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Review Article

APPLICATION OF PIEZOSURGERY IN PERIODONTICS AND IMPLANT DENTISTRY

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ABSTRACT

Piezoelectric ultrasonic units have been used in periodontics and endodontics for many years. Piezosurgery (piezo-electric surgery) is one of the novel approach for hard tissue surgical procedures which can be accomplished using multi-purpose high-end ultrasonic units, with different settings. Piezosurgery is a true revolution in bone surgery with its biological and technical benefits. The precise nature of the instrument allows smooth cut geometries during surgery and enhances the visibility by providing a bloodless and debris free surgical field. This atraumatic approach secure the soft tissues and aids in releasing various cytokines which promotes bone healing.

INTRODUCTION

Dentistry has rapidly developed over the past few years with new inventions ,which uplift the quality of treatment.[1] Different techniques and surgical protocols have been proposed to treat the bone loss be it during periodontal disease, after extraction, infection, trauma or within the context of placing osseointegrated dental implants.[2] Piezoelectric vibration technique has been introduced to overcome the limitations of traditional rotary instruments such as heat produced while cutting, copious irrigation, fractured bone etc

Ultrasonics is a branch of acoustics pertaining to sound vibrations in frequency ranges above an audible level (above 20,000 vibrations per second)[3] and has been in use for many years in periodontics to remove calculus, debride root surfaces, degranulate periodontal defects[4] and more recently in maxillofacial bone surgery.[4]

Piezosurgery is a relatively new technique for osseous surgery that has been gaining popularity in surgical field involving mineralised tissues.[5] The key feature includes selective cutting of bone without damaging adjacent soft tissues, providing clear visibility in operating field without generation of heat.[7]

This article outweighs the advantages of enlightens the advantages of piezosurgery over conventional techniques.

History

Ultrasonic vibrations have been used in dentistry for past two decades in various fields. The instruments used for surgical procedure worked on the principle of microvibrations. This basic concept of microvibrations was first given by French physicists, Jean and Pierre curie in 1880 which lead to further inventions in osseous surgery.[1] Later in 1927, Wood and Loomis explained physical and biologic effects of high frequency soundwaves, this high intensity ultrasound was used in the treatment of neuromuscular and musculoskeletal surgeries.[3] Other possible uses of ultrasonics was given by Balamuth in 1952 and in the same year ultrasonics was used in the field of dentistry for the first time to prepare dental cavities[10].

Following this Eger *et al* assessed the measurement of gingival thickness using ultrasonic device.[9] Use of ultrasound in periodontics for the first time in the form of ultrasonic scalers by Zinner in the year 1955.[9] Later the 'Prophylaxis unit' was introduced by the manufacturer, Cavitron.[10] Based on this ultrasonic microvibrations, in the year 1981, Aro *et al* and Horton *et al* applied this technique in Orthopaedic surgery and Oral maxillofacial surgery respectively.[1]

Following this, an Italian oral surgeon, TomasoVercellotti modified conventional ultrasonic technology and introduced 'Piezosurgery' (piezo-derived from Greek word 'Piezein' meaning Pressure) in 1988 by utilizing innovative ultrasonic surgical apparatus known as Mectronpiezosurgical device

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introduced by Mectron and in the same year he classified the first generation of piezosurgical device.[6] Kwan and Peggy Hawkins refined the use of powered instrumentation in supragingival areas and gave the term 'Microultrasonics' in 1990.[9] Further second generation of piezosurgical device was given by Mectron in 2004 which was more powerful than the previous device and third generation of piezosurgical device was given in 2009.[1]

Parts of Piezoelectric Device

1. Handpiece
2. Base unit/ Main unit
3. Foot pedal/switch
4. Insert tips and dynamometric wrench

Base unit / main unit

The main unit consists of display, electronic touch pad, a peristaltic pump and two holders.[4] The irrigation fluid flows at a rate of 0-60m/min through peristaltic pump.[1]

