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Original Research Article

Piezo-surgery in oral and maxillofacial surgery

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ABSTRACT
The aim of this review is to evaluate the role of piezo surgery in the branch of Oral and Maxillofacial Surgery (OMFS). Piezo-surgery works on the principle of ultrasonic micro vibrations without causing any damage to the surrounding soft tissues such as nerves and blood vessels. Piezo-surgery works by two actions: selective cutting and cavitation under the constant irrigation of fluid. It has become a gold standard for delicate procedures like sinus floor elevations and ridge expansions in Implantology, atraumatic extraction of impacted third molars, orthognathic surgeries, cyst enucleation and reconstructive trauma cases. Patients reported with significantly less postoperative pain and swelling. Piezo-surgery takes a longer operating time and has high cost of equipment. The results are considerably good with piezo-surgery but it requires more patience and financial investment than conventional methods.

1. Introduction

The success of any dental procedure depends upon the technique used. The evolution of surgical techniques is the cornerstone in the modern dentistry. For decades, clinicians were dependent on traditional tools like rotary instruments and burs. They are very commonly used but they still has lot of disadvantages. The most important disadvantage is that they generate frictional heat during the bone cutting which can cause necrosis of the bone. In order to prevent it, continuous irrigation is required [1]. Moreover, they require high mechanical pressure to work with which can cause an issue when working with the fragile or brittle bone and can lead to the increased risk of unintended fractures [2].

In order to overcome these limitations, the concept of ultrasonic micro-vibrations was discovered. The term “piezo” originates from the Greek word piezein, and means “to press tight, squeeze” [3]. Piezoelectricity was discovered by Pierre Curie in 1888. In 1988, then Piezo-surgery was introduced by Professor Tomaso Vercellotti in the field of oral surgery to ease the surgical procedure with minimum limitations [4].

The success of piezo-surgery is based on two principles: the cavitation effect and microvibration phenomenon. When an alternating electric current is applied on any the piezoelectric crystal, it rapidly expands and contracts. It leads to the formation of high frequency ultrasonic micro vibrations that are directly transferred to the tip of the instrument. As this tip vibrates under the constant irrigation of saline, it leads to the formation of microscopic bubbles which then collapse and make the surgical field free from blood and debris. This phenomenon is known as cavitation phenomenon [5].

One of the most important feature of this technology is its selectivity. It operates at a very low ultrasonic frequency i.e. between 25 to 30 khz that allows the selective cutting of the mineralized structures like bone without causing any damage to the soft tissues such as nerves and blood vessels even if the accidental contact occurs [6]. The microvibrations allow the insert tips to move between 60 and 210 µm making the procedure highly under the control of the operator [7].

It is widely used in dentistry in various procedures like root planing, atraumatic tooth extraction, sinus lift procedure, bone graft harvesting, lateralization of inferior alveolar nerve and implant surgery [8]. Because of all the advantages of the piezo-surgery, its major limitations cannot be ignored. One of the major concern is the longer operative time as compared to the high speed rotary burs and due to the electromagnetic nature of the device, it is strictly contraindicated for patients with cardiac pacemakers [1].

Mechanism of action: The mechanism of action of piezo-surgery is a combined effect of physics and mechanical engineering. It was designed to create an ease in the mechanical bone cutting. Based on the recent research papers, the process of piezo-surgery can be easily explained in three

steps: the piezoelectric effect, the tissue selective micro vibrations and the cavitation phenomenon.

1. The Piezoelectric Effect

The piezoelectric effect forms the foundation of the mechanism. It involves the conversion of the electrical energy into the mechanical energy. The piezoelectric handpiece consists of piezoelectric ceramic rings which are subjected to an alternating electrical current. This causes the crystals to rapidly contract and expand leading to the generation of ultrasonic vibrations [4,5]. These vibrations are then amplified and transmitted to the surgical insert tip [23].

