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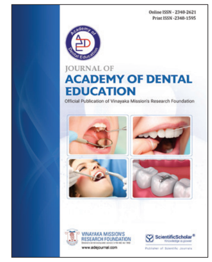

Review Article

Piezosurgery – A novel tool in modern dentistry

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ABSTRACT

Dentistry has undergone significant improvement with a lot of changing concepts involving novel surgical tools over the past two decades. Piezoelectric surgery, also popularly called as piezosurgery (PS), is a rapidly evolving technique of bone surgery which is gaining importance because of its ability to place osteotomy cuts with absolute precision and confidence, especially near the vital structures. Piezosurgical device functions with an ultrasonic frequency (25–29 KHz) resulting in microvibrations in the range of 60–200 µm/s enabling bone cutting that is secured and accurate preserving the underlying neurovascular elements along with improved visibility through bloodless surgical site and thorough debridement using internal irrigation system. Till date, PS has seen wide applications in various disciplines of medicine. In the field of dentistry, PS has emerged as a promising technical modality in bone graft harvesting, alveolar ridge expansion, sinus lift procedures, osteogenic distraction, and endodontic and periodontal surgeries. The present review addresses the efficiency of PS comparing it with the traditional dental surgical equipment. The advantages, limitations, and biological effects of PS as well its various applications in dentistry have also been discussed.

Keywords: Piezosurgery, Piezoelectric surgery, Ultrasonic frequency, Osteotomy, Implants

INTRODUCTION

Over the years, dental treatment has undergone tremendous advancements evolving into a world of painless dentistry. Traditional tools including both manual and motor-driven instruments used in osseous surgeries generated a large amount of heat that could damage the adjacent tissues or delay wound healing and hence required copious external irrigation. Moreover, these instruments exerted considerable amount of pressure and hence made treatment of fractured or brittle bones risky.[1,2] Furthermore, the noise and macrovibrations produced by the traditional motor-driven instruments resulted in fear and stress in patients during bone cutting.[3]

To overcome these limitations, a novel technique termed piezoelectric surgery or piezosurgery (PS) was developed which uses ultrasonic vibrations with an average frequency of 25–29 KHz, favoring selective cutting of hard tissues sparing the adjacent soft tissues.[4] Low surgical trauma, exceptional precision, and fast healing response associated with PS lead to treatment effectiveness and improved post-operative recovery and healing.[5]

PS is performed using piezoelectric effect, first introduced by French physicist Jacques and Pierre Curie in 1880.[6] Piezosurgical device was first invented by Dr. Tomaso Vercelloti in 1997 in collaboration with Mectron Spa[7] which later devised the 2nd generation and (2004) 3rd generation PS devices (2009).[1]

Figure 1: Piezosurgical unit.

MECHANISM OF ACTION

"Piezo" is derived from the Greek word "Piezen" meaning pressure. PS works on the principle of "pressure electrification," according to which piezoelectric effect is detected in certain crystals such as quartz, Rochelle salt, and ceramics. Piezoelectric ultrasonic frequency is developed by passing an electric current from generator over piezoceramic rings, with resultant deformation. The resultant vibration in the transducer creates the ultrasound output which is conducted to the handpiece tip, also called an insert, which exhibits longitudinal movement enabling bone cutting by microscopic shattering of bone.[8]

Frequency range of the micromovements is between 25 and 29 KHz, depending on the insert, with amplitude of 60– 210 μm which selectively cuts mineralized tissue. Soft tissues including the vital structures such as nerves and vessels would be incised by a frequency of above 50 KHz.[9] The power of the device is adjusted at 5 W. A coolant is driven through the oscillating tip while in function, thereby producing a cavitation effect.[1]

This involves vaporization of the coolant, bubble formation followed by implosion of the coolant molecule into tiny fractions of its original size. The water bubbles which explode under high pressure cause erosion and cleaning of the surgical field, thereby improving visibility and the operating skills. The cavitation effects also attribute to the antimicrobial property resulting from the fragmentation of bacterial cell wall, favoring predictable results with minimal morbidity in osseous surgery.[10]

THE EQUIPMENT AND ITS PARTS

The PS device [Figure 1] consists of a handpiece which is controlled by a foot switch.[1] Both receive power supply from a main unit which has holders for the handpiece and the irrigating coolant.[8] The vibrating frequency and the cutting efficiency of the PS tip as well as the speed of irrigation are adjusted using the foot switch with the settings of the key pad in the control panel.[11]

The irrigant refrigerated at 4°C is contained in a bottle hanging from a rod. A peristaltic pump containing the irrigating saline discharges it through a sterile tube at an adjustable rate of 0–60 ml/min to avoid overheating during bone cutting and to clear the debris from the cutting area, thereby ensuring precise cutting.[10] A continuous irrigant flow is maintained throughout the surgery by internal safety control.[1]

Insert tips

Insert tips of different sizes, shapes, designs, and materials are available which could be used for different surgical purposes. The inserts are grouped as sharp, smoothening, and blunt inserts.