The electronic touch pad consists of 4 keys to select,

1. Feature mode
2. Specific program
3. Flow of the fluid from cooling system

Feature mode

It has two feature mode,

1. Root mode
2. Bone mode

Root mode

This mode is characterised by average ultrasonic power without frequency over modulation.[4] It has 2 different programs,

A Endo program
B Perio program

Endo program

This program generates insert oscillation by few microns provided by limited level of power. It is produced by applying reduced electrical tension to the transducer (Transducer coverts electrical energy to mechanical energy in the form of vibrations. Transducer used in this device is ceramic disk). This type of vibration is used in washing out apical area of root canal in endodontic surgery.[9]

Perio program

This program is characterised by intermediate level of power.[4] The ultrasonic wave is transmitted through transducer in continuous sinusoidal manner.[4] This vibration is used in periodontics for root planing.

Bone mode

This mode is characterised by extremely high ultrasonic power compared to root mode.[4] The vibration produced is unique in nature for cutting different types of bone.[4] It has two selections,

Quality 1: For cutting cortical bone or high density spongy bone.
Quality 3: For cutting low density spongy bone.

Special program

It is characterised by standard power level slightly lower than that of bone mode.[4] This special program is designed for specific type of inserts and is limited to experienced surgeons in using piezosurgery who needs precise, extremely thin and effective cut.[4]

Insert tips

Classification of insert tips

Based on colour of tips

1. Gold- Used to treat bone. The golden colour is obtained by coating titanium nitride to improve surface hardness and also for longer working life.[6]
2. Steel - Used to treat soft tissues or delicate structures.[6]

Morphological-Functional classification

1. Sharp insert tips - for osteotomy and osteoplasty where fine and well defined cutting of bone is required.[6]
2. Smoothing insert tips - for precise and controlled cutting effect during osteotomy.[6]
3. Blunt insert tips- to prepare the soft tissues . In periodontics these insert tips are used for root planing.[6]

Clinical classification

The clinical classification includes the inserts (sharp, smoothing, blunt) according to basic surgical technique like osteotomy, osteoplasty, extraction.[6]

1. Osteotomy (OT)- OT1 - OT2 - OT3 - OT4 - OT5 - OT6 -OT7 - OT7S4 - OT7S3 - OT8R/L
2. Osteoplasty (OP)- OP1 - OP2 - OP3 - OP4 - OP5 - OP6 -OP7
3. Extraction (EX) - EX1 - EX2 - EX3
4. Implant site preparation (IM)- IM1 (OP5) - IM2A - IM2P OT4 - IM3A- IM3P
5. Periodontal Surgery (PS) - PS2-OP5-OP3-OP3A- Pp1
6. Endodontic Surgery (EN) - OP3-PS2-EN1-EN2-OP7
7. Sinus Lift- OP3-OT1 (Op5)- EL1 - EL2 - EL3
8. Ridge Expansion- OT7 - OT7S4 - OP5 (IM1) - IM2 - OT4 -Im3
9. Bone Grafting- OT7 - OT7S4 - OP1 - Op5
10. Orthodontic Microsurgery- OT7S4 - OT7S3

The inserts for basic osteotomy, osteoplasty, and extraction techniques are used in combination with each other for different surgical protocol.[4]

Mechanism of Action

Ultrasonic devices works by piezoelectric phenomenon which is an intrinsic property of certain materials commonly including quartz, rochelle salt and certain types of ceramics.[1] An electrical charge is applied to the face of the quartz plate resulting in crystal compression and expansion results by inverting the direction of electrical current.[4] When quartz plate is placed in an alternating electric field, they expand and contract alternatively to produce ultrasonic waves.[4] These ultrasonic waves are mechanical in nature, which induce disorganization and fragmentation of different bodies.[1]

