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Piezoelectric Surgery: Applications in Modern Dentistry

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Abstract

Piezoelectric bone surgery is a new and innovative technology which allows selective cutting of mineralized tissue while sparring soft tissues. A high frequency vibration ranging from 25-35 kHz is transmitted to a metallic tip. This technology is similar to a dental scaler but the power of a piezoelectric instrument is three to six times higher than a dental scaler. High precision, a design that makes curved osteotomies easier, less trauma to soft tissue, preservation of neurological and circulatory systems, decreased hemorrhage, minimum thermal damage to the bone, and an overall improvement in healing are some of this technology's main benefits. The instrument's handpiece has a sterile irrigation system and a light-emitting diode (LED) light to increase visibility and safety in general. (1) Osteotomies were the first procedures performed with piezoelectric surgery by oral and maxillofacial surgeons, but more recently, specialized uses in neurology and orthopedics have been suggested. (2)

Keywords: Piezoelectric, precision, osteotomy

Introduction

Numerous oral surgical methods have advanced quickly during the past few decades, launching a new era of painless dentistry. In the past, osseous surgery was carried out with hand instruments and various rotating instruments with varying burs, which produced heat and need for extensive external irrigation. With the exception of broken or brittle bones, osseous procedures also applied a lot of pressure in addition to heat. (3) Piezoelectric effect was discovered by Jacques and Pierre Curie in 1880. Gabriel Lippmann predicted the converse piezoelectric effect in 1881.

Mechanism

A piezosurgery unit includes-

1. Headpiece
2. Control Units
3. Insert tip
4. Peristaltic pump
5. Foot switch
6. Holders

There are many different headpiece tip options, including scalpel, saw, cone compressor, and bone harvester etch. They come with a titanium or carbide coating and come in a variety of sizes and forms. In order to prevent overheating of the bone and improve sight of the surgical site during piezosurgery, light handpiece pressure and an integrated saline coolant spray are required. The frequency is typically set between 25 and 30 kHz, resulting in micro vibrations with amplitudes between 60 and 210 mm and powers more than 5 W. The device's power is increased by adding a 50 kHz pulse every 10 ns, which allows for more effective bone cutting. By interrupting the cutting process or lowering the solution temperature to 4 °C when cutting the deep layers of bone, cooling efficiency can be improved. (4) The cutting power is influenced by the applied pressure, the speed of the tip making contact with the bone, and the translation speed. Piezosurgery equipment needs just a little pressure to cut precisely. The restricted tip motion caused by the increased pressure leads to overheating and ultimately bone necrosis. (5)

Modes of piezoelectric devices

Usually, three modes are used in dentistry-

1. Low mode (Used in apical root canal treatment)
2. High mode (Used for cleaning and smoothing bone borders)
3. Boosted mode (Used in Oral and Maxillofacial surgery)

Indications of piezoelectric surgery

1. Debridement of soft tissue
2. Root surface smoothening
3. Bone grafting
4. Preparation of implant site
5. Sinus lift procedure
6. Retrograde root canal preparation
7. Removal of cysts
8. Extraction of impacted and ankylosed tooth
9. Orthodontic surgeries

Contraindications of piezoelectric surgery

There are no such absolute contraindications of piezoelectric surgeries. But piezoelectric surgeries should be avoided in patients with

1. Cardiopathy
2. Patients who received radiotherapy within 6 months
3. Patients with pacemakers

Applications in dentistry

(1) **Sinus Lift**: The Piezoelectric Internal Sinus Elevation (PISE) technique is a surgical sinus augmentation technique in which an ultrasonic piezoelectric device with a specialized carbide tip is used in place of the surgical mallet and the sinus membrane is more easily detached from the sinus floor due to hydraulic pressure from internally or externally irrigated saline. The likelihood of a membrane perforation is reduced by the carbide tip's indication of bone depth while executing the osteotomy. Following sinus cortex perforation, the created socket can be filled with bone substitutes or grafts combined with platelet-rich plasma or fibrin adhesives using an amalgam carrier or small spoon-shaped curette. This approach is a more appealing alternative to direct or indirect sinus lift treatments due to a decreased incidence of Benign Positional Paroxysmic Vertigo (BPPV) and membrane perforation. (7) Less patient discomfort and reduced surgical time are the main advantages.

