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PIEZOSURGERY, NEW MODERN IN DENTISTRY: A REVIEW

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INTRODUCTION

In the era of modern dentistry a rapid development in various dental surgical techniques have been seen. Dentistry over last few decades has undergone a lot of advancements in various dental surgical procedures and thereby entering into a world of painless dentistry.[1] The tools and skills are the determining factors for success of any treatment in dentistry. Cutting: micromotor handpiece, aerotor which remove enamel, dentin, cementum as well as bone are the tools for hard tissues. The postoperative outcome depends upon the amount and quality of hard tissue removal of any dental surgical procedure, be it implantology, periodontology or Oral Surgery.[2]

Traditionally osseous Surgery was performed using hand instruments and various rotary instruments with different burs that used to require external copious irrigation because of the production of heat using these instruments. These instruments also exerted considerable pressure in osseous surgeries and hence endangered treatment of fractured and brittle bone. Recently a novel surgical approach has been introduced in the field Maxillofacial Surgery based on ultrasonic micro vibrations for precise and selective cut on the bone without injuring the surrounding tissues. This new technique incorporating properties of ultrasonic is piezosurgery.[2]

The piezen is the Greek word from which the term 'piezo' has originated. **Jacques and Pierre Curie (Figure1.)** first discovered piezoelectricity in the year 1880 who found that applying pressure on various crystals, ceramics, or bone created electricity. The mechanism of action of piezosurgical device is physical interactions and phenomena of basic electric and mechanical dimensions such as electric field strength, polarization, tension and extension in the crystalline field, which states that deformation in crystals on passing electric current results in oscillations of ultrasonic frequency is called as piezo effect. Thus obtained vibrations are amplified and transferred to a vibration tip which produces cutting effect exclusively on mineralised tissue, known as cavitation phenomena. Vibration tips applied with slight pressure on bone tissue.

In 1999, **Dr. Thomas Vercelloti (Figure 2.)** invented piezoelectric bone surgery in collaboration with Mectron Spa and in 2001, piezosurgery was introduced. In 2003, Vercelloti discovered the ideal frequency method endodontic, orthopedic, neurologic, periodontal and Oral and Maxillofacial Surgeries.[1]

Piezosurgical technique achieve unparallel precision, patient comfort, intra-operative sensitivity and visibility, blood free surgical site and reduced damage to the surrounding soft tissues and important structures like nerves, muscles and mucosa. Due to the minimal damage to the osteocytes, survival of bone after harvesting is excellent compared to conventional cutting of bone.[3] As a result, the piezosurgery has increased the treatment effectiveness along with the improvement in postoperative recovery and healing.

Hence this article is an attempt to review the applications of piezosurgery as an alternate approach in comparison to traditional surgical procedures in the field of Oral and

Maxillofacial Surgery, Periodontology, implantology and various other branches of dentistry.

MODE OF ACTION

These devices run according to the piezoelectric principles and are capable of cutting by way of ultrasonic vibration. The name piezosurgery has been derived with reference to the name of first device in the market. Ultrasonic vibrations work at the frequency of 20kHz greater than the upper limit of the audible range for humans. The term sonic is applied to ultra sound waves of very high amplitudes. A piezoelectric device on stimulation with a mechanical stress produces an electric charge. Conversely, on application of electric field a mechanical deformation is produced (the substance shrinks or expands) This effect is formed in crystals that have no center of symmetry.[4]

An ultrasonic transducer is a device used to convert some other type of energy into an ultrasonic vibration. By the far most popular and versatile type of ultrasonic transducer is the piezoelectric crystal, which converts an oscillating electric field applied to the crystal include quartz, Rochelle salt, and certain types of ceramic.[5] The piezoelectric effect**(Figure 3.)** is the creation of electrical tension on some crystal and ceramic materials such as quartz to which a mechanical pressure is subsequently applied. The material in question will expand and then contract leading to an ultrasonic vibration. Also known as 'pressure electrification', it has been defined by the term 'piezo' derived from 'piezein', meaning pressure in Greek language.[6]

The piezoelectric ceramic contraction and expansion leads to production of vibrations in form of ultrasonic transduction, are amplified and transferred onto the insert of a drill.

