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Piezosurgery in periodontics: A new paradigm for traditional approaches: A review

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Abstract
Piezosurgery is a new method that uses piezoelectric ultrasonic vibrations to perform precise and safe osteotomies. It was first discovered by Tomaso Vercelotti to overcome the limitations of traditional instruments in oral bone surgery. Its use was first introduced in the field of preprosthetic surgery alveolar crest expansion and sinus grafting procedures. It is a favorable, scrupulous, and soft tissue sparing system for bone cutting based on low frequency ultrasonic microvibrations. The absence of macrovibration makes the instrument more feasible and allows greater intraoperative control with increase in cutting safety in the more difficult anatomical cutting zone. This article focuses on the broad range of applications of this novel technique in periodontology.

Keywords: Piezosurgery, periodontics, osteoplasty, inserts, piezoelectric device

1. Introduction

PiezoSurgery is a relatively new technique for osteotomy and osteoplasty that utilizes ultrasonic vibration. The piezosurgery device is essentially an ultrasound machine with modulated frequency and a controlled tip vibration range [1].

Ultrasound as a phenomenon has been used medicine to cut tissue widely by different disciplines of for many years [2]. At present, the use of power ultrasonic is becoming very popular within the field of dentistry [3]. Few years ago, ultrasonic dental instruments were exclusively utilized for scaling and root planing. In the 1980's use of devices employing ultrasonics were well known for odontostomatologic surgery. The first attempts at using ultrasonics equipment in bone surgery showed good results in the cutting phase but was not strong enough for performing osteotomy in the presence of highly mineralized bone or when thicker than 1 mm. Repeated application of these instruments had an effect on the cut, but was associated with an excessive increase in temperature including the risk of subsequent bone necrosis [4].

In the last decade, a novel family of power ultrasonic devices has been successfully created to dissect hard tissue in various maxillofacial operations. The Piezosurgery Device consists of a novel piezoelectric ultrasonic transducer powered by an ultrasonic generator capable of driving a range of resonant cutting inserts. This device is designed and commercialised by Mectron Medical Technology to overcome limits of traditional instruments and to reach increasingly higher levels of precision, safety and rapidity in recovery after bone surgery. Micromotors were used earlier which were very dangerous in close proximity to delicate anatomical structures such as vessels and nerves. Also, the traditional motorized instruments generate macrovibrations which reduce the surgical safety. The cutting action of the piezoelectric drill is the result of linear microvibrations of an ultrasound nature with a range of only 60-200 µm in a longitudinal direction with control of surgical procedures in all anatomical situations.

2. Historical background

The instrument used for ultrasonic cutting of bone creates micro vibrations that are caused by piezoelectric effect, which was first described by French physicists Pierre Curie and Marie Curie, in 1880 [5]. They were the first persons who had mentioned that in direct Piezo-Effect certain crystals produce electrical current when under mechanical pressure.

This is the effect being used by the Piezosurgery device in which the electrical field is located in the handle of the saw. Dr. Tomaso Vercellotti, an Italian Periodontist felt the need to change the osseous surgery procedures to make results more predictable, improve healing, minimize trauma and provide greater safety for patients. In 1999 Dr. Tomaso Vercelloti, invented piezoelectric bone surgery in collaboration with Mectron Spa. This technology has been used commercially in Europe since 2000. In 2005, the US Food and Drug Administration extended the use of ultrasonics in dentistry to include bone surgery [6].

Fig 1: Dr. Tomaso Vercelloti

3. All about the piezoelectric device!

The equipment consists of a piezoelectric handpiece and a footswitch that are connected to the main unit, which supplies power and has holder for handpiece and irrigation fluids. The main unit comprises a platform (with a control panel with a digital display and a keypad). This piezoelectric device is with a functional frequency of 25-29 kHz and the possibility of 30 Hz digital modulation and a series of inserts of different forms with a linear vibration ranging from 60 to 200 µm. To complete the system a peristaltic pump irrigating physiological solution is present. The peristaltic pump is for cooling with a jet of solution that discharges from the insert with an adjustable flow of 0 – 60 ml/min and removes debris from cutting area. Cooling is ensured via the device's pump system. For cooling effect, the solution is refrigerated at 40C. The power of the device is 5 W (ultrasonic scaler 2 W) [7, 8].

