Advances in Bioresearch
Adv. Biores., Vol 15 (5) September 2024: 178-182

Print ISSN 0976-4585; Online ISSN 2277-1573
Journal's URL:http://www.soeagra.com/abr.html
CODEN: ABRDC3
DOI: 10.15515/abr.0976-4585.15.5.178182

Advances in Bioresearch

REVIEW ARTICLE

Piezosurgery and Its Dental Considerations: A Review

Sunita R Melwani 1* , Shalabh Mehrotra 2 , Rupinder Singh Dhall 3 , Nishant Bali 4 , Renuka 5 ,Varishu Tewari 6

[1*, 2] Department of Periodontology and Implantology, Teerthanker Mahaveer Dental College and Research Centre, Teerthanker Mahaveer University, Moradabad, India

[3,4,5,6] Department of Prosthodontics and Implantology, Himachal Institute of Dental Sciences, AMRU (Atal Medical and Research University), Mandi,H.P., India

*Corresponding Author's email Address: melwanisunita27@gmail.com

ABSTRACT

Surgical approach in dentistry has evolved with introduction of various new innovative instruments. Piezosurgical instrument is one of the recent additions to surgical armamentarium. Innovations in ultrasonic scalers based on this principle in the 1980s led to the development of a revolutionary piezoelectric bone surgery instrument in the 1990s by Tomaso Vercelloti and Mectron Medical Technology (Italy).There has been numerous research on application of this piezosurgical methods in dentistry including periodontics, orthodontics & oral surgical procedures. This article discusses the application of Piezosurgery and its dental considerations.

Keywords: *Piezosurgery, dental, osteotomy, ultrasonics, piezoelectric, microsurgery*

Received 02.06.2024 Revised 29.07.2024 Accepted 25.09.2024

How to cite this article:
Sunita R M , Shalabh M , Rupinder S D , Nishant B , Renuka ,Varishu T. Piezosurgery and Its Dental Considerations: A Review. Adv. Biores. Vol 15 [5] September 2024. 178-182

INTRODUCTION

The Piezosurgical device is an ultrasonic machine having a modulated frequency with a series of inserts designed to have a controlled vibration range [1]. These instruments utilize ultrasound energy having a frequency of around 20,000 Hertz (Hz). This new and innovative device generates ultrasonic micro vibrations as a result of mechanical pressure on certain crystals like quartz, or ceramic. The "Piezo effect" was first discovered by French scientist brothers Pierre Curie and Jacques Curie in 1880.

The piezosurgical device was developed in the 1950s and have since had many applications in the medical and dental field. In dentistry, ultrasonics with a frequency of approximately 25,000 – 40,000 Hz are used [2]. Ultrasonic vibrations can be achieved by two methods: magnetic and piezoelectric [3]. In magnetostriction, changes in the magnetic field allows transfer of electric magnetic energy to mechanical energy [4]. This leads to a loss of efficiency since dual conversion of energy is required from electric to magnetic and then magnetic to mechanical.[5] For the piezoelectric method, ultrasonic vibrations are generated by mechanical deformation of quartz or piezoelectric disks. The piezoelectric transducers therefore, have a higher efficiency with reduced energy consumption than the magneto strictive transducers [5].

EARLY APPLICATIONS OF PIEZOSURGICAL DEVICE IN DENTISTRY

Ultrasonic devices were first used in prosthetic and operative dentistry for tooth preparation accompanied with an abrasion slurry [6]. They had a lower cutting efficiency when compared to conventional high - and low - speed air turbine instruments and was therefore discontinued. A rise in intrapulpal temperature was also observed.[7] However it was noted that ultrasonics had selective and accurate cutting (conservative), provided better visibility with no damage to the soft tissues and an acoustic streaming action.[2,8] These devices were then introduced in the field of periodontics in 1960s for

scaling and root planing of teeth. They were found to be as effective as hand instruments but left a rough tooth surface. With improved tip design [9] and coatings [10], these instruments are now an integral part in this field of dentistry. Ultrasonics were also introduced in endodontics for root canal preparation in the 1980s. However, due to the stiffness of the stainless-steel files, deviations and elbow formations were observed.[11] With the advent of more flexible NiTi instruments, they are no longer used for canal preparation. However, they have found a place in effective root canal irrigation due to the acoustic streaming action[12] and for the retrieval of gutta percha[13] & separated instruments[14] due to its precise preparation and high frequency vibrations. In the 1990s, they were used in orthodontics for bracket debonding[15] and it was found that bracket fracture significantly reduced to 0%.