The ultrasonic waves allows segmentation of interface from solid to solid by means of distinct vibration and solid to liquid by means of cavitation.[1] When a liquid is subjected to rapid change in pressure, it results in formation of cavities or bubbles within the liquid, where the pressure is relatively low.[5] These bubbles are vapour filled or gaseous bodies, formed as a consequence of force acting on the liquid.[11] The bubbles will grow in the presence of ultrasound field and will undergo breathing pulsation in response to applied pressure.[11] When there is an increase in ultrasound amplitude, the bubble pulsates and transverse waves are produced. As a result of these transverse waves, the bubble becomes unstable and gets distorted. Around this distorted bubble, microbubbles are formed which acts as new site for cavitational activity.[11]

The energy generated within these bubbles result in shockwaves which produce large disruptive forces and consequently disrupts the biological tissues in a precise manner.[10] The cavitation effect fragments the cell walls of bacteria and therefore it has an anti bacterial efficiency.[7] The cavitation phenomenon helps in ultrasonic osteotomy by maintaining good visibility in operating field by dispersing coolant fluid which causes the blood to be washed away. It also brings about haemostasis, which results in bloodless surgery.[5]

The vibrations are produced at a frequency of 25 to 29 khz. It can be modulated with low frequency of 10hz to 60hz and high frequency upto 30khz.[1] In this frequency it is targeted to cut only mineralised tissues[1]. Frequency above 50khz is capable of cutting neurovascular and other soft tissues.[1] The linear vibrations produced ranges between 60 and 200 micrometer horizontally and between 20-60 micrometer in vertical motion. The tip vibrates at controlled speed of 60-200mm/sec.[1] Power and precision are indirectly proportional to eachother. When power increases, it leads to imprecise cutting effect. Therefore power of device is adjusted at 5W which maintains the ideal balance between power and precision.[1]

Applications of Piezosurgery

Piezosurgery has its wide range of applications in the field of dentistry. The use of piezosurgical device, a novel invention is not only limited to dental surgery but also far beyond the horizon in more complex cases and in interdisciplinary works in the field of medical and dental sciences.

Applications In Medicine

1. Rhinoplasty[12]
2. Neurosurgery[8]
3. Orthopaedic surgery[8]
4. Hand surgery[8]
5. Other surgeries: Nowadays piezosurgery is used in different surgeries like otologic surgery, orotracheal intubation, stapedotomy and chain replacement using a prosthetic implant in the stapes, antrotomy, classic mastoidectomy of the intact canal wall, posterior tympanotomy, decompression of the facial nerve and excision of a glomus tumour of the middle ear[8]. In all cases piezosurgery allowed precise cutting without any post operative complications[8]

Applications in Dentistry

Piezoelectric device in oral and maxillofacial surgery

1. Piezoelectric device in dento- alveolar procedures[7]
2. Atraumatic tooth extraction[13]
3. enucleation of jaw cysts using piezoelectric device[7]
4. Piezosurgery in resection of odontogenic tumours[7]
5. Piezosurgery in treating bisphosphonate related osteonecrosis of jaw[14]
6. Other applications:

Piezosurgery also has its applications in various osteotomy procedures in oral and maxillofacial surgery.[7] Used in Lefort I osteotomy, palatal expansion after Lefort, bilateral sagittal split osteotomy(BSSO), Lefort III osteotomy in crouzon syndrome, segmental osteotomy.[7]

Piezosurgery in orthodontics

1. Applications in surgically assisted rapid maxillary expansion (SARME)[15]
2. Piezosurgery in wilckodontics[16]
3. Piezocision[17]
4. Piezosurgery for palatally impacted canine[15]
5. Piezosurgery for the acceleration of tooth movement by corticotomy[15]
6. Orthognathic surgery[15]
7. Piezosurgery in distraction osteogenesis[18]

Application in endodontics

1. Piezoelectric device in enucleation of radicular cyst[19,20]
2. Root end resection[19]
3. Root end cavity preparation[19]

Applications of piezosurgery in periodontics
Periodontal surgery

1. Piezoelectric device for crown lengthening[21]
2. Implant site preparation[22]
3. Sinus lift procedure[23,24,25,26]
4. Ridge expansion procedure[27]
5. Bone harvesting technique[28,29]
6. Piezoelectric device in nerve transposition[30]
7. Piezosurgery in treating peri implantitis and peri mucositis[31]

