among patients; post-operative pain or swelling is much lower than the traditional technique.

3.2. Surgical predictability

Increases treatment effectiveness and ease of using the instrument during the surgery. Minor bleeding, accuracy in cutting, and magnificent tissue healing make it best to enhance surgical results despite being used in the most complex anatomical cases. The piezoelectric device produces ultrasonic vibration (25-29KHz frequency), an oscillation (60-120μm), and power up to 50W. This allows an adequate cutting of bone without damaging the soft tissue.[4] Applying electrical charges to the face of piezoelectric crystals result in crystal compression. In contrast, inverting the direction of electric charge results in expansion. When piezoelectric crystals like quartz or ceramic disk are placed under an alternating electric field, there is compression and expansion of the crystal, which produces a series of vibrations.[20]

These vibrations result in an oscillating shape change of the crystal at the frequency applied, which finally passes onto the working tip, also called inserts, where longitudinal movement occurs, resulting in the cutting of osseous tissue by the microscopic shattering of bone.[21] When this series of vibrations are conducted through a piezoelectric transducer, higher efficiency is obtained. The device uses a specifically engineered surgical instrument characterised by a surgical power that is three times higher than usual ultrasonic instruments. The piezoelectric device can be adjusted over various working frequency setting to perform different procedures. The ultrasonic waves allow the segregation of interface from solid-liquid through micro boiling phenomena called cavitation. This phenomenon occurs by implosion of the droplets causing release of energy as the water spray contacts.[22] This provides advantage in the surgical area by dispersing coolant as an aerosol, provide hemostasis resulting in the clear visibility in the surgical area. Cavitation also fragments bacterial cell walls.[23–25]

3.3. Components of Piezosurgery unit

Composed of

3.3.1. Main body

Main body is composed of touchpad (electronic), display screen, a peristaltic pump, a stand to hold the surgical handpiece,one stand to hold the bag of irrigation and different modes (roots and bone).

3.3.2. Handle

Piezoelectric ceramic discs inside handle generates ultrasonic waves.

3.4. Inserts tips

1. Based on the colour of tips[4,22,26]

(a) Steel tips: For soft tissues or delicate structures, e.g. root of the teeth.
(b) Gold tips: Used to treat bone. Titanium nitride is applied to increase the tips surface hardness.

2. Morphological-functional classification[27]
The morphology represents the structural properties of the tips, while the functional description exemplify the cutting characteristics of the inserts:

(a) Sharp- Cutting
(b) Diamond coated - Abrasive
(c) Rounded - Smoothing

3. Clinical classification (According to basic surgical technique).[27]

Osteotomy (OT) OT1 - OT2- OT3- OT 4- OT5- OT6- OT7- OT7S4 - OT7S3- OT8R/L	**Osteoplasty (OP)** OP1 - OP2- OP3- OP4- OP5- OP6- OP7
Extraction (EX) EX1 - EX2 - EX3	**Implant site preparation (IM)** IM1 (OPs)- IM2A- IM2P- OT 4- IM3A- IM3P
Orthodontic Microsurgery OT7S4- OT7S3	**Sinus Lift** OP3- OT1 (OPs)- EL1 - EL2- EL3
Implant site preparation (IM) IM1 (OPs)- IM2A- IM2P- OT 4- IM3A- IM3P	**Periodontal Surgery** PS2 - OP5 - OP3 - OP3A- PP1
Endodontic Surgery OP3- PS2- EN1 - EN2- OP7	**Ridge Expansion** OT7- OT7S4- OP5 (IM1)- IM2- OT 4- IM3

