Piezosurgery-Precision in Periodontics and Oral Implantology

Dr. Jayashree A Mudda[1], Dr. Pradnya P Wagh[2], Dr Veena A Patil[3]

Abstract: ***Piezosurgery is a relatively new technique of bone surgery that is recently gaining popularity in implantology, periodontics and oral surgery. The piezosurgery instrument, developed in 1988, uses a modulated ultrasonic frequency that permits highly precise and safe cutting of hard tissue. Nerves, vessels, and soft tissue are not injured by the microvibrations (60 to 200 mm/sec), which are optimally adjusted to target only mineralized tissue. The selective and thermally harmless nature of the piezosurgery instrument results in a low bleeding tendency. The precise nature of the instrument allows exact, clean, and smooth cut geometries during surgery. Postoperatively, excellent wound healing, with no nerve and soft tissue injuries, is observed. Because of its highly selective and accurate nature, with its cutting effect exclusively targeting hard tissue, its use may be extended to more complex oral surgery cases, as well as to other interdisciplinary problems. This article discusses about the wide range of application of this novel technique in periodontology.***

Keywords: Piezoelectric, ultrasonic device, piezosurgery, osteotomy, sinus lifting

1. Introduction

Dental surgical techniques have been developed rapidly over the last two decades. A new surgical technique based on the novel application of the principle of piezoelectric ultrasonic vibration is introduced with wide range of applications in dentistry and periodontics. Piezosurgery is a new and modern bone surgery technique for Periodontology and Implantology.[1] It was Pierre Curie who discovered in 1881 piezoelectricity the phenomenon that gave the basis of piezosurgery, developed in the mid 20th century. Piezoelectricity is found in some crystals that, when subjected to mechanical charges, acquire electric polarization.[2] An ultrasonic transducer is a device used to convert some other type of energy into an ultrasonic vibration. By far the most popular and versatile type of ultrasonic transducer is the piezoelectric crystal,which converts an oscillating electric field applied to the crystal into a mechanical vibration. Piezoelectric crystals include quartz, Rochelle salt, and certain types of ceramic. Piezoelectric transducers are readily employed over the entire frequency range and at all output levels. Particular shapes can be chosen for particular applications. Piezoelectric and magnetostrictive transducers also are employed as ultrasonic receivers, picking up an ultrasonic vibration and converting it into an electrical oscillation.[3,4,5] The piezosurgery device is essentially an ultrasound machine with modulated frequency and a controlled tip vibration range. The ultrasonic frequency is modulated from 10, 30, and 60 cycles/s (Hz) to 29 kHz. The low frequency enables cutting of mineralized structures, not soft tissue. Power can be adjusted from 2.8 to 16 W,with preset power settings for various types of bone density.[5] The piezosurgery tip vibrates within a range of 60-200 mm, which allows clean cutting with precise incisions.

Piezo electric bone surgery techniques have been developed for clinical applications in dentistry and are becoming state of the art for a variety of procedures.[6] Piezosurgery was invented by Vercellotti and developed by Mectron Medical Technology. The device consists of piezoelectric ultrasound transducer powered by an ultrasonic generator,capable of driving a range of specially designed cutting inserts.[7]

2. Philosophy of Piezoelectric Bone Surgery[8]

The philosophy behind the development of Piezoelectric Bone Surgery is based on two fundamental concepts in bone microsurgery. The first is minimally invasive surgery, which improves tissue healing and reduces discomfort for the patient. The amount of post-operative pain and swelling is always much lower than with traditional techniques. The second concept is surgical predictability, which increases treatment effectiveness. Indeed, the ease in controlling the instrument during the operation combined with reduced bleeding, the precision of the cut, and the excellent tissue healing make it possible to optimize surgical results even in the most complex anatomical cases.[910,11,12,13,14]

Mechanism of Action of Piezoelectric Devices:
Following are the innovative qualities of a piezosurgery device: [15]
1) Micrometric cutting action for maximum surgical precision and intraoperative sensitivity.
2) Selective cutting action for minimal damage to soft tissue,maximum safety for the surgeon and the patient.
3) Cavitation effect for maximum intraoperative visibility and a blood –free surgical site.

Distinguishing Features of Piezoelectic Surgery:[20]
1) Cavitation
2) Heat
3) Formation of bubbles
4) Ultra message
5) Electrical and acceleration

3. Characteristics of Piezosurgery Surgical Instruments[8]

The piezosurgery unit is composed of the main body, activated with a pedal, a handle, and number of inserts with different shapes depending on the surgical need.

Main Body
The main body has a display, an electronic touchpad, a peristaltic pump, one stand for the handle and another to hold the bag containing irrigation fluid.

The interactive touchpad has four keys that enable to select the feature mode, the specific program and the flow of the flowing cooling liquid. Every command is shown on the display.