Biological Aspects of Piezosurgery in Bone Tissues

In any regenerative surgery, viability of cells and structure of bone plays vital role in proper healing. It has been documented that the temperature threshold for tissue survival during osteotomy is 47°C for 1 minute.[32] When the temperature exceeds this particular temperature, it leads to tissue necrosis and loss of bone. Histomorphometric analysis was done to evaluate the particle size, vitality of bone, number of osteocytes per unit surface area following piezoelectric osteotomies. It showed that there were more number of osteocytes with vital bone structure when compared to traditional drills and manual instrumentation. The bone samples taken from implant site prepared by piezosurgery was evaluated. The analysis showed that neo-osteogenesis was consistently more active than normal. There was also an early proliferation of BMP 4, TGF 2, and few proinflammatory cytokines in bone around the implants with better inflammatory process control.[8]

Advantages of Piezosurgery over Other Conventional Techniques

1. The design of the insert tips and full control over vibration rate contributes greatly to the precision of this technique. Avoiding the risk of damage to adjacent soft tissue while cutting through hard tissues.[7]
2. Piezosurgery provides the ease of harvesting intra or extra oral autogenous graft. Due to its inserts with various angles, it can be easily used in areas where it is difficult to access.[12]
3. Clear vision of the surgical area from the pressurized irrigation and haemostasis is ensured through cavitation effect[7] which is difficult to attain with other conventional techniques.
4. Healing occurs fast, because no damage is inflicted on the living osteocytes and it induces an earlier bone morphogenetic protein release.[7]
5. The cut is selective, since the vibration frequency used only cuts bone tissue, not soft tissue.
6. The surgical field remains relatively free of blood, because of the irrigation and ultrasonic effects on the irrigation solution.The integrity of adjacent soft tissues (notably the periosteum and vascular/nerve bundles) and very good visibility in the surgical field can be maintained.
7. There is some risk of tissue lesion if the technique is not used correctly (eg, if excessive pressure is applied with the insert tip, if the tip is allowed to overheat or break). This latter risk is lower with piezoelectric instruments than with conventional instruments.
8. Reduced indirect thermal damage to the bone surface and adjacent structures such as teeth.
9. It produces less vibration and noise than conventional rotary instruments and in using chisel and mallet.
10. Piezoelectric bone surgery seems to be more efficient in the first phases of bony healing. 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 which is faster than the conventional therapy.

Drawbacks

1. The main disadvantage of piezosurgery is its operative time, being longer than that of conventional techniques. The duration of the surgical procedure is longer with the application of piezosurgery.[12]
2. The piezosurgery tips were unable to reach all of the desired positions and the additional instruments are required for surgical procedures in some cases.[7]
3. Use in patients with pacemakers is not recommended.[7]
4. Purchase of a device may initially be a financial burden.[7]
5. To gain experience with piezosurgery in the oral and maxillofacial areas, more practice time might be required for clinicians.[7]
6. Increasing the pressure exerted by the operator on the piezoelectric device over bone prevents the vibration of the tip, turning energy into heat and causing thermal damage in target tissues.[7]

CONCLUSION

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. Piezosurgery ensures the 3 ‘P’s, that is Predictability, less Post operative pain and increased Patient’s compliance. It appears to be an advanced and conservative tool when compared with the existent methods for the treatment of bone and soft tissues. As the device selectively cuts bone, considerable nerve lesions can be avoided and minimal invasive surgeries are possible.

Considering the advantages and disadvantages of this new technology, the oscillating technology allows clinicians to perform atraumatic bony surgery in operator-sensitive cases, improving the clinical outcome in challenging cases in implant therapy. It provides substantial improvement in dental/implant surgery, benefiting the surgeon by ease of use and the patient by minimizing surgical trauma and promoting rapid healing.Piezoelectric tools will be a part of armamentarium of any procedure in maxillofacial surgery and implantology in the near future.

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