Sharp inserts warrant smooth and precise bone cutting and hence used in osseous procedures such as implant site preparation, osseous shaping, and harvesting bone chips that need sharp and precise cuts.[1]

Smooth inserts present with diamond coated surface enabling an accurate and adequate control over bone. These tips can be particularly used in the management of sinus window or delicate nerve structures.[9]

Blunt inserts have an unsharpened tip which is non-cutting and is employed for soft-tissue procedures (e.g.) Schneiderian membrane elevation or nerve lateralization. These tips are also used for root planing in periodontics.[8]

The color of the tips is either golden or steel in nature. Titanium nitride imparts the gold color coating which enhances the strength as well as the shelf life of the tips which are particularly used on osseous surface. Soft tissues and the roots of teeth are managed using steel colored tips.[1] The inserts are fitted to the handpiece using a dynamometric wrench with a predefined force.[8]

The PS unit has two key programs, namely, bone and root. Based on the quality of bone, the PS device is adjusted to any four levels of bone program. Piezo or endo program can be set from the root program.[8] Clinically, three different power modes are available in the PS unit, namely, low, high, and boosted modes. Low mode is used for orthodontic surgery and apico-endo canal cleaning. High mode is employed for debriding and smoothening the osseous and radicular surfaces. Boosted mode is frequently employed in cutting and reshaping of bone.[9]

During use, the PS handpiece is placed over the surgical site firmly with optimal pressure.[11] Pressure exerted and the heat generated in the bone are inversely proportional. Moreover, increased pressure from the handpiece compromises the cutting efficiency of the insert since the oscillation of the insert is affected. Hence, with minimal pressure, the PS handpiece is moved continuously back and forth with a load of 150 g, thereby achieving maximal depth of penetration.[10,12]

The density and the degree of mineralization of bone, the insert design, and the load applied to the handpiece are a few important factors that affect the cutting characteristics of the insert. Based on the procedure to be performed, the vibrating frequency of the insert, the power settings, and the amount of coolant spray are adjusted as needed.[13]

APPLICATIONS IN DENTISTRY

Periodontics

1. Supra and subgingival scaling and root planing[8]
2. Curettage of periodontal pockets[8]
3. Crown-lengthening procedures[8]
4. Procuring bone chips/block grafting for periodontal regeneration[8]
5. Osteoplasty and ostectomy to obtain positive bony architecture of bony defects.[15]

Oral and maxillofacial surgery

1. Craniomaxillofacial surgeries[11]
2. Enucleation of cyst and tumors[7]
3. Jaw resection[1]
4. Exostoses treatment[14]
5. Removal of osteosynthetic materials[11]
6. Atraumatic extraction of 3rd molars.[7]

Implant surgeries

1. Implant site preparation[8]
2. Extraction for immediate implant placement[1]
3. Bone graft harvesting[1]
4. Alveolar ridge expansion[7]
5. Distraction osteogenesis[11]
6. Sinus lift procedures[1]
7. Nerve mobilization for implant prosthetic issues[14]
8. Removal of implants.[14]

Orthodontics

1. Orthodontic microsurgery[1]
2. Corticotomy[1]
3. Exposure of impacted canines[9]
4. Orthognathic surgeries such as LeFort I osteotomy, surgically assisted rapid maxillary expansion, and bilateral sagittal split osteotomy.[9]

Endodontics

1. Root canal preparation[1]
2. Removal of root canal fillings and fractured instruments from the root canal[1]
3. Hemisection[1]
4. Root amputation[1]
5. Apical end resection.[1]

PS VERSUS CONVENTIONAL SURGERY

Advantages

- PS units are thrice more efficient than the conventional ultrasonic units hence effectively cut osseous tissues[8]
- Micrometric and selective cutting: The inserts vibrate with a range of 60–200 μm at a modulated ultrasonic frequency facilitating accurate and secured osseous surgery conserving the adjacent vital structures better than the rotary instruments[8]
- Incisions can easily be placed on bone with lesser strength using PS and hence has maximum control when compared to surgical drills and saws[8]
- Due to the effect of cavitation, PS provides a clear operative field with minimal intraoperative bleeding hence ensuring optimal visibility[1]
- Angulated inserts of PS device favor easy procurement of autogenous bone grafts from inaccessible intraoral and extraoral sites[7]
- Sterile coolant used in the PS device maintains an aseptic environment[6]
- PS seems very efficacious in the early stages of bone remodeling hence provides faster wound healing with accelerated bone regeneration[3]
- The incidence of subcutaneous emphysema is lesser compared to osteotomy with rotary instruments[7]
- PS device produces less noise and only microvibrations compared to conventional rotary instruments hence reducing the psychological stress and fear in the patient. PS can be safely performed in pediatric and medically compromised patients.[7]