2.Tissue Selectivity and micro cutting

The piezoelectric tip moves in a linear or slightly elliptical path unlike the traditional burs that works by rotation. The device operates at a low ultrasonic frequency ranging between 25 and 30 kHz [6, 17]. These micro-vibrations allow the insert tips to move within a very small range i.e. between 60 and 210 µm [7, 23]. This small range enables the surgeon to make precise micrometric cuts with enhanced tactile control [5, 21].

One of the most important advantage of piezo-surgery is its selectivity. Because of the low frequency micro vibrations generated between the range of 25–30 kHz, the tip is able to cut the mineralized tissues like bone and teeth effectively [6, 23]. In contrast to the elastic soft tissues such as the Schneiderian membrane, nerves, and blood vessels, which only vibrate at the same frequency without being torn or cut [3, 20]. This protects the vital anatomical structures even in the case of accidental contact [6, 8].

3. The Cavitation Effect

The cavitation effect is the result of the interaction between the vibrating tip of the handpiece and the irrigation fluid (usually sterile saline). As the tip vibrates at a very low ultrasonic speed it forms the microscopic bubbles in the field, which ultimately implode and generate the shockwaves. It leads to the "cavitation effect" in the coolant [4, 17]. It performs two important functions:

(a) Hemostasis: The implosion of the microscopic bubbles helps the small blood vessels to collapse which leads to the bloodless surgical field [5, 23].

(b) Cleaning: The turbulence created by the shcokwaves wash away the debris from the surgical site maintaining a clear line of sight for the surgeon [5, 7].

2. Materials and methods

The Piezo-surgery unit setup consists of components that convert the electrical energy into the ultrasonic vibrations.

1. The Control Panel

The control panel acts as the brain of the setup and manages the ultrasonic output. It has a digital touch panel that allows the surgeon to select specific programs based on the density of the bone whether it is highly mineralized cortical bone or softer cancellous bone. Frequency can be adjusted between the range of 25 and 30 kHz. It is connected to a handpiece and interchangeable inserts**.**

2. The Piezoelectric Handpiece

It is connected to the control panel by a flexible cord. The handpiece consists of ceramic rings that rapidly expand and contract when an electric current is applied leading to the formation of micro vibrations. It is very easy to handle the handpiece because of its lightweight. So, it provides high tactile sensitivity during the delicate procedures like sinus floor elevations or ridge expansions.

3. Specialized Surgical Tips and Inserts

The working end of the device consists of various interchangeable tips that can be fitted in the handpiece using a torque wrench to ensure they are secure. The torque wrench is used to ensure that the tips are attached with the adequate amount of pressure required for the generation of ultrasonic vibrations without damaging the handpiece.

These tips come in various shapes and coatings depending on the clinical use:

- Sharp Tips: Used for efficient osteotomies and bone harvesting.
- Diamond Coated Tips: Ideal for precise work near delicate membranes.
- Blunt/Smooth Tips: Designed for atraumatic procedures like lifting the sinus membrane without causing perforation.

