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Peizosurgery- A Minimally Invasive Surgical Tool: In Periodontology and Implantology

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Abstract

Peizosurgery, a novel innovation utilises the ultrasound vibrations and created a revolution in dentistry since its introduction. This device satisfies both technical and biological criteria and is considered to be safe and precise over the traditional instruments used for bone cutting in surgeries. The micrometric cutting, safety to use near the soft tissue structures, less bleeding at the post-operative site has opened a new era for this device to be used a minimally invasive tool. This review outlines the effects of Peizosurgery in periodontology and implantology as a minimally invasive tool.

Keywords: peizosurgery, iultrasound, periodontology, implantology, minimally invasive.

1. Introduction

Dentistry, over the past few years has undergone and seen a lot of advancements in its daily practice[1]. Newer diagnostic imaging techniques like Ultrasonography, Cone beam computed tomography and procedures like Microsurgery, Implants, Lasers and Nanotechnology have made dentistry, as one of the front runners in medical fraternity. These advances have lead to new world of painless dentistry [2&3]. Ultrasounds have been routinely used in periodontology to remove calculus and degranulate tissues. The advent of peizosurgery by Thomas vercellotti has been a boon to periodontology and implantology as a novel approach. The evolution was based on the principle of minimally invasive dentistry and improved surgical predictability [4].

Peizosurgery, also known as piezoelectric surgery produces ultrasound vibrations in frequency of 25-29 KHZ. The micro vibrations and shock waves generated due to contraction of piezoelectric crystals make precise osteotomy cuts in selective bone possible.This innovative device is designed and commercialised to overcome limits of traditional instruments and to reach increasingly higher levels of precision, safety and rapidity in recovery after bone surgery with limited morbidity [5&6].

Use of micromotors could be very dangerous in close proximity to delicate anatomical structures such as vessels and nerves. The piezoelectric drill has a control action near the anatomical structures.Bloodless surgical field,Increase patient comfort and less soft tissue damage are added advantages [7].

So Piezosurgery can be used as a saw, particularly in performing curvilinear osteotomies.characterized by the versatility of a drill. Piezosurgery's patented, controlled three-dimensional ultrasound vibrations open up a new

age for Periodontology, Implantology, Endodontics and Surgical orthodontics as an emerging minimally invasive tool[5].

This review describes the mechanism of action of peizosurgery,its biologic effects on the bone, its advantages and limitations and its applications mainly in Periodontology and Implantology.

2. History Of Evolution Of Peizosurgical Device

The piezoelectric effect was initially defined by French physicists Jean and Marie Curie, in 1880.Within the field of dentistry ultrasonic surgery became recognized mainly in periodontology and endodontics following the first reports on by Catuna in1953 about effects of high-frequency sound waves on dental hard tissue[8].In 1998, Thomas Vercellotti modified the conventional ultrasonic technology. The first device was designed by mectron medical units. The second and third generation was developed later[9].In 1999 Tomaso Vercellotti introduced the name PIEZOSURGERY for the new method. Currently piezosurgery is very commonly and successfully used in periodontology and implant dentistry [3].

3. Mechanism Of Action

The word peizo is derived from the greek word peizein meaning pressure. They work on the principle pressure electrification. When electric current is applied, the crystals expand and contract producing ultrasonic vibrations.Various piezoelectrical crystals include quartz, Rochelle salt and certain types of ceramic. When these crystals are subjected to an electrical charge, they expand and contract alternately to produce ultrasonic waves. Theultrasonic waves can induce disorganization and fragmentation of different bodies.[10]

The microvibrations are in the range of 25 to 29 khz modulated with a low frequency of 10 to 60 Hz and highest upto 30 KHz. They have a controlled speed 60-200mm/sec and targeted to cut only mineralized tissue without damaging adjacent soft tissues Frequency above 50 kHz is only capable of cutting neurovascular tissues and other soft tissues[9]. The vibration amplitude is also adjustable in the range of 30-60 micro meter. The cavitation effect maintains bone temperature, and flushes debris, reduces haemostasis and provides a clear vision of the surgical field.Henceforth increases visibility and ease of operation. In addition cavitation also shows an anti-bacterial property which enhaces high predictability and low morbidity in bone surgery.The antibacterial property is due to the fragmentation of bacterial cell wall [3&11].

