International Journal of Applied Dental Sciences

ISSN Print: 2394-7489
ISSN Online: 2394-7497
IJADS 2025; 11(1): 240-243

www.oraljournal.com
Received: 06-01-2025
Accepted: 08-02-2025

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Advances in piezoelectric Instruments: Applications and outcomes in oral surgery

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DOI: https://www.doi.org/10.22271/oral.2025.v11.i1d.2124

Abstract
Piezoelectric instruments have gained significant traction in surgical applications over the last two decades. By utilizing piezoelectric technology, which converts electrical signals into mechanical vibrations, these devices offer precise, controlled cuts with minimal damage to surrounding soft tissues. This article reviews the key applications of piezoelectric instruments in oral surgery, examining their benefits, limitations, and potential for future advancements.

Keywords: Piezoelectric, hemostasis, osteotomy, minimal trauma, advancements

Introduction

A more contemporary surgical method called piezo surgery allows the hard tissues to be sectioned while preserving the nearby soft tissues, including the brain, mucosa, and neurovascular systems. Ultrasonic micro vibrations are the basis for its operation [1].

In oral and maxillofacial surgery, manual tools like the chisel, osteotome, or gouge have long been used for hard tissue treatments. Recent years have seen the use of motorized devices that can be powered by electrical energy or air pressure. These devices have a number of disadvantages, such as the potential for soft tissue damage to critical anatomical structures like the maxillary sinus or inferior alveolar nerve, tissue necrosis from overheating bone, loss of fine-touch sensitivity from the need for pressure on the handpiece, difficulty determining cutting depth, and iatrogenic impairment in undesirable areas due to inaccurately adjusting the speed of a rotating head or saw [2].

HISTORY

The French physicists Jean and Marie Curie originally explained the piezoelectric effect theory in 1880 [3]. By altering the typical ultrasonic technology, Italian oral surgeon Tomaso Vercellotti created the novel piezo surgery approach later in 2000 to get over the limitations of traditional apparatus in oral bone surgery. “Piezo" comes from the Greek word "piedin", which means "to press tight, ‘’squeeze". The core idea behind piezo surgery is the "piezo-effect" theory, which states that crystalline structures may change their electrical fields [4]. In 1881, Gabriel Lippmann used mathematical inference from thermodynamic principles to predict the opposite piezoelectric phenomenon, which states that applying an electric field to crystal materials results in the internal development of a mechanical strain.

In a 1980 study on dogs’ alveolar bone, Horton *et al*. compared bone regeneration using rotating instruments and ultrasounds. They found that while the ultrasonic group's bone regeneration was superior to that of the rotating instrument group, the rotating instrument group's surface appeared smoother [5]. Piezoelectric bone surgery was created in 1999 by Vercelloti T and Mectron Spa. The first human clinical trial employing "piezoelectric bone surgery" to preserve bone integrity was reported by Vercelloti T in 2000 [6]. After combining the piezo effect with ultrasound, the Piezo surgery® was released as a surgical instrument in 2001. In 2002, this gadget received commercial approval in Germany. Vercelloti created the ideal frequency techniques for carrying out surgical operations in 2003 [7].

In 2005, the US Food and Drug Administration continued to use ultrasonics in dentistry to conduct various bone surgeries.

Principles of piezoelectric surgery

The cavitation effect and micro vibration phenomena serve as the foundation for the piezoelectric effect, which is the basis for piezo surgery. When exposed to an electric field, the crystals in piezoelectric materials undergo deformation. Ultrasonic oscillations are generated by periodic changes in the polarity of the field, amplified, and transmitted to a vibration tip in a variety of solid, liquid, or gaseous materials. The cavitation phenomenon is a mechanical cutting action produced by the tip applying a little amount of pressure to the bone tissue [8, 9].

Mechanism of action

When electrical charges are applied to piezoelectric crystals, they compress. The crystal grows when the electric charge is reversed. Piezoelectric crystals, like quartz or ceramic discs, may alternate between compressing and expanding when exposed to an alternating electric field. This causes a series of vibrations in the transducer that release ultrasonic energy. Following transmission of these vibrations to a resonance tip, linear motions result in the cutting of mineralized tissue. The saline solution's cavitation effect refers to fluids vibrating at an intermediate frequency, creating vapor bubbles that burst and send shockwaves out. This impact improves vision, preserves tissue pH and oxygenation, and encourages haemostasis in the operative field [10-12].

Applications in oral and maxillofacial surgery

Dento-alveolar procedures

In treatments that call for the careful preparation of a little bone or a fragment of a tooth, such as tooth sectioning or the extraction of a fragment of a damaged wisdom tooth that is closely related to a significant anatomical feature, piezo surgery offers benefits [13].

Implantology

Harvesting (chips and blocks), splitting of crestal bone, and elevation of the sinus floor are methods of augmenting bone in oral surgery, especially in implantology. The alveolar ridge may be divided in bone with sufficient density to prevent autologous bone transplants. Elevating the sinus floor is often the most effective way to cure bone loss in the posterior maxilla, allow air to enter the sinus following tooth loss, or both [14].

Implant site preparation

Overheating during implant-site preparation has a detrimental effect on the osseointegration process and the ultimate result of implant rehabilitations. The temperature produced by various tips varies; the smoothest tips produce the lowest temperature. The way the cutting is done and the unique characteristics of the bone itself are two further elements that will affect the temperature increase. Noetzel N, *et al.* examined several acoustic and ultrasonic instruments with rotating burs in pig jaw segments in this context. The osteocytes and trabecular bone appeared to be undamaged in this investigation, despite the fact that piezo surgery had the most temperature increase [15].