Fig 2: Piezosurgery device and it's various parts.

The inserts used are those whose vibrations can enter in resonance with the piezoelectric ceramic chips of shaft and can be classified as follows: [FIG 3]

- Titanium nitrate coating: They are effective for osteoplasty technique or for harvesting bone chips because they have the maximum cutting efficiency, avoid corrosion, and increase working life.
- Diamond coating: Used in case of thin bone osteotomy or for complete osteotomy close to anatomical structures offering clinically less efficacious cut, histologically are more traumatic than cutting inserts, but much safer. They may be classified as:
- Sharp insert tips: Sharp insert tips 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.
- Smooth insert tips: The smoothing insert tips have diamond surfaces enabling precise and controlled work on the bone structures. Smoothing insert tips 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.
- Blunt insert tips: Blunt insert tips 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 [9].

4. How Does This Work?

Ultrasonics is a branch of acoustics dealing with sound vibrations in a frequency that ranges above the audible level i.e., >20 kHz where sonic is an ultrasound wave of high amplitude produced by three different methods.

- Mechanical Method – up to 100 kHz
- Magnetostatic Method – 18–25 kHz
- Piezoelectric effect – 25–50 kHz

In piezoelectric ultrasonic devices, the frequency is created by driving an electric current from a generator over piezoceramic rings, which leads to their deformation [10]. The resulting movement from the deformation of the ring sets up a vibration in a transducer and/or amplifier, which creates the ultrasound output. These waves transmitted to the handpiece tip, also called an insert, where the longitudinal movement results in cutting of osseous tissue by microscopic shattering of bone [11]. The conversion of electrical pulses to mechanical vibrations and the conversion of returned mechanical vibrations back to electrical energy is the main aim for ultrasonic testing. The active element is the transducer as it converts the electrical energy to acoustic energy, and vice versa. The active element is a piece of polarized material (some parts of the molecule that are positively charged and other parts of the molecule are negatively charged) with electrodes attached to two of its opposite ends. When an electric field is applied through the material, the polarized molecules will align themselves with the electric field, resulting in induced dipoles within the molecular or crystal structure of the material. This alignment of molecules will cause the material to change dimensions. This method is known as electrostriction. Also, a permanently-polarized material such as quartz (SiO_2) or barium titanate ($BaTiO_3$) will produce an electric field when the material changes dimensions as a result of an imposed mechanical force. This process is known as the piezoelectric effect. Cavitation is the microboiling phenomenon that occurs in liquids on any solid–liquid interface vibrating to an intermediate frequency, corresponding to a rupture of the molecular cohesion in liquids and the appearance of zones of depression that fill up with vapor until they form bubbles that are about to implode. Cavitation occurs when the water spray contacts the insert vibrating to intermediate frequency [12].

5. Piezosurgery in Periodontics- Its Implementation

Applications of piezosurgery in the field of periodontology are as follows:

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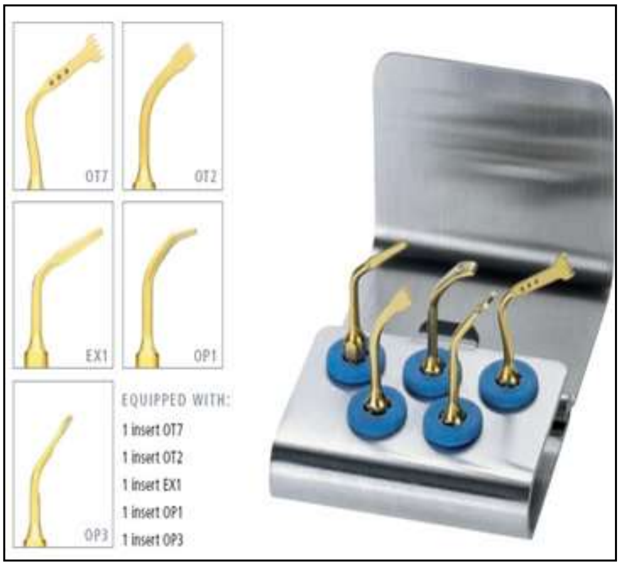

Fig 3: Inserts

6. How does this work?

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7. Piezosurgery in periodontics: its implementation

Applications of piezosurgery in the field of periodontology are as follows

Supragingival and subgingival scaling and root planning [13]. (FIG 5)

- Periodontal pocket lavage [14].
- Crown lengthening [15]. (FIG 6)
- Soft tissue debridement
- Resective surgeries
- Regenerative surgeries - To obtain autogenous grafts for treatment of periodontal intrabony defects.