WORKING OF A PIEZOELECTRIC ULTRASONIC DEVICE

Electromechanical transducers utilize the piezoelectric phenomenon, which is an intrinsic property of certain materials like quartz and ceramic. By exploiting the mechanical changes of these substances, ultrasonic vibrations are generated. When an electric charge is applied on the quartz/piezoceramic disk, compression of the crystal occurs, and similarly expansion is observed when the direction of the electric charge is inverted. Therefore, when this quartz/piezoceramic disk is kept under an alternating electric field, alternate compression and expansion of the crystal can be achieved that produces a series of vibrations. These vibrations when conducted through the transducer will generate micrometric movements at the instrument tip which can be used for delicate mechanical operations (removal of calculus, bone osteotomy). Piezoelectric transducers have a high efficiency with reduced energy consumption & rise in temperature.

THE PIEZOSURGICAL UNIT

Innovations in ultrasonic scalers in the 1980s led to the development of a revolutionary piezoelectric bone surgery instrument in the 1990s by Tomaso Vercelloti and Mectron Medical Technology.[5] Surgical inserts that served as working tips for the device were developed according to the specific clinical need.

The resonance frequency for the Mectron-Piezosurgery® device was kept at a range of 24,000 – 29,500 Hz coupled with forced oscillation having a frequency range depending on the type of mineralised tissue from 10 – 60 Hz. This allows the insert movement consisting of 2 oscillations with same direction but different frequency. This ingenious design makes the device to cut bone at low power with minimal debris thus reducing heat generation on the insert and tissue operated upon.[5]

The Piezosurgery unit has a main unit which is activated with a foot pedal, a handle and a number of various inserts of different shapes to suit the particular surgical need.

a) The main unit:

(i) consists of a display and keypad on which various commands are shown.

(ii) An interactive electronic touchpad that enables the surgeon to choose the feature mode, the desired program and the flow of the coolant liquid (saline).

There are three power levels based on the clinical need – low, high and boosted. The low power is reserved for orthodontic microsurgery and cleaning of the apical root canal; high power is for cleaning and smoothening the radicular surface of the tooth and; the boosted mode is used for osseous surgeries like osteoplasty and osteotomy.

b) Handle: this houses the piezoelectric ceramic disks for the generation of the ultrasonic waves/vibrations which are sent to an amplifier and transmits them to the tip of the insert.

c) Inserts: there are various inserts based on the surgical procedure – osteotomy, osteoplasty, extraction, implant site preparation, sinus lift, periodontal and endodontic surgeries, ridge expansion, bone grafting and orthodontic microsurgery. The tips of these inserts can either be titanium nitrate or diamond coated and sharp, smooth or blunt.

PROPERTIES OF THE PIEZOSURGERY UNIT

Precision in cutting - The precision in cutting of the piezosurgical unit depends on the microscopic linear vibrations. The linear oscillations occur between 20 – 80 µm and the frequency is approximately 30,000 times per second which provides microsurgical precision while cutting hard tissues.

Selective cutting action - The sharp inserts and low frequency of the ultrasonic waves permits cutting of mineralised tissue only and not soft tissues. This device is hence safe to use in areas that lie in close proximity to important anatomical structures like the maxillary sinus[16] and blood vessels & nerves[17].

Surgical control - The device produces micro vibrations leading to a reduced force applied to the handle thus enhancing surgical control.

Bloodless surgical field – The cavitation property of ultrasonic instruments which stops blood from flowing out of capillaries during cutting provides a surgical field that is blood free.[18] However, bleeding resumes after the cutting ends. This property allows the surgeon to perform the procedure in a clean field, thereby improving visibility.

Minimal operation stress – This device is minimally invasive and both patient and clinician have demonstrated reduced stress during operation using piezosurgical units. Since the micro vibrations are tolerable to the patient and due to its enhanced precision coupled with better surgical control, the surgeon has minimal stress.[5] Also studies have shown better healing of tissues when the piezosurgical unit was used.[19,20]

DENTAL APPLICATIONS OF THE PIEZOSURGICAL DEVICE

The piezosurgical® device has two primary operating modes: ROOT and BONE mode.

ROOT MODE: This consists of two different programs – ENDO and PERIO Programs. The vibrations for this mode comprise of average power without any frequency over – modulation. The ENDO program is mainly used for washing out the apical part of the root canal during endodontic surgery.

BONE MODE :The BONE mode is characterized with extremely high ultrasonic power accompanied with frequency over – modulation. Frequency over – modulation is a unique feature of the Piezosurgery® device that enables the surgeon to cut either cortical bone or low-density spongy bone.