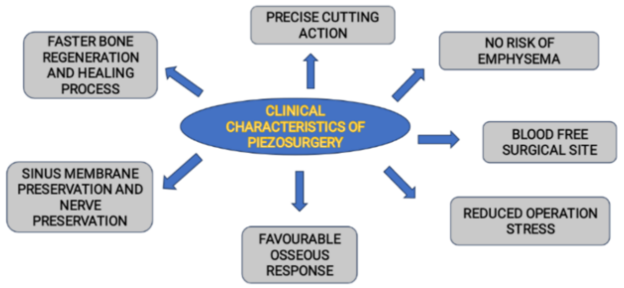

Figure 1: Clinical characteristics of Piezosurgery cutting activity (Figure 1)

3.5. Clinical applications

1. Periodontology

(a) Supragingival and subgingival scaling:
(b) Curettage.
(c) Crown lengthening.
(d) Resective surgery.
(e) Bone harvest.

2. Implantology

(a) Maxillary sinus lift
(b) Ridge expansion
(c) Inferior alveolar nerve laterization
(d) Bone harvesting techniques
(e) Perimucositis, periimplantitis, implant drill
(f) Implant removal

3. Oral surgery

(a) Dental extraction, including third molar extraction
(b) Osteogenic distraction
(c) Cyst removal
(d) Endodontic surgery (apicoectomy)
(e) Extraction of ankylosed teeth
(f) TMJ ankylosis treatment

4. Orthodontic surgery- In Vilcodontics, PAOO (Periodontally accelerated osteogenic orthodontics).

Movement occurs and in that different width and depth of osteotomy has to be performed. (corticotomy).

3.6. Scaling (supra gingival and sub-gingival) and Curettage

The piezosurgery device with a vibrating tip is used for removing the debris and calculus from the teeth. Inserts are placed vertically parallel to the tooth's long axis and are moved continuously, providing better patient comfort and maximum calculus removal. The cavitation effect and micro-streaming disrupt the bacterial cell wall.[28] It can also efficiently remove diseased soft tissue by debridement of the pocket wall's epithelial lining, resulting in "micro-cauterisation" by using thin tapered tips and altered power settings.[29]

3.7. Surgical crown lengthening

This procedure is done to reposition the periodontal bone and soft tissues to a more apical position with appropriate biologic dimensions.Performing this technique using piezosurgery allows clinicians to efficiently reduce bone while preserving the root surface integrity. Ostectomy is performed while keeping the instruments parallel to the root, and there is no risk of damaging the root. Once the Osteotomy is completed, smoothing is performed parallel to the root surface and the bony micro-spicules are removed with the tip of the inserts.[30]

3.8. Maxillary sinus lifting

Maxillary sinus surgery for implant purposes enables the placement of an implant in the posterior maxilla when the crest of the bone is not sufficient. During conventional sinus lift procedures most common obstacle faced by clinician is the perforation of the Schneiderian membrane that leads to a communication between the oral cavity and maxillary sinus. This perforation increases the risk of sinusitis and infections.[31] Introduction of Piezosurgery in the maxillary sinus lift procedure abate the risk of Schneiderian membrane as the tips only cuts the mineralized tissues without damaging the soft tissue.[32] Maxillary sinus lift procedure using piezoelectric surgery shows approximately only 5% of membrane perforation,[33] whereas with rotary instrumentation varies between 5% and 56%.[34,35]

4. Ridge Expansion Technique

The minimum width of an edentulous crest for placing a 4 mm diameter implant is 6 mm to obtain at least 1mm width of the buccal and lingual bone side. Narrow ridges are most frequently experienced by the clinician during placement of the dental implants. To overcome this, the ridge is expanded or splitted for expanding the bone to ease implant placement.[36] The ridge splitting of the mandible can also be done using conventional instruments but the risk of bone fracture as well as inferior alveolar damage is very high.[37,38] To achieve ridge expansion with very less trauma the Piezosurgery unit is equipped with specific designed inserts that provides minimal fracture risk even in D1 type bone, where the chance of fracture is more.[38–40]