In Implantology

- For harvesting Block (bone) grafts and eventually implant placement in the recipient sites [16]. (FIG 6)
- Osteotomy procedures
- Distraction osteogenesis followed by Implant placement [17].
- For Retrieval of blade implants
- Ridge Expansion and implant placement.
- Maxillary sinus elevation procedures
- Drilling hole in the bone for implant placement
- For insertion of implant.

Fig 4: Crown Lengthening Procedure

Fig 5: Scaling and Root

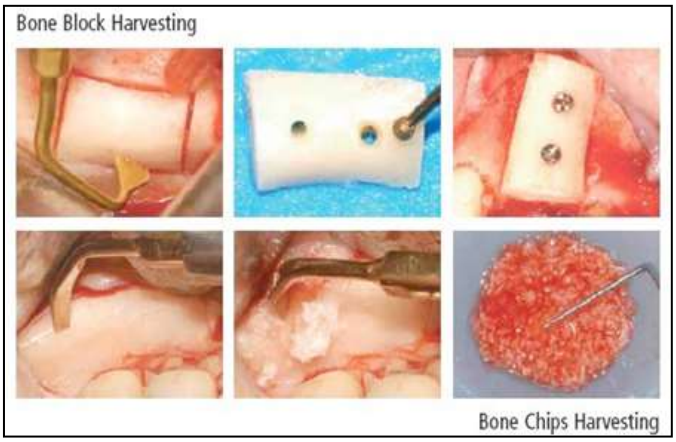

Fig 6: Harvesting Block (bone) grafts and eventually implant placement in the recipient sites.

8. Biological effects on bone cut by piezoelectric device

The effect of mechanical instrument on structure of bone and viability of cells is important in regenerative surgery. Its effect on the cortical and cancellous bone and the surface roughness produced by different osteotomy techniques all have a strong biological effect on the bone and healing of the bone.

For piezoelectric osteotomy the cutting speed can be selected (depending on the indication and on the condition of the tissue) by modulating the frequency and amplitude on the piezo surgical unit.

The comparatively low amplitude of the cutting tool, as opposed to that of an oscillating saw, yields more precise cutting in clinical practice [18]. The blood free surgical site is another advantage, as it gives a better intraoperative view. Local overheating, Flow of the cooling fluid, cavitation effects, or intravascular thrombosis caused by the use of piezoelectric tools may be possible explanations for the absence of blood at the osteotomy site [19].

9. Benefits of piezosurgery device over the traditional surgical equipment's

Compared with the conventional rotary instrumentation, piezosurgery requires much less hand pressure. The micromotors used in bone surgery transform the electric energy into mechanical energy; the cutting is, therefore, the result of rotation produced by the movement of the drill or by the oscillating movement of the bone saw [20]. The drill produces a cutting action, combining the speed and the torque of the drill, with the pressure exerted on the handle and the cutting action of the bur. Nevertheless, it is this very pressure that makes the surgical procedure more difficult to control and, therefore, less safe. This results in better operator sensitivity and control, stating that the clinician can develop a better sense and precision for the cutting action because of the microvibration of cutting tip. The cutting action is less intrusive, producing less collateral tissue damage, which results in better healing. Due to the cavitation effect on physiological solutions (like blood), piezosurgery creates a bloodless surgical site that makes visibility in the working area much clearer than with conventional bone cutting instruments. Unlike traditional burs and micro saws, piezosurgery inserts do not become hot, which again reduces the risk of postoperative necrosis [21].