Various applications of the piezosurgical device in the field of dentistry:

1. **Tooth extraction:** The piezosurgery instrument can be used for tough to remove teeth that may need a surgical approach. These include impacted third molars and ankylosed roots. With the piezosurgical device, there is haemostasis by the cavitation effect of the cool saline solution which is beneficial during location and removal of apical root fragments. The integrity of the alveolar walls are maintained even in situations having thin buccal walls, due to its precise cutting action and increased operator sensitivity.[5] For cases requiring sectioning of the roots within the alveolus, the piezosurgical inserts that are extremely thin should be preferred over burs since they cause minimal/no damage to the bony walls.
2. **Crown lengthening:** This is a common periodontal resective procedure in which the gingival margins are placed apically along with pericoronal ostectomy so that the supracrestal attached tissues (biologic width) is not violated when the tooth receives a restoration.[21] When the piezosurgical device is employed damage to the root surface is avoided due to its precise cutting and also provides a bloodless field. The osteoplasty that follows ostectomy when done with this device can have various advantages over the bur/chisels like unwanted bony spikes are not created since one is able to work in close contact with the root and still not damage it.[20] Also bone healing has been found to be more favourable with the piezosurgical unit than the bur.[20]
3. **Ridge expansion:** Narrow width edentulous regions that can be replaced with dental implants may require a ridge split procedure to accommodate the implant. The piezosurgical device is minimally invasive, precise, quick and provides adequate control & speedy tissue healing.[20] The specific thin inserts can be used even in extremely narrow ridges due to its precision and is capable of preparing an osteotomy depth according to the surgical requirement. It also allows for differential implant site preparation.[20] This can be explained in surgical situations where high density spongy bone reduces the elasticity of bone. This means that with a 2 mm expansion, a 4 mm implant can be placed which is not possible with traditional instruments.
4. **Maxillary sinus lift:** When the height of bone in the posterior maxilla is insufficient that it impedes the placement of a dental implant, sinus lift procedures are then employed to increase the height of bone and lift the sinus membrane. The membrane can be lifted either through the crest or by a bony window buccally. Initially the crest approach was described using manual instruments for osteotomy preparation followed by use of a mallet. This was quite effective when the bone was soft and less mineralized. However, when the crest bone was mineralized, the vibrations created by the mallet was traumatic for the patient. Studies performed comparing the conventional methods and piezosurgical device have shown a significant reduction in discomfort after one hour and two days in patients undergoing maxillary sinus lift procedure in the piezoelectric group.[22] The use of the piezosurgical device in such situations is also highly effective since the chances of sinus membrane perforation is minimal due to its selective cutting action. During any osteoplasty procedure while using the piezosurgical device, the fragments of bone can be gathered and used for grafting later which is another advantage. The sinus membrane can be separated around the perimeter of the bony window with the piezosurgical insert to eliminate any tension before manual instruments are used.

Even when 2 or 3 mm of residual bone is present, the implant site can be prepared with minimal crest fractures since it produces only microvibrations [5].

5. **Bone grafting:** This involves correction of bone deficiencies in edentulous areas by harvesting autogenous bone from common intra oral sites like the mandibular body or ramus, symphysis region, mandibular torus or maxillary tuberosity depending on the extent of defect. The piezosurgical unit has several advantages over the conventional method of burs and chisels for harvesting bone. Firstly, bone fragments can be collected in a quick and precise manner with enhanced operator control. With this, the visibility is also maintained. The process with burs is traumatic, slow and with no surgical control. Secondly, due to the macrovibrations and diameter of even the narrowest burs, some amount of graft width is always lost. However, with the piezosurgical instrument, the cuts produced are precise with minimal/no loss of graft width. Thirdly, while making the holes for the screws to retain the graft, the surgeon can hold the block between his/her fingers when using the piezosurgical device.[5] When operating with burs, however, the screw holes have to be made before the block is separated from the donor site as bur rotation can lead to dislocation of the graft [5].
6. **Orthodontic microsurgery:** Alveolar corticotomy is a new procedure that helps in the enhancement of orthodontic tooth movement especially in the adult patients and hence reducing treatment time.[23] This can be achieved with multiple traditional tools like burs and chisels. The piezosurgical device is dedicated for bone microcutting and their application in orthodontics is beneficial for this purpose. An innovative and novel technique for corticotomy that is minimally invasive was described by Dibart in 2009 [24]. This novel method involves flapless corticotomies 3 mm deep with the piezosurgical micro saw and called this procedure as "Piezocision". The piezosurgical device for this procedure enables placement of these corticotomy cuts even in areas where the roots lie close to each other (mandibular anteriors) due to dedicated inserts (micro saws) meant for this purpose. These inserts are small in size and have a width of 0.35 mm.

CONCLUSION

New, innovative techniques and equipment have made dental surgical procedures easier and quicker while allowing the tissues to heal faster and with minimal discomfort to the patients. However, adopting these new techniques and equipment require intensive training that benefits the clinician and the patient in due course of time. One such device is the piezosurgical unit.

