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Research paper

PIEZOSURGERY: A versatile tool in periodontology and oral implantology

Bharath Chandra GNR *, Narayan N Valavalkar, Shobha Prakash

Depmartment(s) and institution(s): Department of Periodontics, College of Dental Sciences, Davangere, Karnataka, India 577004
**Corresponding author E-mail:bharath.chandra.319@gmail.com*

Abstract

Piezosurgery is a relatively a new technique of bone surgery, that is recently gaining popularity in implantology, periodontics and oral surgery. Piezoelectric ultrasonic vibrations are utilized to perform precise and safe osteotomies. Becauseof its highly selective and accurate nature, with its cutting effect exclusively targeting hard tissue, its use may be extended to more complex oral surgical procedures, as well as to other interdisciplinary problems. It can be used for selective cutting of bone depending on bone mineralization, without damaging the adjacent soft tissue (e.g. vessels, nerves or mucosa), providing a clear visibility in the operating field, and cutting with sensitivity without the generation of heat. So this review discusses the equipment, mechanism of action biological effects on bone, indications, contraindications, advantages and disadvantages of this new technology.

Keywords: *Ultrasonic; Piezoelectric; Osteotomies*

1. Introduction

Periodontitis is a chronic inflammatory disease of the supporting tissues of the teeth which is associated with crestal bone resorption which alters the morphology of the alveolar process and also produces reverse osseous architecture at times.The treatment is largely based on the removal of local factors , and restoration of the bony architecture. Traditionally, osseoussurgery has been performed by either manual or motordriven instruments. Motorized cutting tools also decrease tactile sensitivity. Slower rotational speed necessitates increased manual pressure, which increases the macrovibration of the cutting tool and further diminishes sensitivity (Seshan H et al 2009 p 155). Microultrasonic instruments have been developed with the aim of improving root surface debridement. Piezosurgery (PS) (Mectron Medical Technology, Carasco, Italy) uses piezoelectric ultrasonic vibrations to perform precise and safe osteotomies (Bains VK et al 2008 p 55) Moreover; it reduces damage to osteocytes and permits good survival of bony cells during harvesting of bone (Labanca M et al 2008 p 265)
Piezosurgery device is a sophisticated ultrasonic device which can be used in a variety of dental surgical procedures like periodontal surgery, periapical surgery, removal of impacted teeth, in implant surgery for facilitating bone ridge expansion, in bone regeneration techniques and inferior dental nerve lateralization and trans positioning (PenarrochaDiago M et al 2008 p E143). This device is designed to cut or grind the bone without damaging the adjacent soft tissues. The mechanism of this instrument is mainly based by the "Piezo effect

2. Background and history

Piezoelectric effect was first described by French Physicist Jacques and Pierre Curie in 1880. In 1953, within the field of dentistry, ultrasonics established itself mainly in periodontology, and endodontics when Catuna first reported cutting effects of highfrequency sound waves on the dental hard tissue (Gonza;ez Garcia A et al 2009 p. 360; Stubinger S et al 2005 p. 1283)Piezosurgery was first introduced by Dr.TomasoVercellotti in 1997 First developed by Mectron (Italy) Medical Technology in 1998. (Vercellotti T et al 2001 p. 561)

3. Ultrasonics

Ultrasonics are branch of acoustics concerned with sound vibrations in frequency ranges above audible level-that is, louder than about 20 KHz. The term sonics is applied to ultrasound waves of very high amplitudes(Hema S et al 2009 p. 155) Production of Ultrasonics: can be by 3 different methods Mechanical method: up to 100 KHz, Magnetostrictive system: 18-25 KHz, Piezoelectric system: 25-50 KHz.The word 'piezo' has been derived from the Greek word termed "piezein", which means to press or squeeze. In this, mechanical energy in the form of tension and compression is converted into electrical energy (Yaman Z, Suer BT 2013 p.1) When opposite occurs i.e. Electrical energy (voltage) is converted into mechanical energy (tension and compression) it is called as Inverse Piezoelectric effect , and here the voltage is in direct proportion to Force applied.

4. Piezoelectric equipment (mectron dental indiapvt. ltd.)

Piezoelectric devices usually consist of hand piece and footswitch these are connected to the main power unit. This has a holder for the hand piece and contains irrigation fluids that create an adjustable jet of 0–60 ml/min through a peristaltic pump removing debris from the cutting area and maintains a bloodfree operating area because of cavitation (production of imploding bubbles) of the irrigation solution giving greater visibility particularly in complex anatomical areas by dispersing coolant fluid as an aerosol.(Labanca M et al 2008 p 265;Gonza;ez Garcia A et al 2009 p. 360) The instantaneous frequency is generally automatically controlled in response to the pressure load on the tip. The parameters under the control of theoperator, apart from the pressure applied, are the pulse frequency(when available), the rate of delivery of coolant fluid, and the applied power, which in some instruments is limited to 3–16W and in others has a maximum of as much as 90 W. In most instruments, power is controlled by selecting the type of bone to be cut or the procedure to be performed. The peak-topeak a mplitude of tip oscillations, typically in the range of 30–200mm in the plane perpendicular to the shaft of the working piece(some instruments also or exclusively oscillate along the shaft),ensures precise micro abrasive incision (Gonza;ez Garcia A et al 2009 p. 360).

