Galore International Journal of Health Sciences and Research
Vol.5; Issue: 1; Jan.-March 2020
Website: www.gijhsr.com
Review Article *P-ISSN: 2456-9321*

Piezosurgery in Periodontics

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ABSTRACT

Dental surgical techniques have been developed rapidly over the last two decades. In all these, one 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. Ultrasonic vibrations have been used to cut tissue for two decades. However, it is only in the last five - six years that experimental applications have been used routinely for standard clinical applications in many different fields of surgery.[1]Until a few years ago, ultrasonic dental instruments were exclusively utilized for tooth scaling. Ultrasonic scalers are handheld devices which remove calculus and plaque on teeth through the vibrational movements of resonant inserts driven by magnetostrictive, or piezoelectric ultrasonic transducers.[2]

In the 1980's use of devices employing ultrasonic (US) were well known for odontostomatologic surgery. The first attempts at using US 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 did effect a cut, but was associated with an excessive increase in temperature including the risk of subsequent bone necrosis.[3] In the last decade, a novel family of power ultrasonic devices has been successfully created to dissect hard tissue in various maxillofacial operations. This revolutionary surgical technique, known as piezosurgery was invented by Professor Thomas Vercellotti in 1988 to overcome the limits of traditional instrumentation in oral bone surgery by modifying and improving conventional ultrasound techonology. It is a promising, meticulous and soft tissue sparing system for bone cutting, based on ultrasonic microvibrations.[4] 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 innovative 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.[2] Use of micromotors could be 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 20-60 ɳm in a longitudinal direction with control of surgical procedures in all anatomical situations. So, Piezosurgery can be defined as a saw characterized by the versatility of a drill particularly in performing curvilinear osteotomies.[3]

This article thus aims to review Piezosurgery in Periodontics its mechanism of action, the instrument, its biologic effects on the bone, its advantages and limitations and its applications.

Key Words: Scaling, Root planning, Periodontal Surgery, Piezosurgery

INTRODUCTION

The instrument used for ultrasonic cutting of bone creates microvibrations that are caused by piezoelectric effect was first described by French physicists Pierre Curie and Marie Curie, in 1880.[4] They were the first persons who had mentioned that in direct Piezo-Effect certain crystals produce electrical current while 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. In 1999 Dr. Tomaso Vercelloti, invented Piezoelectric bone surgery in collaboration with Mectron Spa. In the United States, Vercellotti first published on this topic in 2000. 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.[5]

MECHANISM OF ACTION

Most dentists use ultrasonic scaler at some point in their careers to help in removal of plaque and calculus from root structure. The ultrasonic (or ultrasound) frequency, as the name implies, is a frequency above the audible range for humans, usually above 20 kHz. In dental applications, the frequency used ranges from 24 kHz to 36 kHz, the frequency range capable of cutting mineralized tissue. With piezoelectric ultrasonic, the frequency is created by driving an electric current from a generator over piezoceramic rings, which leads to their deformation. 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 hand piece tip, also called an insert, where the longitudinal movement results in cutting of osseous tissue by microscopic shattering of bone.[6]

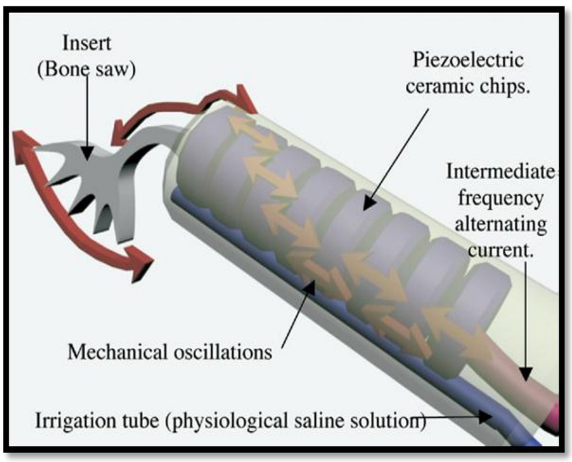

Fig 1: A piezosurgery hand piece with a piezoelectric ceramic chip.[6]