There are two primary operating modes:
a. Bone Mode
b. Root Mode

Root Mode
The vibrations generated by selecting root mode are characterized by average ultrasonic power without frequency over modulation.

Two different programs:
a. ENDO Program: a limited level of power provided by applying reduced electrical tension to the transducer, which generates insert oscillation by a few microns. These mechanical microvibrations are optimal for washing out the apical part of the root canal in endodontic surgery.

b. PERIO Program: an intermediate level of power between the endo program and the bone program. The ultrasonic wave is transmitted through the transducer in continuous sinusoidal manner characterized by a frequency equal to the resonance frequency of the insert used.

Bone Mode
The vibrations generated by selecting bone mode are characterized as follows: extremely high ultrasonic power compared to root mode. Its performance is monitored by several sophisticated software and hardware controls.
Frequency over modulation gives the ultrasonic mechanical vibrations its unique nature for cutting different kinds of bone.
The selection recommended is:
- Quality 1: for cutting the cortical bone or high density spongy bone.
- Quality 3: for cutting low density spongy bone.

Special Program: was designed with a standard power level slightly lower than the bone programs and is characterized by the same frequency over modulation. The special program is dedicated to a limited series of surgical inserts that are particularly thin and delicate. The latter are recommended only for surgeons who have experience using piezosurgery and would like an extremely thin and effective cut.

Handle
The cutting action is based on the generation of ultrasonic waves by piezoelectric ceramic disks inside. These ceramic plates are subjected to an electrical field produced by an external generator and vary their volume to generate ultrasonic vibrations. These are channeled into the amplifier, which transmits them to the sharp end of the handle. The insert is tightened with a special key for that purpose. In this manner, the highest degree of efficiency is obtained for the cut and duration of the inserts.

Inserts
The design and features of all inserts used in Piezoelectric Bone Surgery have been conceived and developed by the Mectron Medical Technology. The prototype of each specific insert was developed to satisfy the specific clinical needs of each surgical technique. The inserts have been defined and organized according to a dual classification system, taking into consideration morphological-functional and clinical factors. This system helps understand the cutting characteristics and clinical instructions for each insert.

Morphological-Functional Classification:
The morphological description defines the structural properties of the insert, while the functional description outlines the cutting characteristics:
- Sharp - Cutting
- Diamond-coated - Abrasive
- Rounded – Smoothing

Clinical Classification
The clinical classification sorts the inserts (sharp, abrasive, smoothing) according to basic surgical technique: osteotomy, osteoplasty, extraction.

1. Osteotomy (OT)- OT1 - OT2 - OT3 - OT4 - OT5 - OT6 - OT7 - OT7S4 - OT7S3 - OT8R/L
2. Osteoplasty (OP)- OP1 - OP2 - OP3 - OP4 - OP5 - OP6 - OP7
3. Extraction (EX)- EX1 - EX2 - EX3
4. Implant site preparation (IM)- IM1 (OP5) - IM2A- IM2P - OT4 - IM3A- IM3P
5. Periodontal Surgery- PS2-OP5-OP3-OP3A- Pp1
6. Endodontic Surgery- OP3-PS2-EN1-EN2-OP7
7. Sinus Lift- OP3-OT1 (Op5)- EL1 - EL2 - EL3
8. Ridge Expansion- OT7 - OT7S4 - OP5 (IM1) - IM2 - OT4 - Im3
9. Bone Grafting- OT7 - OT7S4 – OP1 - Op5
10. Orthodontic Microsurgery- OT7S4 - OT7S3

The inserts for basic osteotomy, osteoplasty, and extraction techniques are used in combination with each other and with specific inserts in the surgical protocol for each technique.

Method of Use:[21]
The handpiece can be fitted with different tips for osteoplasty, osteotomy, separating soft tissue from bone, and cutting bone. When compared to oscillating micro-saws, the movement of the Piezosurgery scalpel tip is very small. The cutting is more precise and causes less discomfort for the patient. When using conventional micro-saws, the clinician must apply a certain degree of pressure. By contrast, the Piezosurgery device needs only a very small amount of pressure, which enables a highly precise cut.[16]Too much pressure limits the movement of the tip, and heat is generated. More power increases the cutting ability, but the device requires thicker tips, which cause thicker and more imprecise cuts. The 5-W power is the ideal compromise between speed and precision .[16] Piezosurgical tips have been developed for various surgical applications tip width and thickness vary according to the density of the bone being operated on and adjustments in the power setting being used.