(2) **Removal of impacted third molar by surgery:** Whereas the control group's pain scores were higher than those of the ultrasonic group on a visual analogue scale, no statistically significant differences were discovered. On the other hand, when compared to the control group, the test group's consumption of analgesics was much lower. When compared to the test group, the control group experienced much more trismus. At the fifth-day visit, the rotary group's clinical values for cheek swelling were higher than those of the ultrasound group. (8) Damage to the surrounding tissue was examined the same day, however dry socket wasn't assessed until the third postoperative day. In comparison to the Piezosurgery group, more patients in the traditional group complained of pain, needed more painkillers, and frequently developed trismus. (9)

(3) **Splitting/ridge expansion:** Ridge splitting is advised in cases where the alveolar bone height is adequate but the bone width is insufficient, particularly before implant insertion. To stop bone resorption, split thickness flaps are frequently utilized. Pressure trauma and wrongly maintained vertical dimension and width of alveolar bone are the most frequent difficulties with conventional rotary instruments or chisels, which can be avoided by using a piezoelectric bone cut. (10)

(4) Alveolar nerve decompression: Piezosurgery encourages osteotomy accuracy and precision for alveolar nerve decompression, reducing thermal or mechanical harm to neurovascular structures as a result. (11)

(5) Periodontic surgery: By positioning the tips vertically and moving them continually in a line parallel to the long axis of the tooth, it is possible to remove supra- and subgingival calculus, stains, and debris through piezosurgery. (12) By performing regenerative procedures to produce autogenous grafts in the form of bone chips or mono cortical blocks, crown lengthening where bone is reduced successfully preserves root surface integrity, and debriding epithelial lining of the pocket wall.

(6) Endodontic surgery: Piezo surgery is recently used to remove the fractured instruments and root canal fillings from root canals. It also reduces the risk of apical leakage and also a smaller number of exposed dentinal tubules are seen. Additionally, it provides better cavity wall cleaning and a smaller amount of smear layer after root canal preparation. (13)

(7) Orthognathic surgeries: The use of piezo surgical techniques in the field of orthognathic surgery is gaining popularity, particularly for surgically assisted fast maxillary expansion, Lefort I and II osteotomies, and bilateral sagittal split osteotomies. The majority of earlier research on piezosugically assisted orthognathic operations highlights the safety and accuracy of the piezoelectric devices without heat or mechanical damage to nearby structures and bony necrosis, hence minimizing postoperative swelling and hematoma**.** (14,15)

Piezo surgically conducted bilateral sagittal split osteotomies (BSSO) improve the preservation of the inferior alveolar neurovascular bundle, which lowers the risk of edema and hematoma after surgery. After undergoing bilateral sagittal split osteotomy using piezo surgery, Landes et al. and Geha et al. found enhanced retention and recovery of inferior alveolar nerve sensory capabilities. (16,17)

(8) Osteonecrosis: When performing LeFort I osteotomies on the pterygoid disjunction, Ueki et al. reported using an ultrasonic bone curette without causing any harm to the surrounding tissues, including the descending palatine artery and similar neurovascular systems. (18) When an antiresorptive drug causes osteonecrosis of the jaw, the necrotic bone remnants can be removed using a piezoelectric device (ARONJ). In a cohort study conducted in 2009, Crosetti et al. found that piezo surgery can stop bone from further necrosis after it has been removed. (19)