The conversion of electrical pulses to mechanical vibrations and the conversion of returned mechanical vibrations back into electrical energy is the basis for ultrasonic testing. The active element is the heart of the transducer as it converts the electrical energy to acoustic energy, and vice versa. The active element is basically a piece of polarized material (i.e. some parts of the molecule are positively charged, while other parts of the molecule are negatively charged) with electrodes attached to two of its opposite faces. When an electric field is applied across 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 phenomenon is known as electrostriction. In addition, a permanently-polarized material such as quartz (SiO2) or barium titanate (BaTiO3) will produce an electric field when the material changes dimensions as a result of an imposed mechanical force. This phenomenon is known as the piezoelectric effect.[6]

The active element of most acoustic transducers used today is a piezoelectric ceramic, which can be cut in various ways to produce different wave modes. In the early 1950's, piezoelectric crystals made from quartz crystals and magnetostrictive materials were primarily used. They also operate at low voltage and are usable up to about 300^{o}C. The first piezoceramic in general use was barium titanate which was followed during the 1960's by lead zirconate titanate compositions, which are now the most commonly employed ceramic for making transducers. New materials such as piezo-polymers and composites are also being used in some applications.

APPLICATIONS

Soft Tissue Applications of Piezosurgery devices:

Ultrasonic instrument uses high frequency mechanical energy to offer the surgeon controlled and precise incision and haemostatis. The machine operates at 55,500 Hz and requires less energy than either cutting diathermy or laser. The instrument tip vibrates at amplitude of 50 µm to 100 µm. Vessels up to 2mm in diameter may be sealed by coaptation with the blade before division. No special training or precautions are required before using the self-cleansing device. It produces considerably less smoke or smell than either diathermy or laser, which reduces the need for instrument exchanges or smoke evacuation. Resterilization of the harmonic scalpel will allow it to be used on any number of patients and appreciably reduce the procedure related expenses after initial outlay. The device has been successfully used in both open and laparoscopic general surgical, gynecological procedures and for resections of squamous cell carcinoma of the tongue. A clear, relatively bloodless field was obtained with good visibility.[7]

Fig 2: Piezosurgery device.[15]

Hard Tissue Applications of Piezosurgery devices [8]

1. Cranial Osteoplasty
2. ENT surgery, neurosurgery, paediatric surgery and orthopaedics
3. Rhinoplasty
4. Otologic surgery
5. Orthodontic Applications
   - Corticotomy
   - Exposure of impacted canines
6. Oral surgery
   - To treat TMJ ankylosis
   - Nerve mobilization or nerve transposition procedures
   - Atraumatic extractions
   - Cyst removal
7. Periodontology
   - Supragingival and subgingival scaling and root planning
   - Periodontal pocket lavage
   - Crown lengthening
   - Soft tissue debridement
   - Resective surgeries
   - Regenerative surgeries - To obtain autogenous grafts for treatment of periodontal intrabony defects.
8. Implantology-
   - For harvesting Block (bone) grafts and eventually implant placement in the recipient sites.
   - Osteotomy procedures
   - Distraction osteogenesis followed by Implant placement.
   - Ridge Expansion and implant placement.
   - Maxillary sinus elevation procedures
   - Drilling hole in the bone for implant placement
   - For insertion of implant

Scaling and root planing:

Cavitation was assumed to be able to liberate some energy for the removal of deposits. However, it has been found that using only the cavitation without the touch of the vibrating tip is not sufficient to remove the calculus, and that a direct contact between the vibrating tip and the calculus is necessary. Therefore, it is now accepted that the mechanical energy produced by the vibrating tip (chipping action) along with cavitation is responsible for the removal of deposits. The piezosurgery ultrasonic scaler set on function On/Mode Periodontics (ROOT), with the insert PS1 and PP1, applied at a medium power of two for 15 sec is used on all the surfaces for removal of deposits (Fig.3). Movements were parallel to the tooth axis and the working strokes were perpendicular to the tooth axis. The piezoelectric device appears to produce better results in terms of roughness and less damage to the root surface than the conventional magnetostrictive ultrasonic scaler.[9]

Fig 3: Scaling and Root Planing.[16]

Periodontal surgery:

The use of piezosurgery in periodontal surgery simplifies and improves handling of soft and hard tissues. In resective periodontal surgery, for example, after raising the primary flap with a traditional technique, using a scaler-shaped insert (PS2) (Fig.4) or an insert in the shape of a rounded scalpel (OP3) makes it easier to detach the secondary flap and remove inflammatory granulation tissue. This phase has little bleeding as the result of the cavitation of the saline solution (coolant). With the right inserts and power mode, the ultrasound device facilitates effective scaling, debridement, and root planing. In particular, debridement with a special diamond-coated insert enables thorough cleaning even for interproximal bone defects. The mechanical action of ultrasonic microvibrations, together with cavitation of the irrigation fluid (pH neutral; isotonic saline solution) eliminates bacteria, toxins, dead cells, and debris, which creates a clean physiology for healing. Healing is improved by applying ultrasound to produce micropits at the base of the defect to activate cellular response of healing mechanisms. The ability to work on the bone defect with magnifying systems makes it possible to exploit the benefits of piezosurgery microprecision in preparing the recipient site and stabilizing micrografts.[9]

Fig 4: Periodontal surgery.[16]

Ridge expansion:

Horizontal alveolar ridge expansion is an extremely useful technique for increasing bone width and simultaneously placing implants in narrow ridges. The great advantage is that both augmentation and implant placement are accomplished in one surgical procedure. Piezosurgery is an indispensable tool used to create a horizontal osteotomy through the alveolar bone crest caused by its precise (narrow) cutting action. In some cases (e.g., areas of dense bone with little elasticity), it may also be necessary to make one or two vertical cuts in the alveolar bone to allow ridge expansion. The horizontal osteotomy is expanded in subsequent steps using piezoelectric inserts for implant site preparation together with screw-type or fan-type expanders for increasing the diameter or section, respectively. [9]

ADVANTAGES: [10, 11, 12]

1. 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.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 μm /s.

2. Surgical control with piezosurgery is maximum as the strength required by the surgeon to affect a cut is far less compared to that with a drill or with oscillating saws. The piezosurgical handpiece reaches its highest efficiency when applying a load of 0.5 kg as compared to conventional drills thatmust be loaded with a force of 2 kg to 3 kg.
3. Piezosurgery is a very convenient device by which it is possible to have direct visibility over whole osteotomies.
4. 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.
5. Piezosurgery is accompanied by minimal intra-operative bleeding. The reason for this is that the cavitation effect creates bubbles from the physiological salt solution and these lead to implosion and generate the shock wave causing microcoagulation.
6. Visibility of the surgical site but with minimal risk of damage to adjacent oral soft tissues and with less loss of bone since the bone cut is smaller in dimension. Protects vital structures such as schneiderian membrane and nerves.
7. The surgical site during piezosurgery is surprisingly clear, because of the cavitation effect created by the interaction between the irrigant solution and the oscillating tip.
8. Faster bone regeneration and healing as oxygen molecules released during cutting have an antiseptic effect and ultrasound vibration stimulates cells' metabolism. Moreover, the lack of necrosis in the cut area accelerates bone regeneration. Soft tissue damage is not noticed.
9. Piezosurgery provides an easy harvesting of intra-or extra-oral autogenous grafts. It can be easily used in areas where it is difficult to see and reach with its angled inserts. Due to the absence of macro-vibrations, patients feel very comfortable during surgeries under local anesthesia.
10. The risk of subcutaneous emphysema is reduced due to the aerosol effect that the ultrasonic device produces unlike the effect of air-water spray generated be osteotomy with rotary instruments.
11. Decrease in post-intervention pain because of the action being less invasive and producing less collateral tissue damage, it results in better healing.
12. The device produces less noise and only microvibrations in comparison with a conventional motor, so the fear and

psychological stress of the patient are reduced.