REFERENCES

1. Vercellotti T. (2004). Technological characteristics and clinical indications of piezoelectric bone surgery. Minerva Stomatol;53(5):207-14j
2. Plotino G, Pameijer CH, Grande NM, Somma F. (2007). Ultrasonics in endodontics: a review of the literature J Endod, 33:81-95
3. Laird WR, Walmsley AD. (1991). Ultrasound in dentistry. Part 1– Biophysical interactions. J Dent. 19:14-17
4. Yen-Liang C, Hao-Hueng C, Yu-Chih C, Chun-Pin L. (2013). Application and development of ultrasonics in dentistry, J Formosan Med Assoc ;112(11):659-665
5. Vercellotti T. (2000). Essentials in Piezosurgery. Clinical advantages in dentistry. Quintessence Publisher. #rd Edition.
6. Oman CR. U(19757). ltrasonic cavity preparation J Am Dent Assoc ,55:795-803
7. Vanderlei AD, Borges AL, Cavalcanti BN, Rode SM. (2008). Ultrasonic versus high-speed cavity preparation: analysis of increases in pulpal temperature and time to complete preparation J Prosthet Dent;100:107-109
8. Van der Sluis LW, Versluis M, Wu MK, Wesselink PR. (2007). Passive ultrasonic irrigation of the root canal: a review of the literature Int Endod J;40:415-426
9. Oda S, Ishikawa I. (1989). *In vitro* effectiveness of a newly-designed ultrasonic scaler tip for furcation areas J Periodontol;60:634-639
10. Lavespere JE, Yukna RA, Rice DA, LeBlanc DM. (1996). Root surface removal with diamond-coated ultrasonic instruments: an in vitro and SEM study J Periodontol;67:1281-1287
11. Ahmad M, Ford TRP. (1989). Comparison of two ultrasonic units in shaping simulated curved canals J Endod, 15:457-462
12. Bhuva B, Patel S, Wilson R, Niazi S, Beighton D, Mannocci F. (2010). The effectiveness of passive ultrasonic irrigation on intraradicular Enterococcus faecalis biofilms in extracted single-rooted human teeth Int Endod J ;43:241-250
13. Pirani C, Pelliccioni GA, Marchionni S, Montebugnoli L, Piana G, Prati C (2009). Effectiveness of three different retreatment techniques in canals filled with compacted gutta-percha or Thermafil: a scanning electron microscope study J Endod;35:1433-40
14. Cherukara GP, Pollock GR, Wright PS (2002). Case report: removal of fractured endodontic posts with a sonic instrument Eur J Prosthodont Restor Dent:10: 23-26

15. Bishara SE, Trulove TS. (1990). Comparisons of different debonding techniques for ceramic brackets: an *in vitro* study. Part I. Background and methods Am J Orthod Dentofacial Orthop:98:145-153
16. Boyne PJ, James RA. (1980). Grafting of the maxillary sinus floor with autogenous marrow and bone. J Oral Surg ;38:613-16
17. Schaller BI, Gruber R, Merten HA, Kruschat T, Schilephake H, Buchfelder M et al. (2005). Piezoelectric bone surgery: a revolutionary technique for minimally invasive surgery in cranial base and spine injury? Neurosurgery Technical notes. Operative Neurosurgery 57(4): 56-61
18. Vercellotti T. (2005). Caracteristicas technologicas e indicaciones clincas de la cirugia osea piezoelectrica. Revista Mundo Dental :26-28
19. Stubinger S, Landes C, Seitz O, Zeilhofer HF, Sader R. (2008). Ultrasonic bone cutting in oral Surgery: a review of 60 cases [Article in German] Ultraschall Med;29(1):66-71
20. Vercellotti T, Pollack AS. (2006). The new bone surgery device: Sinus grafting and periodontal surgery. Compend Contin Educ Dent;27(5)319-25
21. Nugala B, Kumar BS, Sahitya S, Krishna PM. (2012). Biologic width and its importance in periodontal and restorative dentistry. J Conserv Dent.15(1):12-7
22. Martins M, Vieira WA, Paranhos LR, Motta RH, da Silva CS, Rodriguez C, et al. (2021). Comparison of piezosurgery and conventional rotary instruments in schneider's membrane sinus lifting: A pilot randomized trial. J Clin Exp Dent;13(8):e802-e808
23. Lee W. (2018). Corticotomy for orthodontic tooth movement. J Korean Assoc Oral Maxillofac Surg. 44(6):251-258.
24. Dibart S, Sebaoun JD, Surmenian J. (2009). Piezocision: a minimally invasive, periodontally accelerated orthodontic tooth movement procedure. Compend Contin Educ Dent;30(6):342–4, 346, 348–50.