4. Integrated Irrigation System

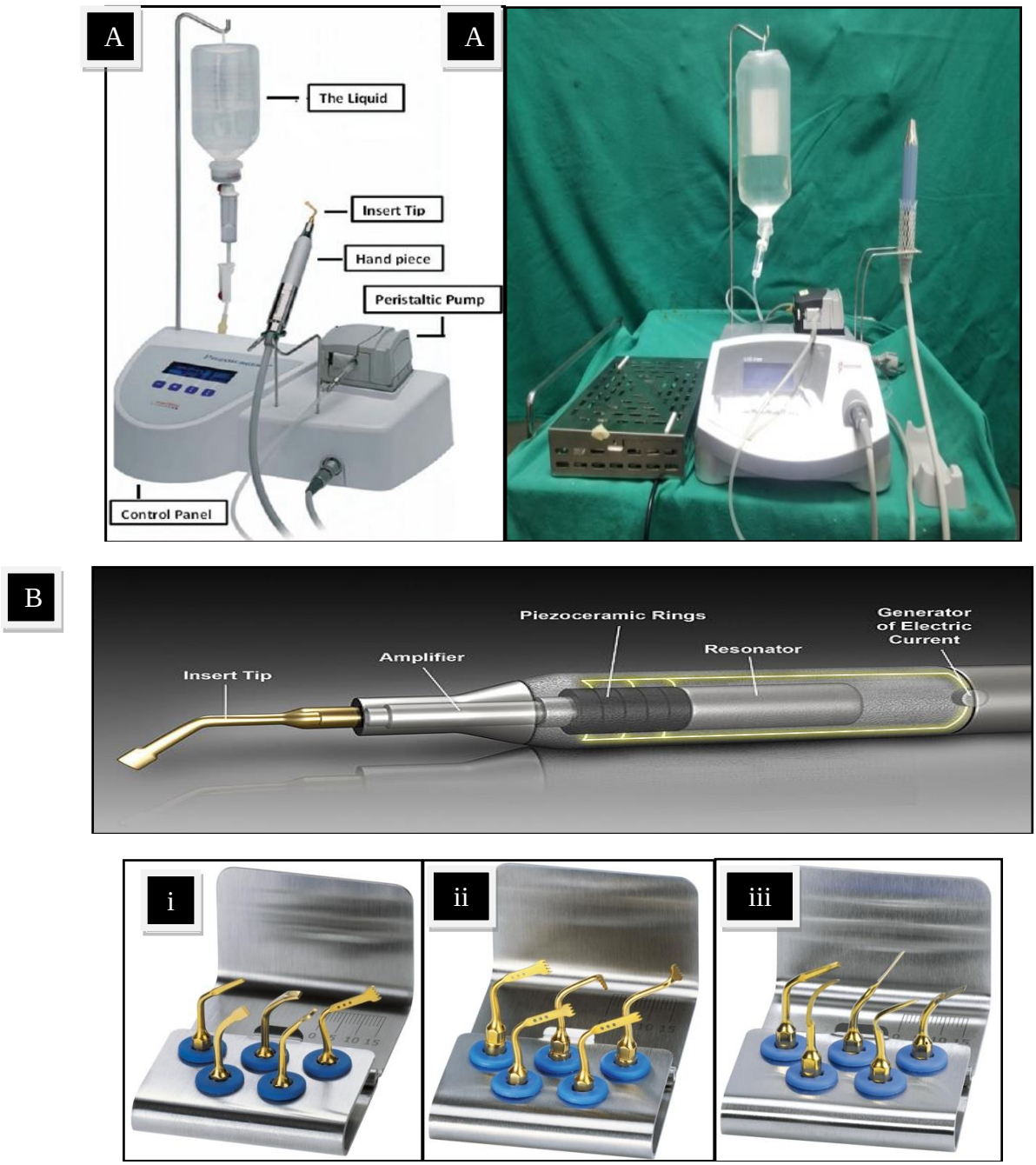
A builtin peristaltic pump is present in order to prevent the bone from overheating and to maintain a clear field of vision. The system is connected to a bottle of sterile saline which is directly transferred to the surgical tip through a tube. The liquid used for irrigation was sterile saline which is refrigerated at 4°C before the use. The constant flow of cool irrigating fluid serves a dual purpose: it prevents thermal necrosis of the bone and clear away blood and debris to make the surgical site visible through the cavitation effect.

5. The Multi-Function Foot Pedal

To maintain a completely sterile environment, the foot pedal can be used to operate the system. This handsfree system allows the clinician to start and stop the ultrasonic vibrations and adjust the irrigation flow rate without touching the main unit during the surgery.

6. Sterilization and Maintenance Kits

The equipment must be autoclavable because the device is used in surgical operations. This setup includes the specialized trays for the sterilization.