5. Mechanism of action

Piezoelectric crystals, commonly used are Rochelle salt,quartz, and certain types of ceramics . .Applying electrical charges to the face of a piezo electric crystals result in crystal compression, and by inverting the direction of electric charge, resulting in expansion. When the piezo electric crystals like quartz or ceramic disk is placed under an alternating electric field, it is possible to alternate between compression and expansion of the crystal thus producing a series of vibrations. (Yaman Z, Suer BT 2013 p.1)This will result in an oscillating shape change of the crystal at the frequency applied which is then passed onto the workingtip.
When this series of vibrations are conducted through a piezoelectric transducer higher efficiency is obtained. The piezoelectric unit operates at frequency of 25-50 KHz.The resultant vibration produces the tip movement that is primarily linear in direction and generally allows only two sides of the tip to be active at any time. The device uses as pecifically engineered surgical instrument characterized by a surgical power that is 3-times higher than normal ultrasonicnstruments as shown in figure 2. (JashreeTukaramKshirsagar et al 2015 p.19;Deepa D 2016 p.27)
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.(Vercellotti T et al 2001 p. 561) The piezosurgerytipvibrates within a range of 60 to 200mm, which allows clean cutting with precise incisions.

6. Application in dentistry

Piezosurgical equipment can be used for retrograde preparation of root canal; it performs bone cutting withgreat precision facilitating ridge augmentation and ridge expansion,(Palti A, Hoch T 2002 p.73)tooth extraction, ankylotic tooth extraction(Vercellotti T et al 2001 p. 561) and surgical orthodontic surgeries (Grenga V, Bovi H 2004 p. 446 ; Robiony H et al 2004)

7. Application in periodontology

The piezosurgery device with avibrating tip is used for removal of supra and sub gingivaldebris, calculus and stains from teeth. Cavitation effect and micro streaming disrupts the bacterial cell wall. The inserts are placed vertically parallel to the long axis of the tooth and is moved continuously providing better patient comfort and calculus removal (Walsmsley AD 1988 p.539)Piezosurgery device are used for the debridement of the epithelial lining of the pocket wall resulting in microcauterization. Piezosurgery device can be used for efficient removal of diseased soft tissue and removal of root calculus compared to manual instruments by using thin taperedtips and altered power setting (Hema S et al 2009 p. 155)
It simplifies and improves handling of soft and hard tissues. In resective periodontal surgery, it uses a scaler shaped insert to detach the secondary flap and remove inflammatory granulation tissue. Cavitation of the saline solution (coolant) facilitates effective scaling,debridement, and root planing and bleeding is minimal .Diamond coated insert enables thorough cleaning of the inter proximal bone defects. The mechanical action of ultrasonic micro vibrations, together with cavitation of the irrigation fluid (pH neutral; isotonic saline solution) eliminates toxins, bacteria, debris, dead cells and which creates a clean physiology for healing(Carr H 1999 p.2)Healing is improved by Piezo as it produces micro pits at the base of the defect to activate cellular response of healing mechanisms. It reduces the invasiveness of traditional surgery by making surgery faster and by ensuring thorough cleaning of the surgical site. It also favours tissue healing in the osteoplasty procedure (JashreeTukaramKshirsagar et al 2015 p.19). The crown lengthening technique performed with piezosurgery using appropriate inserts makes it possible to effectively reduce bone while preserving root surfaceintegrity. The osteotomy is simple to perform using piezo surgery in direct contact with the root surface because control of the instrument during surgery is precise, even invery difficult proximity cases. Root planing can be performed very effectively using blunt ultrasonic inserts(Sherman JA, Davies HT 2000 p.530)