13. Maintenance of asepsis due to sterile water environment.
14. Cooling solution is used at 4 degree centigrade which prevents damage due to overheating during the procedure.

DISADVANTAGES: [10, 13]

1. It is worthwhile stressing the fact that piezosurgery is a new cutting method; therefore, compared to other techniques, a different learning curve is necessary. In fact, correct use of piezosurgery requires overcoming psychological obstacles, as well as familiarity with handling of the surgical procedures. The learning curve for using piezosurgery for this type of application is not impossibly steep. It is important to acquire both adequate dexterity and a gentle touch.
2. To address problems with the speed of cutting during surgery, instead of increasing pressure on the handpiece (as in traditional techniques with burs and saws), it is necessary to find the correct pressure to achieve the desired result. With piezoelectric surgery, increasing the working pressure above a certain limit impedes the vibrations of the insert, and the energy is transformed into heat. Thus, the most effective way to use a piezosurgery hand piece is with a higher speed and a lower pressure.
3. One of the main disadvantages reported, so far, in the literature, regarding the piezoelectric drill, concerns the increase in the operating time, compared with that with traditional cutting instruments.
4. Another disadvantage encountered with piezosurgery was the difficulty or impossibility to perform the deeper osteotomies (eg: maxillo-pterygoid disjunction), due to lack of inserts of the appropriate length.
   Certainly, for performing osteotomies rapidly and without difficulty (particularly mandibular osteotomy), the handles and inserts, currently available, are inadequate. It is necessary not only to increase the length of the inserts, but also the thickness, in order to avoid the surgeon, in attempting to improve the cutting power, increasing the pressure of the hand, thus preventing microvibration of the insert.
5. Another modification concerns the ergonomy of the handpieces is that it should have a longer stem and with a sufficient diameter in order to be able to reach the bottom of the cavities, thus avoiding phenomena of “flatting”, typical of other osteotomy instruments, for example, the drills and saws.
6. Another feature which should not be overlooked is that concerning the economic aspects: also the purchase price of the piezoelectric drill is worth bearing in mind as it is certainly competitive with the usual drills and saws. The handles and the inserts can, in fact, be repeatedly sterilized.
7. Piezosurgery inserts get worn away very rapidly. It is recommended never to go beyond ten little uses in bone surgery. Despite their hardness, inserts do not resist very long to violence of microabrasive impacts and may break or cause damage to the tissues by uncontrollable heat.
8. The use of this device is not recommended in patients with pacemakers.

Aimetti et al. (2016) conducted a study to evaluate the early inflammatory response following osseous resective surgery (ORS) with piezosurgery compared to commonly used diamond burs. A sample was selected of 24 bilateral posterior sextants requiring ORS in 12 chronic periodontitis patients in a split-mouth design. In 12 sextants, bone recontouring was performed using a piezoelectric device. In the contralateral sextants, rotary instruments were used. Sextants treated with Piezosurgery obtained similar 12-month clinical results but lower postsurgical gene expression of interleukin-1β (IL-1β), a well-known proinflammatory cytokine, and lower patient morbidity compared with sextants treated with rotary instruments. It was cocluded that in spite of the longer surgical time, the use of Piezosurgery for ORS seems to promote more favorable wound healing compared with rotary instruments, as the lower pain and the low levels of IL-1β mRNA at the surgical sites suggest a milder underlying inflammatory response. [14]

SUMMARY:

Piezosurgery is a relatively new surgical technique in periodontology and implantology that can be used to complement traditional oral surgical procedures, and in some cases, replace traditional procedures. 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 has also been found to have additional effects regarding bone healing and seems to be more efficient in the first phases of bony healing. It has been reported that 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. 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.