A. piezoelectric handpiece along with insert tip, B. Insert tips: (i) Basic kit (OT2, OT7, OP1, OP3 and EX1), (ii) Osteotomy kit (OT7, OT7S-4, OT7S-3, OT8R, OT8L), (iii) Extraction Kit (EX1, EX2, EX3, PS2 and PS6).

Clinical applications in oral and maxillofacial surgery

- Sinus Floor Elevation: It safely removes the bone without perforating the delicate Schneiderian membrane.
- Ridge Expansion: Ridge expansion can be done for the implant placement.
- Atraumatic Third Molar Surgery: Used for the atraumatic extraction of impacted third molar.
- Bone Harvesting: Ideal for collecting high quality bone blocks or chips for grafting.
- Periodontal Surgery: Useful for crown lengthening and cleaning root surfaces with minimal trauma.
- Nerve mobilization or nerve transposition: Allows the surgeon to remove the highly dense bone around the nerve without causing any damage to the nerve, even upon accidental contact.
- Cyst removal: Enables the creation of a bony windows to without puncturing the thin cystic lining.
- Orthognathic Surgeries and Osteotomy of malunited segments: Can create micro metric cuts during major jaw realignment such as Le Fort I or mandibular osteotomies.

In the recent studies, a piezoelectric surgical unit system was used to perform various procedures across four different surgical procedures. All the procedures were conducted under local anesthesia (2% lignocaine with 1:80,000 adrenaline) or general anesthesia, depending on the complexity of the case and patient anxiety levels.

1. Third Molar Extraction

In case of impacted third molar extraction, a full-thickness mucoperiosteal flap was reflected to visualize the bone. Instead of using a high-speed rotary bur, a saw shaped tip was

used to perform the buccal guttering because traditional instruments are not capable of differentiating between the mineralisation and hardness of bone and teeth [25]. Also, the piezo produces the micro vibrations whereas the rotary burs that produce the macro vibrations, which annoy both the operator and the patient [26]. On tooth exposure the same tip used in a gentle sweeping motion with a minimal pressure to section the crown and roots while preserving the soft tissue and neurovascular bundle.

2. Direct Sinus Lift

Use of the traditional instruments for Cadwell Luc operation can lead to the Schneiderian membrane perforation. Profuse bleeding can also result due to the rupture of the anastomosis between the posterior superior alveolar artery and infra orbital artery which is present along the lateral wall of the maxillary sinus [25]. The piezo electric device was introduced to limit these complications. The first study on this was done by Torrella [24]. In patients requiring maxillary posterior bone augmentation (where at least 3-mm residual bone is available under the maxillary sinus floor), a diamond coated spherical tip was used to create a window until the Schneiderian membrane became visible. The hydraulic pressure generated by the device's irrigation mist was used to separate the membrane from the internal sinus wall.

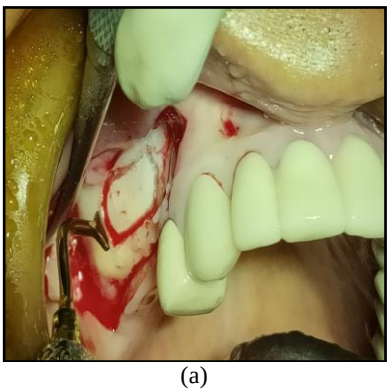
3. Osteotomy of Malunited Segments

Osteotomy of malunited segments is a corrective procedure used when a bone has healed in an improper position as a result of the fracture or the previous surgery i.e. the malunion has occurred. It can lead to the functional problems due to malocclusion or aesthetic issues such as facial asymmetry [4, 14]. In this procedure, the bone is intentionally re break where the malunion has occurred by making small cuts. This allows the surgeon to reposition the bone segments manually for the proper alignment so they can heal properly [4, 11, 14]. In the procedure, the site identification was done and a sharp piezoelectric saw was used to perform the osteotomy along the fusion line. This method preserved the vascularity of bony segments [4, 7, 14, 16]. Piezo-surgery reduces the thermal damage leading to the quick healing and presents with less postoperative swelling and pain [2, 4, 7, 15, 22] as compared to the conventional burs where cuts are not small enough which leads to more trauma to the bone and delayed healing.