Disadvantages

- Increased operating time required for bone preparation using PS is the main disadvantage[1]
- PS needs a different learning curve to acquire both adequate dexterity and a gentle touch[7]
- Unavailability of PS inserts with appropriate dimensions makes it is difficult or impossible to perform deeper osteotomies[8]
- Tip breakage can be frequent necessitating to maintain a stock of tips[15]
- PS device is not as cost effective as the conventional instruments[15]

- PS is not advisable in patients and operator using pacemakers.

BIOLOGICAL EFFECTS OF PIEZOSURGERY

Temperature alterations associated with osseous surgeries often have an impact on the structure of the bone as well as the vitality of the bone cells.[3] Very precise customized cutting of PS done along with minimal bleeding enhances wound healing. The continuous flow of the cool irrigant decreases the ill effects of heat generation during bone cutting thereby reducing the chances of osseous necrosis.[16]

PS inserts do not generate pressure and vibrations in the bone when it is being prepared when compared to rotary instruments.[15] Piezosurgical osteotomy preserved the original bone structure with minimal surface superficial roughness when compared to conventional osteotomy techniques.[17]

Vercellotti *et al*. stated that the PS insert vibrated within a width of 60–200 μm at a modulated ultrasonic frequency avoiding a rise in temperature, thereby eliminating bone damage resulting in favorable osseous healing.[18]

Expression of heat shock protein (HSP 70), a potential biomarker of stress, is relatively lower at mRNA level and at protein level in the alveolar bone following PS compared to conventional bone cutting techniques. This indicates low stress to patients helping in cell repair after PS procedure.[19]

A few histomorphometrical, immunohistochemical, and molecular analysis comparing piezosurgery with conventional drills and oscillating saws[18] observed similar rate of bone healing but slightly more bone formation following piezosurgery.[16] Bone harvested using PS device was found to contain more osteoblast like cells.[20] Stubinger *et al*. observed better periosteal microcirculation while using PS device for subperiosteal preparation which could be an incentive for enhanced bone metabolism.[16]

PS device could delicately shape and thin a layer of cortical block that could support reconstructed alveolar process.[21] Bone blocks removed by PS contained a significant number of surviving osteoblasts and osteocytes when compared to rotary instruments.[15]

The primary stability of the implants placed using PS was found to be similar to that of conventional implant placement techniques. Moreover, osteotomy performed using PS preserves the bone microstructure, thereby facilitating bone healing resulting in optimal osseointegration which decides implant success.[15] Piezoelectric osteotomy done in distraction osteogenesis procedure before placing implants was simple with lesser intraoperative complications when compared with conventional osteotomy procedures.[22]

In sinus lift procedures, PS device cuts the bony window with simplicity and precision avoiding membrane perforation even in anatomically complex situations because of the shape of the bone scalpels which work with ultrasonic modulating vibrations.[23,24]

Osseous resective surgery performed using PS device resulted in lower post-surgical inflammatory response and minimal patient morbidity with clinical results similar to rotary instrumentation 12 months postoperatively.[25] PS device employed in crown-lengthening surgeries achieved effective bone reduction conserving the integrity of the root surface.[3] Piezosurgery, therefore, plays a promising role in osseous surgery.

CONCLUSION

Piezosurgery is an elegant and safe bone cutting mechanism which applies ultrasonic microvibrations achieving highly predictable results. The major benefits of piezosurgery include precise bone cutting, soft-tissue protection, minimal blood loss, clear surgical field, minimal sound and vibration, and good patient comfort with optimal safety to the tooth structures. Piezosurgery, in spite of the longer intraoperative time and the need to acquire professional skill and training, has transformed highly demanding procedures into easy and highly feasible procedures even in inaccessible regions. Post-operative recovery and wound healing following PS are favorable achieving optimal bone regeneration. With the emerging technological advances, piezosurgical device will be a promising modality with numerous applications in the various disciplines of dentistry.

Declaration of patient consent

Patient's consent not required as there are no patients in this study.

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Conflicts of interest

There are no conflicts of interest.

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