4. Biological Effects Of Peizosurgery On Bone

- The effect of mechanical instrumentation on structure of bone and viabitity of cells is important in regenerative and osseous surgery. Any alteration in temperature are injurious to cells and may cause necrosis of bone [3&12].
- Erikson et al, showed that local bone necrosis would occur in cases where the temperature exceeds 470 C for 1 minute due to the contact of rotating tools.

Some studies were performed on the piezoelectric surgery effect on bone cell viability. Different methods of collecting autogenous bone grafts were examined with microphotography and histomorphometric analysis of the particles' size, the percentage of necrotic and vital bone, and osteocyte number per unit of surface area. The results showed that the best vital bone collection methods are chisels, osteotomes, and piezoelectric surgery. These results confirmed previous studies on the effects of the piezoelectric device on the morphology and cell viability after bone particle collection[13].

There was early proliferation of bone morphogenetic proteins and better inflammatory process control, and bone remodeling was evident in 56 days.Thus to conclude neo osteogenesis was proven to be consistently more active in cases where piezosurgery is used. Its been

observed that the critical temperature rises only when the irrigation volume is as low as 20 ml per minute. Piezosurgery, therefore has a potential role in osseous surgery [14].

5. Benefits Of Peizosurgery Over Traditional Bone Cutting Instruments

Piezosurgery offers the following advantages

- ***Micrometric* –bone cutting is precise due to microvibrations and** maintains the bone constantly clean, thus avoiding excessive temperatures due to cavitation effect [16].
- ***Selective cutting limited to mineralised bone structures*** because of the difference in ultrasonic frequencies for hard and soft tissues,the surgical action terminates when the scalpel comes into contact with non-mineralised tissues[15].
- ***Safe*** and enable osteotomy to be performed even in close proximity to delicate structures such as vasculo-nervous structures without damaging them [3&16]
- **Controlled movement of the surgical device**s.
- Piezosurgery provides **direct visibility** over whole osteotomies.
- In comparison to conventional ultrasonic units, Piezosurgery units are some **3 times more potent**which allows them to cut highly mineralized cortical bone. The reduced range and the linearity of the vibrations allow for precise control of cutting [15&16].
- **Bleeding-free surgery site:** Piezosurgery is accompanied by **minimal intra-operative bleeding**. Because the method does not traumatize bone thermally post-surgical wound healing is rapid. 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 [16-19].
- Block grafts can be harvested **with clear visibility** of the surgical site using straight and angled piezosurgery tips,with less tissue damage to adjacent oral soft tissues and bone. 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.
- Enhanced visibility of surgical site, because of the cavitation effect created by the interaction between the irrigant solution and the oscillating tip [3].
- **Reduced sensitivity and faster recovery** of the tissues[21&22].
- **Faster bone regeneration and healing process:** ultrasound vibration stimulates cells' metabolism and oxygen molecules released during cutting showed an antiseptic effect and moreover, the lack of necrosis in the cut area accelerates bone regeneration [15&16].
- **Less risk of emphysema:** The aerosol effect reduces the risk of subcutaneous emphysema unlike the traditional instruments[16&17].
- **Reduced post operative pain :**Owing to the less invasive nature, peizosurgery device produces less collateral tissue damage and aids in better healing [16&18].
- **Reduced stress and discomfort:** In comparison with traditional motors, the device produces less noise and only microvibrations, so the fear and psychological stress of the patient are reduced [19].

These advantages imply them as minimally invasive conservative tool.

6. Clinical Applications

Peizosurgery in Periodontology:

Theclinical applications of piezo surgery in periodontology are broad; these include scaling and root planing, osteoplasty and osteoctomy , crown lengthening, The piezosurgery device can be used for soft-tissue

debridement in periodontal flap surgery. 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 [4].