Macrovibration and Macrovibration
Osseous surgery has been performed by either manual or motor-driven instruments. Manual instruments offer good control when used to remove small amounts of bone in areas

with relatively less dense mineralization.Motor-driven instruments are often used when bone is very dense.[16]These instruments generate a significant amount of heat in the cutting zone that must be minimized by water irrigation. Overheating of adjacent tissue may alter or delay the healing response. [1] Reduced rotational speed decreases frictional heat but also decreases cutting efficiency. Motorized cutting tools also decrease tactile sensitivity. Slower rotational speed necessitates increased manual pressure, which increases the macro-vibration of the cutting tool and further diminishes sensitivity.[1]This is particularly troublesome when cutting across an area of dense cortical bone into either trabecular bone or soft tissue, as when drilling an osteotomy above the mandibular canal or preparing a lateral window for sinus grafting. These surgical instruments can cause soft tissue complications such as lacerations or burns during osteotomy. In addition, these surgical devices are loud and produce macrovibrations during osteotomy. The noise and macrovibrations can cause fear and stress in patients when surgery is performed with local anesthesia.[17] .Piezoelectric surgery systems use ultrasonic microvibrations to create an osteotomy. These microvibrations make selective bone cuts possible .[17]The Piezosurgery device does not work on soft tissue, so the device causes little or no soft tissue trauma during intraoral bone harvesting. Nonetheless, because the mechanical energy of the device is not used to completely cut mineral structures, the energy can be passed to the soft tissue as heat. Cooling is ensured via the device's pump system. For effective cooling, the solution is refrigerated at 4°C.

Advantages

- Micrometric cutting action
- Selective cutting action: minimum soft tissue damage - ultrasonic frequency used does not cut soft tissue
- Maximum intra-operative visibility (cavitation effect)
- Minimum surgical stress - Excellent tissue healing .The cutting action is safe, less invasive, producing less collateral tissue damage, which results in faster healing.
- Sterile water environment for better asepsis (free from contamination).
- Creates a virtually bloodless surgical site.[1]
- Piezosurgery inserts do not become hot which again reduces the risk of postoperative necrosis.[1]

Disadvantages

- Operating time for osteotomies is slightly longer than with traditional saws,[16]
- increasing the working pressure impedes the vibration of devices that transform the vibrational energy into heat, so tissues can be damaged.[18,19]
- The technique can be difficult to learn.[20]

Indications: [21,22]

a) Periodontology

1. Crown lengthening technique.
2. Resective and Regenerative Surgery.

b) Implantology

1. Maxillary sinus lift
2. Ridge expansion (crestal splitting),
3. Alveolar nerve decompression,
4. Harvesting techniques.

c) Oral surgery

1. Dental extraction,
2. Third molar extraction
3. Osteogenic distraction,
4. Cyst removal
5. Endodontic surgery,
6. Bone harvesting (chips and blocks) and bone grafting.
7. Cystectomy [22]

d) Orthodontic Surgery

1. Osteotomy and Corticotomy

Applications in Periodontology and Implantology:[1,8,21]

The removal of supra and subgingival calculus deposits and stains from teeth, periodontal pocket lavage with simultaneous ultrasonic tip movement, scaling, root planing and crown lengthening, periodontal ostectomy and osteoplasty procedures requires careful removal of small quantities of bone adjacent to exposed root surfaces to avoid damaging the tooth surface .[23] The piezosurgery device is used to develop positive, physiologic architecture of bone support of the involved teeth. The piezosurgery device can be used for soft-tissue debridement to remove the secondary flap after incision through retained periosteum. By changing to a thin, tapered tip and altering the power setting, the piezosurgery device can be used to debride the field of residual soft tissue and for root surface scaling to ensure thorough removal of calculus. Osteoplasty and ostectomy is performed using the piezosurgery device to create positive architecture for pocket elimination surgery .[23] The device allows for precise removal of bone, with minimal risk of injury to underlying root surfaces. Final smoothing of root surfaces and bony margins using a specific ultrasonic insert,creates a clean field, with ideal bony architecture ready for flap closure. The piezosurgery device is used in bone grafting of an infrabony periodontal defect. Autogenous bone can be readily harvested from adjacent sites with minimal trauma and therefore minimal postoperative effects[24] .Implant site preparation, implant removal [25] and bone harvesting, bone grafting and sinus lifts can be done with much ease and less soft tissue trauma.