4.1. *Harvesting autogenous bone graft*

Autogenous bone graft is considered the “gold standard” for bone grafting procedures. Autogenous bone graft can be harvested as particulate or as a block grafts. Autogenous bone grafts are most commonly harvested from the ramus and body of the mandible, chin, symphysis, mandibular tori (if present) which shows good osteogenic properties, little resorption. Iliac crest, is considered for harvesting larger bone volumes.[36] The introduction of piezosurgery has further improvised the bone harvesting technique. Bone graft harvesting using a piezoelectric device showed greater short-term cell viability and slightly more new bone deposition and bone remodelling.[41] Piezosurgery utilises significantly less hand pressure than rotary instruments; hence precise cutting of bone is easily possible.[42,43]

4.2. *Inferior alveolar nerves lateralisation*

In regions with significantly less visibility, performing the osteotomies with a tool that reduces the risk of nerve damage is essential. This goal can be possible with the Piezosurgery device due to its control, specialised tips and cavitation effect.[44] The specially designed tips of piezoelectric device precisely cuts allowing the lateral cortical bone over the neurovascular bundle. This procedure is performed to preserve and protect the nerve structure after nerve retraction and transposition.[45]

4.3. *Removal of osseointegrated implants*

Removal of an osseointegrated implant becomes utmost necessary for various reasons, including the undesirable position or primary esthetic concern, implant failures etc.

The osseointegrated implants (implant-bone interface) do not allow easy implant removal. Removal of such implants by conventional methods such as using burs, saw, chisel etc., have high risk of fracturing bone around the implants. The piezosurgical device have specially designed précised tips to remove osseointegrated implants. It makes easier for the surgeon as it improves efficacy and reduces trauma during the procedure.[36]

4.4. *Contraindications of piezosurgery*

1. Uncontrolled diabetic patients.
2. Patients with cardiopathy
3. Patients with pacemakers & ICD (Implantable Cardioverter Defibrillator)
4. On metal and ceramic crown and bridges.

5. Discussion

Piezosurgery is a new surgical technique in periodontology and oral implantology.[26] Piezosurgery instruments allow the clinician to perform more technique sensitive procedures which enabled better grip and, hence, increased precision while cutting. The cutting action is less invasive, leading very less collateral tissue damage.[27] Cavitation effect produced as the oscillating tip moves the irrigation fluid, there is a bloodless field of surgery and also fewer chances of postoperative necrosis. Due to the ultrasonic device’s aerosol effect, hazard of developing subcutaneous emphysema is drastically reduced as compared to air-water spray released by rotary instruments for osteotomies.

Due to micro-vibrations, significantly less noise is produced when compared with a conventional motor system making less fear and reduces psychological stress among the patients.[28] Use of rotary instruments lead to high heat generations which are lethal to the cells and may cause tissue necrosis.[27] There have been many studies conducted for analysing the effects of piezoelectric surgery on the bone and the bone cells; not only is this piezoelectric technique is clinically effective, but histological and histo-morphometric observation on experimental animal models also indicated that postoperative wound healing and rate of bone formation and tissue response is more favourable compared to conventional bone cutting with diamond or carbide rotary instruments.[26,29] Every coin has two sides. Piezosurgery is also associated with certain limitations. The use of irrigants helps in cavitation and avoids overheating. The intensity of the cooling liquid can be adjusted depending on different preparations. The cooling solution is used at 4 degrees centigrade.[30]

6. Conclusions

The Piezosurgery technique has numerous advantages over conventional surgical procedures. This technique allows the clinician to perform planned surgery in more efficient and predictable manner with minimum adverse effect. The use of Piezosurgery may increase treatment outcome, very less postoperative complications and an excellent healing. Piezosurgery due to specially designed tips and other properties has the future to revolutionize periodontal bone surgeries, implantology and redefine the concept of minimally invasive surgery in osteotomy and osteoplasty procedures. However, professional training and experienced guidance is required to achieve a better clinical skill enhancement.

7. Source of Funding

None.

8. Conflict of Interest

None.

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