- **Osteoplasty and ostectomy** is performed using the piezosurgery device to create positive architecture for pocket elimination surgery. The device allows for precise removal of bone, with minimal risk of injury to underlying root surfaces. Final smoothing of root surfaces and bony margins using a specific ultrasonic insert which creates a clean field, with ideal bony architecture ready for flap closure [4&24].
- In **resective and regenerative therapy**,the piezosurgery device is used in bone grafting of an infrabony periodontal defect. Autogenous bone can be readily harvested from adjacent sites with minimal trauma and therefore minimal postoperative effects. Straight or angled piezosurgery tips helps to collect autologous grafts monocortical blocks or bone chips [25]. Bone chips with varied dimensions have different advantages; (i)small sized chips provide early remodelling (ii)larger particles provides slower remodelling and mechanical support; acts as a scaffold for bone formation in the grafting site. This device doesn't traumatize bone thermally, So post operative wound healing is rapid. & minimize bleeding by the cavitation effect created by the interaction between irrigant and the oscillating tip; results in improved visibility [24&25].
- **Clinical crown lengthening** is the most common periodontal surgical (ostectomy) operation considered to increase crown height.The clinical crown lengthening technique entails performing a periradicular ostectomy of a few millimeters, which allows repositioning of the periodontal flap in a more apical position. The traditional surgical technique entails raising a full-thickness flap, performing the ostectomy with manual instruments, osteoplasty with a bur for crest bone architecture recontouring, periradicular bone removal, root planing, and finally, replacing the flap in an apical position. The crown lengthening technique performed with piezosurgery using appropriate inserts makes it possible to effectively reduce bone while preserving root surface integrity [26&27].

Peisosurgery in implantology

The peizosurgery is a new and modern technique in bone surgery in implantology.

Implant site preparation, implant bone removal and grafting, sinus lifts can be done with much ease and less trauma. The various clinical applications are been described below.

- Piezosurgery used **to prepare osteotomy site in the bone and for insertion of implant.**

The first tuned device to drill holes in bone. The composite vibrational mode greatly facilitates the insertion of the implant in the created cavity [4].

- **Implant site preparation procedure:**

Special piezosurgery inserts developed for bone perforation have enabled the development of a new technique for ultrasonic implant site preparation (UISP). The first advantage of UISP is related to the cutting characteristics of piezosurgery, which facilitate differential preparation of the cortical and cancellous bone. The differential implant site preparation (DISP) technique can be used within the initial osteotomy site to correct the implant axis by selectively directing the cutting action in the desired direction [14 &28].

- **Harvesting Block (bone) grafts and eventually implant placement in the recipient sites.** This can be done by two techniques.**Particulate Bone Chip Harvesting Technique.** Particulate bone chips are harvested using special osteoplasty inserts to scrape the bone surface.**Block Harvesting Technique** Harvesting block bone with piezosurgery is extremely simple, precise and fast. The most common donor sites for harvesting monocortical-cancellous block bone are the mandibular ramus and symphysis. Harvesting a monocortical-cancellous bone block from the mandibular ramus is generally preferable to the symphysis region because of the reduced level of morbidity.. Osteotomies performed with piezosurgery allow an extremely precise, clean, and smooth vertical cut through bone with excellent visibility [29&30].
- **Maxillary sinus elevation procedures.:**Procedures used to lift the floor of the maxillary sinus for bone augmentation make it possible to use dental implants to replace teeth in the atrophied posterior maxilla. Approaches to sinus lift techniques typically involve the use of a lateral window or crestal osteotomy. The lateral window approach enables the surgeon to visually see and monitor the integrity of the sinus membrane at each step in the process. The traditional technique using a high-speed rotary bur to remove bone runs a high risk of damaging the schneiderian membrane, which often results in membrane perforation (approximately 14% to 56% incidence). Lateral window osteotomy outline created using a piezosurgery diamond-coated scalpel Separation of the membrane from the inner wall is made using an inverted cone insert detaches the membrane around the perimeter of the bony window. This reduces membrane tension facilitating further separation and lifting with piezoelectric or manual instruments. Once completely elevated, bone augmentation material is inserted and packed and the bony window is closed with a collagen membrane. Piezosurgery simplifies the sinus lift technique and increases predictability with its selective cutting action, which enables surgeons to maintain membrane integrity. This has resulted in a considerable reduction in patient morbidity in maxillary sinus surgery [31- 33].
- **Ridge Expansion and implant placement:**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. In brief, it can be said that this technique exploits bone elasticity so it is necessary to necessary to know the bone anatomy of each implant site to create the appropriate osteotomy site, this technique requires preservation of periosteum integrity while elevating mucogingival flaps enough for access. 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 which can be done with narrow piezosurgery insert.Piezoelectric bone surgery has radically simplified the ridge expansion technique in the horizontal osteotomy phase, which can be performed with micrometric precision, and in the site preparation phase, which exploits the different degree of cortical resistance compared to cancellous bone [24 &34].
- **Distraction Osteogenesis followed by Implant placement:**Distraction osteogenesis provides a method to regain both hard tissue and soft tissue

without any grafting. A case report describes a patient who had severe maxillary anterior bony defects that were restored by means of piezoelectric distraction osteogenesis, followed by dental implant placement. Clinical, radiological, and histological results showed that the reconstruction was successful [35].