Biological Effects on Bone Cut by a Piezoelectric Device [8,21]

The effects of mechanical instruments on the structure of bone and the viability of cells is important in regenerative surgery. Relatively high temperatures, applied even for a short time, are dangerous to cells and cause necrosis of tissue. There have been several studies about the effect of piezoelectric surgery on bone and the viability of cells .[26,27] Recently autologous bone that had been harvested by different methods (round bur on low and high-speed handpiece, spiral implant bur on low-speed hand-piece, safe scraper, Rhodes back action chisel, rongeur pliers, gouge shaped bone chisel, and piezoelectric surgery) was examined using microphotography and histomorphometric analysis that evaluated particle size, percentage of vital and necrotic bone, and the number of osteocytes /unit of surface area. The results showed that the best methods for harvesting vital bone are: gouge-shaped bone chisel, back action, enblock harvesting, rongeur pliers, and piezoelectric surgery. It confirmed earlier studies the effects of piezoelectric devices on chip morphology and cell viability when harvesting bone chips.[28,29] Bone that has been harvested with a round bur on low and high speed hand-pieces, a spiral implant bur,or safe scrapers, is not suitable for grafting because of the absence of osteocytes and the predominance of non-vital bone.

Insert Tips[21]

Smoothing Insert Tips

The smoothing insert tips have diamond surfaces enabling precise and controlled work on the bone structures. Smoothing insert tips(Fig 1 and 2) are used in osteotomy when it is necessary to prepare difficult and delicate structures.For example, those preparing for a sinus window or access to a nerve. In osteotomy, smoothing insert tips are used to obtain the final bone shape.


Figure 1 **Figure 2**
Smoothing Insert Tips

Sharp Insert Tips

The sharp edge of the insert tips enables gentle and effective treatment of the bony structures. Sharp insert tips(Fig 3and 4(A and B)) are used in osteotomy whenever a fine and well-defined cut in the bone structure is required. There are also insert tips with sharp edges that are used for osteoplasty techniques and/or harvesting bone chips.

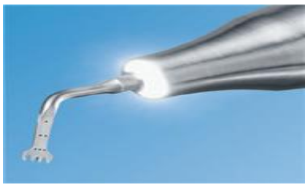


Figure 3 **Figure 4**
Sharp Insert Tips

Blunt Insert Tips

Blunt insert tips(Fig 5) are used for preparing the soft tissue. For example, for elevating Schneider's Membrane or for lateralizing nerves. In periodontology, these tips are used for root planing .

Figure 5: Blunt Insert Tips

Insert Tips Color

Gold colour is used for all insert tips used to treat bone. The gold color of the insert tips is obtained by applying a coating of titanium nitride to improve the surface hardness which means a longer working life. Steel is used for all insert tips used to treat soft tissue or delicate surfaces such as the roots of teeth.

4. Discussion

Piezosurgery is a relatively new surgical technique for periodontology and implantology that can be used to complement traditional oral surgical procedures, and in some cases, replace traditional procedures .[24] Useful in a variety of surgical procedures, piezosurgery has therapeutic features that include a micrometric cut (precise and secure action to limit tissue damage, especially to osteocytes), a selective cut (affecting mineralized tissues, but not surrounding soft tissues), and a clear surgical site (the result of the cavitation effect created by an irrigation/cooling solution and oscillating tip). Because the instrument's tip vibrates at different ultrasonic frequencies, since hard and soft tissues are cut at different frequencies, a selective cut enables the clinician to cut hard tissues while sparing fine anatomical structures (e.g., schneiderian membrane, nerve tissue). An oscillating tip drives the cooling-irrigation fluid, making it possible to obtain effective cooling as well as higher visibility (via cavitation effect) compared to conventional surgical instruments (rotating burs and oscillating saws), even in deep spaces. As a result, implantology surgical techniques such as bone harvesting (chips and blocks), crestal bone splitting, and sinus floor elevation can be performed with greater ease and safety. Piezoelectric bone surgery seems to be more efficient in the first phases of bony healing; it induces an earlier increase in bone morphogenetic proteins, controls the inflammatory process better, and stimulates remodelling of bone as early as 56 days after treatment .[14] The low pressure applied to the instrument enables a precise cut; additionally, the selective cut characteristically protects soft tissues. Nerve transpositioning, sinus floor elevations, distraction osteogenesis, and a number of other sensitive procedures are easier and safer to perform with Piezosurgery.[14]There are few limitations. Operating time for osteotomies[30] is slightly longer than with traditional saws,[16] and increasing the working pressure impedes the vibration of devices that transform the vibrational energy into heat, so tissues can be damaged[18,19] .

5. Conclusion

The piezosurgery device is a new instrument that can be used for bone surgery in a variety of dental surgical specialties. The advantage of piezosurgery is that it can precisely cut hard tissue, while precluding injury to soft tissue. Minimal heat is generated during cutting, thus maintaining vitality of adjacent tissue. It provides substantial improvement in dental/implant surgery, benefiting the surgeon by ease of use and the patient by minimizing surgical trauma and promoting rapid healing. The ultrasound unit allows for precise removal of bone with minimal risk of injury to underlying soft tissues. It allows a more successful and more complication-free surgeries. Not only does it give minimal operative invasion, but also it decreases post-intervention pain and reduces traumatic stress, not to mention less bleeding intra- and postoperatively .

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