Recent research has demonstrated that the treatment of stage 1 and stage 2 jaw osteonecrosis can be successfully accomplished using a minimally invasive surgical technique called flapless piezoelectric surgery. Yoshimura et al. reported that piezo surgery could precisely remove the bone next to the inferior alveolar nerve and perform transposition of the IAN, even in the irradiated mandible, whereas it is difficult to remove the bone accurately

using conventional instruments such as rotating carbide inserts and oscillating cutting tools in close vicinity to the neurovascular structures. (20

(9) **Temporomandibular joint area osteotomies:** The risk of damaging the internal maxillary artery and meningeal arteries is minimized because it enables a precise and safe bone cut in the medial surface of the condyle and the medial aspect of the articular eminence. In cases of condylar hyperplasia and TMJ ankylosis, it is one of the major advantages during condylectomy treatments. (21)

(10) **Rhinoplasty:** In rhinoplasty, lateral osteotomy is typically carried out using a chisel, which applies a lot of power to the soft tissues, bone, and cartilage beneath. When used carelessly and blindly, chisels can harm sensitive nasal tissue and underlying blood vessels like the nasal angular artery, leading to haemorrhage and periorbital ecchymosis. The precise and efficient piezo surgical osteotomy described by Robiony et al. can reduce these postoperative problems**.** (22)

(11) **Implantology:** Bone can be increased through harvesting (chips and blocks), splitting of crestal bone, and elevation of the sinus floor in oral surgery, especially in implantology. The alveolar ridge may be split to prevent autologous bone grafts in bone with good density. (23)

Overheating during implant-site preparation has a deleterious impact on the osseointegration process and the final result of implant rehabilitations. Temperatures produced by different tips vary, with smooth tips producing the lowest temperatures. Other elements, such as how the cutting is done and the specific characteristics of the bone itself, will also affect the temperature increase. (24) A new method for implant site preparation uses a set of piezo surgery inserts that were created specifically for the procedure. The preparation of the piezo surgical site enables the selective expansion of just one socket wall. Vercellotti refers to this as "differential ultrasonic socket preparation."(25)

By measuring the implant-stability factor in sites prepared by either conventional drilling or piezoelectric inserts via resonance-frequency analysis, da Silva Neto et al. in a prospective study demonstrated the improved stability of implants placed by using piezoelectric method compared to implants placed using the conventional technique. They found that the piezo surgery group's quotient values significantly increased in their study. (26)

(12) **Nerve transportation:** According to Sakkas et al. in their cross-over study from 2008, piezosurgery offers a safe and effective method to transpose the mental nerve that had hyperesthesia by a dental prosthesis. (27)

Advantages of piezoelectric surgery

While performing osteotomy close to essential structures such nerves, blood vessels, Schneiderian membrane, and dura matter, mechanical and thermal harm can be avoided. (28)

1. The pressured irrigation and cavitation effect provide for clear visibility of the operative area.
2. less noise and vibration, which lessens the patient's anxiety and tension.
3. Vitality of tooth is preserved.
4. The cavitation effect ensures hemostasis.
5. lessen the likelihood of osteotomized pieces developing coagulation necrosis.
6. Eliminates the need of rotary instruments.
7. Produce micrometric bone cuts with greater precision.
8. The harvesting of intra- or extra-oral autogenous grafts is made simple by piezosurgery. It is conveniently utilized in places where it is challenging to see and reach because to its inserts with different angles.
9. Because no harm is done to the living bone morphogenetic protein release, healing happens quickly.

Disadvantages of piezoelectric surgery

1. Expensive.
2. When piezosurgery is used, the surgical procedure takes longer to complete.
3. Technique sensitive.
4. Less skilled surgeons run the risk of damaging soft tissues like blood arteries and nerves.

Conclusion

In the field of maxillofacial surgery, piezosurgery is on the rise due to its ability to perform precise, secure, and efficient osteotomies while protecting the nearby important structures. By causing an early rise in bone morphogenetic proteins and reducing inflammation, it aids in bone mending. Although it requires a lot of effort and has a steep learning curve, its clinical benefits outweigh these disadvantages. In the recent past, it began to demonstrate promise as a surgical modality with numerous clinical uses across the board.

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