- Piezosurgery device has been used for **Removal of blade implants:**An ultrasound device was used to perform an ostectomy for the removal of blade implants in order to save as much bone tissue as possible, so that root form implants might later be inserted [24].

7. Recent Advances

- **Piezosurgery-Assisted, Flapless Split Crest Surgery for Implant Site Preparation:**Resorption of the alveolar ridge can, at times, be surgically corrected at the time of implant placement. Split crest or split ridge procedures are done routinely. Recently, flapless approach have become popular and aim to reduce post treatment side effects, improved healing and avoid bone resorption caused by flap elevation[36]. Brugnami et al 2014- used a novel approach by combining the use of a piezoelectric scalpel and a tapered bone expander in a flapless fashion to perform split crest procedures and showed improved patient acceptability and predictability. A combination of these procedures appear to be safer for the clinician and cause less trauma and discomfort for the patient they reduce the risk of buccal plate fracture [37]

- **Peizoincision-minimally invasive technique:** Corticotomy-assisted orthodontics was developed to increase the rate of tooth movement and thus reduce treatment time.' In 2007, Vercelotti and Podesta introduced the use of piezosurgery, instead of burs, in conjunction with the conventional flap elevations to create an environment conducive to rapid tooth movement [26]. Although very efficient, this technique was met with some resistance from the dental community because of its invasive nature.After the advent of peizosurgery ,in 2009 Dibart described a new minimally invasive procedure that he called Piezocision. [38]. This technique combines micro-incisions limited to the buccal gingiva that allow for the use of a piezoelectric knife to decorticate the alveolar bone and initiate the regional acceleratory phenomenon (RAP). The procedure allows for rapid tooth movement while correcting hard- and soft-tissue deficiencies when needed. This novel technique can be combined with different orthodontic treatment modalities to satisfy today's adult patient population

Advantages of this procedure include decreased chairside time, minimally invasive,less traumatic to the patient and It allowed for soft-tissue grafting at the time of surgery to correct mucogingival defects if needed, a well as bone grafting in selected areas by using localized tunneling. Disadvantages are increased risk of tooth damage and tunnelling is invasive and difficult procedure and does not allow corticotomies between each tooth, which is essential to create sufficient demineralization around the tooth for accelerated movements [38].

- **MIRO technique; minimally invasive rapid orthodontics: Jofre et al 2013:** present a case series that proposes a technique that uses metal markers as radiographic references or guides for accurate corticotomy by means of intraoral periapical radiographies. Moreover, a minimally invasive flapless procedure is described. Due to its atraumatic nature, this procedure promotes healing without oedema or patient discomfort[39].

8. Drawbacks

Just like how a coin has two sides, piezo surgery has its own share of boon and bane. The application technique is still in infancy.

Limitations of piezoelectric surgery include

- A **definitive learning curve** is necessary. The clinician should be familiar with handling of the surgical procedures. It is important to acquire both adequate dexterity and a gentle touch.
- 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,excessive pressure should be avoided.
- The **increase in the operating time,**in comparison to traditional cutting instruments.
- Difficulty or impossibility to perform the deeper osteotomies (eg: maxillo-pterygoid disjunction), due to lack of inserts of the appropriate length.
- Expensive equipment
- 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 [5,40].

9. Conclusion

Piezo surgery appears to be a cutting-edge 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. Using the fine tip enables curved cutting and provides an opportunity for new osteotomy techniques. The use of ultrasound in application to hard tissues can be regarded as a slow technique compared with the conventional rotary instruments, since it requires special surgical consideration.

Piezo surgery ensures the 3 ‘P’s, that is Predictability, less post-operative pain and increased patient’s compliance. Need not say, the use of piezosurgical device, a novel invention is not only limited to the field of dental surgery, but can be utilised for complex interdisciplinary medical cases.

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