8. Applications in Implantology

As a new technique, implant sitepreparation can be performed with a specifically designed set of piezo surgical inserts. Piezosurgical site preparation allows for the selective enlargement of only one socket wall(Haydarpasa Teaching Hospital, Istanbul) This is called ‘differential ultrasonic socket preparation’ by primary stability and short-term survival rate of an implantwhen compared with conventional site-preparation techniques. Stelzle et al.(Stelze F et al 2012) emphasized that the applied load on the handpiece may increase the preparation speed but it may alsoincrease the negative thermal effect on the bone. Therefore, it is recommended that a maximum load of 400 g is used during implant site preparation.
In 2000, a new technique was developed that entails cutting an antrostomy (lateral window)using piezo surgery. This technique has greatly reduced the riskof membrane perforation (approximately 5% to 7%). Walla ceet al, reported the perforation rate was reduced from the average of 30% with rotary instrumentation to only 7% with piezo surgery. Piezo electric osteotomies cuts mineralized tissues without damage to the schinderian membrane piezoelectric elevators to separate and raise the membrane easily without perforation. There is no risk of damage to the adjacent structures. Cavitation cleans the working are aim proving visibility (Vercellotti T et al 2001 p. 561), (Wallance SS 2007).

9. Biological effects on bone

The effects of mechanical instruments on the structure of bone and the viability of cells are important in regenerative surgery. Relatively high temperatures, applied even for a short time, are dangerous to cells and cause necrosis of tissue. This techniques clinically effective and also histological and his to-morphometric observation of postoperative wound healing and formation of bone in experimental animal models has indicated that the response of tissue is more favorable after piezo surgery than after conventional bone cutting techniques with diamond or carbiderotary instruments (Happe A 2007 p.241),(Sohn DS 2007 p.127)
The result of a histologic comparison of the effect of a standard dultrasonic insert to a rotary bur,and a surgical chisel has shown that the ultrasonic insert, like the surgical chisel, was found to cut and not burnish bone and the rotary bur was observed to produce the smoothest surface of bone, the rate of bone healing proceeded best when the bone was removed by a surgical chisel or ultrasonic insert.(Horton JE 1975 p.536) The rate of postoperative level of

bone change was used to compare the effectiveness of this instrument with a standard carbide bur and a standard diamond bur and the results indicated that PS provided a more favorableosseousresponse than traditional carbide and diamond burs when surgical ostecto my and osteoplasty procedures were performed.(Vercellorti T et al 2005 p.543)Because the PS insert vibrated within a width of 60–200 mm at a modulated ultrasonic frequency, an increase in temperature was avoided that eliminated bone damage. Ultrasonic osteotomy preserves the bone microstructure which facilitates bone healing and, in turn, osseointegration, which is the key to implantsuccess (Rashad A et al 2012p.S110).

10. Advantages

1) Piezoelectric bone surgery seems to be more efficient in thefirst phases of bony healing; it induces an earlier increasein bone morphogenetic proteins, controls the inflammatory process better, and stimulates remodeling of bone as early as 56 days after treatment. (Preti G et al 2007 p. 716)
2) Micrometric cutting action: Precise incision with no damage to adjacent structures (Mari Grace Poblete-Michel 2009).
3) Selective cutting action: sectioning does not damage the adjacent soft tissue(Wallance SS 2007).
4) It provides faster bone regeneration and healing process
5) Great control of surgical device
6) Selective cutting and minimal operative invasion
7) Reduced traumatic stress
8) Decreased postintervention pain, andNo risk of emphysema. (Labanca M et al 2008 p 265; Deepa D 2016 p.27).

11. Disadvantages

1) The main disadvantage of the piezosurgery unit is the increased operation time that is required for bone preparation
2) Tip breakage can be frequent which makes it necessary to maintain a stock of tips.
3) The cost of ultrasonic osteotomy equipment is more than mechanical osteotomes(JashreeTukaramKshirsagar et al 2015 p.19 ; Deepa D 2016 p.27).

12. Precautions

The piezo surgery technique immensely lessens the risk of damaging soft tissues, such as sinus floor membrane, nerves, and vessels, but nevertheless precautions must be taken as the ultrasonic waves have mechanical energy, and this energy can be converted into heat and pass into adjacent tissues. For this reason the use of irrigation is essential, not only for the effect of cavitation, but also to avoid overheating. The intensity of the cooling liquid can be adjusted depending on different preparations. (Swyeta Jain Gupta et al 2015 p.1205).

13. Contraindications

There are no absolute contraindications, but one such is electrical pacemakers, in either the patient or the operator, which is a contraindication for piezo surgery. Age factor is a relative contraindication for any surgery (Swyeta Jain Gupta et al 2015 p.1205)

14. Conclusion

Piezo surgery is a new surgical technique for bone surgery with many clinical applications in dentistry. It is a promising, highly precise, and safe bonecutting system that is based on ultrasonic micro vibrations which are optimally adjusted to target only mineralized tissue and spares soft tissue, nerves, and vessels. The precise nature of the instrument allows exact, clean, and smooth cut geometries during surgery and this could be of great help in performing precise bone surgeries.

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