Piezosurgery is accompanied by minimal intra-operative bleeding. Because the method does not traumatize bone thermally, post-surgical wound healing is rapid. In contrast, traditional cutting or drilling osteotomes are relatively crude tools, with rotating instruments capable of producing excessively high temperatures during osseous drilling, resulting in marginal osteonecrosis and impaired bony regeneration. Thermal stress with conventional bone cutting methods is a major problem clinically, and for that reason, it is strongly recommended to use careful surgical technique and to limit frictional heating with saline solution irrigation.

Other than this, one additional advantage of piezosurgery is that block grafts can be harvested with clear visibility from the surgical site with minimal risk of damage to adjacent oral soft tissues, and with less loss of bone. Less bone loss with piezosurgical device is related with smaller dimension of bone cut with this tool. Using piezosurgery tips, the harvested bone can then be modified and shaped to fit accurately to the recipient site, before being stabilized with a fixation screw. The surgical site during piezosurgery is surprisingly clear, because of the cavitation effect created by the interaction between the irrigant solution and the oscillating tip.However it must be noted that there are a few limitations. When compared with traditional saws operating time for osteotomies is slightly longer for piezosurgery. Also increasing the working pressure impedes the vibration of devices that transform the vibrational energy into heat, so tissues can be damaged.

CONCLUSION

Ultrasonic is a branch of acoustics concerned with sound vibrations in frequency ranges above audible level. Ultrasound uses the transmission and reflection of acoustic energy. A pulse is propagated and its reflection is received, both by the transducer. For clinical purposes ultrasound is generated by transducers, which converts electrical energy into ultrasonic waves. The understanding of its basic principles and properties allow us to consider more fully, the effectiveness, safety, limitations, and rationale of ultrasound in dentistry. The piezo device provides a great facility during some surgical procedures and even to some extent becomes indispensable. 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 surgical result for a less experienced surgeon that could be especially beneficial for preparation of the Schneider membrane during sinus lift procedure or relocating or preparation of the inferior alveolar nerve. Not only does it give minimal operative invasion, but also it decreases post-intervention pain and reduces traumatic stress, accompanied with minimal bleeding postoperatively.

Piezoelectric devices are an innovative ultrasonic technique for safe and effective osteotomy or osteoplasty compared with traditional hard and soft tissue methods that use rotating instruments because of the absence of macrovibrations, ease of use and control, and safer cutting, particularly in complex anatomical areas. Ultrasound bone surgery (UBS) with its various ranges of tips has a variety of applications in dentistry like in the fields of Periodontology and Implantology and Oral and Maxillofacial surgery. It also has few limitations like different learning curve, difficulty to perform the deeper osteotomies and the economic aspects of the device. But the biologic effect of UBS on bone has been reported to be more favourable for osseous repair and remodelling than conventional motorized instruments. It is also shown that use of UBS is better for osseointegration of implants than traditional drills.

Although a great deal of scientific research focuses on new products for tissue engineering and bone regeneration, the importance of minimal surgical trauma for optimal bone healing and regeneration should not be overlooked. A new appreciation for the effectiveness of piezosurgery has the potential to redefine the concept of minimally invasive surgery in osteotomy and osteoplasty procedures. Thus, piezosurgical device is a novel invention with variable frequency and variable power and is a platform for wide range of applications in minimally invasive caries therapy, prosthodontics, periodontology, oral surgery and medicine making such a unit a highly effective tool in clinical practice.

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How to cite this article: Bhagat M, Tapashetti R, Fatima G et.al. Piezosurgery in periodontics. Gal Int J Health Sci Res. 2020; 5(1): 121-129.

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