A study was done to investigate the influence of a new piezoelectric device, designed for harvesting autogenous bone chips from intra-oral sites on chip morphology, cell viability and differentiation. 69 samples of cortical bone chips were randomly gained by either (1) a piezoelectric device (PS), or (2) conventional rotating drills (RD). Results showed 88.9% of the RD and 87.9% of the PS specimens, an outgrowth of adherent cells nearby the bone chips was observed after 6-19 days. Confluence of cells was reached after 4 weeks. Positive staining for alkaline phosphatase activity (AP) and Osteocalcin (OC) identified the cells as osteoblasts. The analysis showed a statistically significant more voluminous size of the particles collected with PS than RD. Thus, it was concluded that, both the harvesting methods are not different from each other concerning their detrimental effect on viability and differentiation of cells growing out of autogenous bone chips derived from intra-oral cortical sites. [22].

Esteves *et al*. in his study compared the differences of osteotomies performed with piezosurgery and a conventional drill with regard to histomorphometrical, immunohistochemical and molecular analysis. This study revealed that, histologically and histomorphometrically, the bone healing showed no differences between the two groups, except for a slight higher amount of newly formed bone seen 30 days after the use of the piezosurgery device [23].

A study was conducted by Sonke Harder *et al*. to evaluate and to compare the bone cutting performance and intraosseous temperature development of 3 modern ultrasonic devices for bone surgery. The 3 devices used were Piezosurgery II professional tip OT7 (Mectron), Piezotome, tip BS1 (Acteon), Surgy Sonic tip ES007. In the experiment the handpieces were immobilized and bone specimens from mid diaphysis of bovine femur were moved in longitudinal direction under the cutting tip to a standardized depth of 3.0 mm. Intraosseous temperature development was measured and the cutting performance was defined by the time required to reach the cutting depth of 3.0mm. Among the 3 tested devices Piezotome and Piezosurgery II showed significantly higher cutting performance than the Surgy Sonic. The Piezotome produced the smallest increase in intraosseous temperature [24].

10. Advantages: Unlike traditional cutting instruments, Piezosurgery offers the possibility of a cut with the following characteristics:

- Micrometric: The insert vibrates with a range of 60-200 µm at a modulated US frequency during cutting and maintains the bone constantly clean, thus avoiding excessive temperatures.
- Selective: The vibration frequency is optimal for the mineralized tissues.
- Safe: The reduced range of the micrometric vibrations offers the possibility to perform surgery with very great precision. The cut can be controlled as easily as if drawing an outline. This enables osteotomy to be performed even in close proximity to delicate structures such as vasculo-nervous structures without damaging them. Eventual contact with soft tissue does not mean that it is immediately cut, as normally occurs with hand or mechanical instruments. The only important aspect is that, once contact is made the cutting should be immediately interrupted in order to avoid unnecessary heat on the soft tissue.
- Piezosurgery uses a modulated ultrasonic frequency that permits highly precise and safe cutting of hard tissue while adjacent soft tissue and nerve remain unharmed.
- The accuracy and selectivity of Piezosurgery is superior to conventional rotating instruments.With Piezosurgery, we can osteotomize hard tissue as precisely as possible by micrometric and linear vibrations of 60 to 200 micron/s.
- Surgical control with piezosurgery is maximum as the strength required by the surgeon to effect a cut is far less compared to that with a drill or with oscillating saws.
- Piezosurgery is a very convenient device by which it is possible to have direct visibility over whole osteotomies.
- -The slightly increased time for operation using the Piezosurgery instrument compared with that of the conventional drill, is negligible.
- Piezosurgery units are some 3 times more powerful than conventional ultrasonic units (5 Watts) which allows them to cut highly mineralized cortical bone. The reduced range and the linearity of the vibrations allow for precise control of cutting [25].

However, there are few limitations as well,

a. Increase in operative time compared to traditional cutting instrument.
b. Difficulties encountered in deeper osteotomies sites because lack of insert of appropriate length and thickness to avoid the increasing pressure of the hand preventing microvibration of the insert.
c. Adequate dexterity and gentle touch is required for this type of procedure with a different learning curve [11].

11. Conclusion

Piezosurgery belongs to the category of tools that transform critical operations in simple and feasible procedures. Effectively, surgeries performed in difficult-to-access areas come to be of less risk to soft and neurovascular tissues. With their variable frequency and variable power, multipurpose piezosurgery units are a platform for a range of applications in Periodontology, Implantology and various oral surgical procedures, making such a unit a highly efficacious tool in clinical practice. The professional skill and training for its use should also be taken into consideration, because the technique requires a longer surgical time compared with the use of conventional rotary and oscillating saws.

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