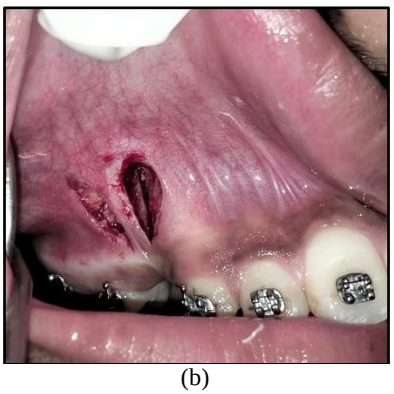
4. Corticotomy (piezo incision) for the orthodontic movements

Corticotomy is also known as piezocision when ultrasonic tools are used. It is a fast-forward method for moving teeth. While traditional braces rely on slow migration of teeth. The corticotomy temporarily softens the bone to make the process quick and more efficient [1, 8, 25].

For the movements, the surgeon made thin vertical inter proximal incisions between the with the help of a fine piezo electric knife. The linear vertical cuts were made through cortical plate without penetrating the underlying bone or damaging the roots [4, 7, 20]. The ultrasonic tip is so precise that it leads to small incisions and small flap [8, 17, 25]. So, the wound requires minimal suturing and patient generally present with less post-operative pain and swelling as compared to the traditional bone cutting methods [2, 15, 22].



(a)



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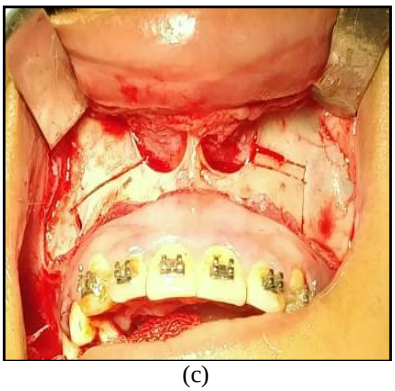

(c)

(a) Corticotomy in canine region; **(b)** direct sinus lift in implant surgery; (c) Le Fort I Osteotomy.

Advantages

- Micrometric Precision: Allows highly controlled delicate cuts in bone.
- Selective Cutting: Allow the specific cutting of hard tissue while leaving the soft tissues like nerves, vessels, and membranes unharmed.
- Cavitation Effect: Creates a bloodless surgical field for maximum visibility during the procedure.
- Enhanced Healing: Results in less postoperative pain, reduced swelling and faster tissue recovery as compared to the traditional burs.

Disadvantages

- Increased Time: Cutting through dense bone is generally slower with piezo-surgery than using conventional rotary instruments because the amount of bone removed per vibration is less. So, it takes more time to cut as compared to the high-speed bur.
- Learning Curve: It is technique sensitive
- High Cost: The equipment and the specialized tips require a significant financial investment.

3. Conclusions

In conclusion, piezo-surgery is an "emerging boom" in dental practice [1, 4]. One of the major advantages is that it protects the soft tissue and lead to better postoperative healing [3]. The most considerable limitation is the increased operative time [9]. Cutting through very dense or thick bone is slower with piezo unit than with traditional high-speed rotary burs [7, 9, 10]. Moreover, it is difficult to use in the areas with very restricted access [7, 11]. Hence, still not widely used in the field of dentistry.

Authors' contributions

All authors contributed equally to the conception, design, experimental work, data analysis, interpretation of results, and preparation of the manuscript. All authors reviewed and approved the final version of the manuscript for publication.

Conflicts of interest

The author declares no conflict of interest.

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Data availability

No new data were created.

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