Alveolar ridge splitting

Horizontal distraction osteogenesis, directed bone regeneration, and onlay bone transplants are substitutes for the alveolar ridge split procedure. The invasiveness of onlay bone grafts, the existence of an extra donor site associated with the need for bone harvesting, and the regular resorption that the grafted bone experiences in relation to the selected donor site are their main drawbacks. The primary issues with guided bone regeneration are the possibility of membrane exposure and collapse as well as the possibility of resorption that the grafting material will experience upon membrane removal.

Traditional ridge-split techniques use oscillating or revolving saws and extremely sharp bone chisels. A mallet is used to provide precise, soft blows that push chisels into the bone. This takes a lot of time and calls for technical knowledge that is hard to acquire. Although rotating saws are faster, they can damage soft tissues like the tongue, cheek, or lips when preparing bone incisions. Additionally, the surgery is complicated by nearby teeth. In contrast to piezoelectric surgery, which does not have the risk of bone thermo-necrosis and has a lower chance of causing injury to the surrounding soft tissues, vertical incisions require more work and attention. Any shaped horizontal or vertical bone incision may be created with ease without endangering nearby structures, and there is no chance of soft tissue damage. Cavitation has the dual benefits of cleaning the workspace and increasing visibility [16].

Sinus floor elevation

A sinus-floor elevation is frequently the best way to create a sufficient donor site for implant placement in edentulous individuals with inadequate bone volume and, consequently, a lower alveolar crest height. In order to provide room for implants, the maxillary sinus floor is frequently raised. When performing an osteotomy with burs or raising the membrane with manual elevators, there is a chance that the Schneiderian membrane will sustain injury. The mineralized tissue may be easily separated thanks to the piezoelectric bony osteotomy, which slices it without rupturing the membrane. Other approaches, such as the approach from the crestal and palatal sides, have been documented, even though the lateral window is likely the most widely employed strategy [17].

Inferior alveolar nerve lateralization

The patient's quality of life depends on the inferior alveolar nerve remaining intact. In the edentulous jaw, the inferior alveolar nerve can have a variety of different locations. In the horizontal layer, the localization appears to be rather stable. This explains the lateralization of the inferior alveolar nerve and the extraction of highly impacted wisdom teeth, which are frequently found near the nerve. If implants are intended for an edentulous jaw, this surgery serves as an alternative to the augmentation approach [18].

Bone graft harvesting

Berengo M *et al.* done a comparative study on Histomorphometric evaluation of bone grafts harvested by different methods the study provides a qualitative evaluation of autologous bone harvested by 9 methods: the harvested bone was analysed through microphotography and histomorphometric analysis, measuring the surface area of bone fragments and the percentages of vital and necrotic bone. The results show that one of the best methods to harvest vital bone are is through piezo surgery [19].

When doing maxillofacial surgery with piezoelectric devices instead of surgical burs or oscillating saws, there is a 25-30% decrease in blood loss. The decrease in blood loss might be attributed to many sources. Effects of a piezoelectric device on biology on bone. In regenerative surgery, the impact of mechanical tools on bone form and cell survival is crucial. Even brief exposure to relatively high temperatures can harm cells and result in tissue necrosis [8].

Enucleation of jaw cysts

Piezoelectric devices can be used more successfully to remove both odontogenic and nonodontogenic cysts of the jaws. Piezo surgery facilitates the safe removal of cysts without endangering other critical structures and encourages bone repair following the procedure. The ability to carefully remove the thin layer of bone covering the cyst and handle it without rupturing the epithelial wall is one obvious benefit of piezo surgery over traditional methods. This might lower the incidence of problems and postoperative recurrence [20].

Other indications include utilizing ultrasonic oscillations, piezo surgery was frequently utilized to remove shattered instruments from root canals, as well as supragingival and subgingival plaque. The typical operating frequency for ultrasonic scalers is 20 kHz. By eliminating the necessity for root sectioning, ultrasonic piezoelectric retro tips lower the danger of apical leakage and the quantity of exposed dentinal tubules. Additionally, it provides better cavity wall cleaning and a smaller smear layer volume during root canal therapy [21]. Other indications include Soft tissue debridement, smoothening of root surfaces, removing an implant, retrograde root canal preparation, apicectomy, cystectomy, extraction of ankylosed teeth, and orthognathic surgeries [22, 23].

Limitations

Absolute Contraindicated in patients with Cardiopathy, patients with uncontrolled diabetes mellitus, patient receiving radiotherapy, patients with metal/ceramic crowns, patients with pacemakers [24].

Conclusion

Piezo surgery, also known as piezo-electric surgery, is a type of hard tissue surgery that may be performed using multifunctional, high-end ultrasonic units by adjusting the basic ultrasonic unit's parameters. In addition to providing the operator with the ability to perform clear-cut, precise osteotomies in a bloodless, transparent field without the risk of harming soft tissues and nerves, piezo surgery can also help patients by reducing postoperative swelling and trismus and expediting the healing process.

Conflict of Interest

Not available

Financial Support

Not available

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How to Cite This Article
Rilna P, Vishwanathan C, Sudhakaran A, Aswin, Athira. Advances in piezoelectric Instruments: Applications and outcomes in oral sugery. International Journal of Applied Dental Sciences. 2025;11(1):240-243.