The site for the electrical field is located in the handle of the saw in this device. A cutting- hammering movement is produced at the tip of the instrument due to the electrical current in frequency range of 25 to 29 kHz with amplitude of 60 to 210 µm. Thus only selective mineralized tissue is cut. Frequency used for soft tissue and neurovascular tissue cut is above 50 kHz.[8]

In piezoelectric surgery, as a result of decrease and increase in pressure because of ultrasonic vibrations, the cavitation phenomenon**(Figure.4)** occurs and describes the process of vapourization, bubble generation and subsequent implosion (growth and collapse of bubbles into many minute fractions of its original size microscopic gas bubbles) in a flowing liquid. A good visibility is maintained in the operative field by dispersing a coolant fluid as an aerosol that washes away the blood from surgical field during ultrasonic osteotomy cut. Furthermore, it results in a bloodless surgery as it bring about the hemostasis.[9]

The mode of action piezoelectric device can be summarized as

- Micrometric Cutting: Precise bone cutting along with high tactile sensitivity.
- Selective Cutting: Bone cutting along with preservation of soft tissues.
- Asepsis: Sterile water.
- Cavitation Effect: High predictability accompanied with maximum intra operative visibility.
- Minimum surgical stress: Excellent tissue healing.

COMPONENTS OF PIEZOSURGERY DEVICE

The piezosurgery unit is composed of :-

- main body,
- pedal,
- handle,
- dynamometric wrench and
- inserts {different shapes depending on the surgical need.}[10] **(Figure.5)**

Main Body

The main body consist an electronic touchpad, a display, a peristaltic pump, one stand for the handle and another to hold the bag containing irrigation fluid. The four interactive touchpad keys enable to select the feature mode, the specific program and the flow of the cooling liquid. Every commands are visible on the display board.

There are two primary operating modes

A. BONE MODE

The vibrations generated are extremely high ultrasonic power. Several sophisticated software and hardware controls the performance of piezosurgery unit. The property for cutting different kinds of bone with the help of these ultrasonic mechanical vibrations is because of the controlled frequency over modulation.

The selection recommended is:

- Quality 1: for cutting high density spongy bone or the cortical bone.

- Quality 2: for cutting low density cortical bone.

The special program is dedicated to A limited series of surgical inserts that are particularly thin and delicate are controlled by a specially fixed programme. These are meant only for surgeons and who would like an extremely thin, precise and effective cut and have experience of using piezosurgery.

B. ROOT MODE

Two different programs

a. Endo Program: This kind of programme includes the production of limited level of power provided by applying reduced electrical tension to the transducer, optimal for washing out the apical part of the root canal in endodontic surgery.

b. Perio Program: This includes an intermediate level of power between the endo and bone program. Here the ultrasonic wave has frequency equal to the resonance

frequency of the insert used and is transmitted through the transducer in continuous sinusoidal manner.

HANDLE (Figure.6)
The piezoelectric ceramic disks inside play the role of cutting action. An external generator produces the electric field which is applied on the ceramic plates to generate ultrasonic vibrations of various volumes. Amplification of these ultrasonic vibrations is carried out and transmitted to the sharp end of the handle. Then for the function of piezo unit insertion tips tightened with a special key.

DYNAMOMETRIC WRENCH (Figure.7)
A dynamometric wrench is used for tightening of insert tips which applies a predefined force to obtain energy transmission.

THE PERISTALTIC PUMP(Figure.8)
The purpose of this peristaltic pump is to discharge the irrigating solution from the insert with an adjustable flow of 0–60 ml/min for cooling and removal of detritus from cutting area. Cooling effect is created by refrigerating the solution at 4°C and the quantity of liquid may be adjusted using + and – buttons. A cord is attached to the handpiece tip through which the liquid is drawn from the bottle hanging over a provided rod with it.

INSERTS
Specific insert were developed to satisfy the specific clinical needs of each surgical technique. The inserts are organized according to a dual classification system. The system helps understand the cutting characteristics and clinical instructions for each insert.[10]

Morphological-Functional Classification:[10] The morphological description defines the structural properties of the insert, while the functional description outlines the cutting characteristics:

- Sharp - Cutting
- Diamond-coated - Abrasive
- Rounded – Smoothing

Clinical Classification[10]
The inserts (sharp, abrasive, smoothing) have been classified according to basic surgical technique:
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 - IM2A- IM2P - IM3A- IM3P
5. Periodontal Surgery- PS2-OP5-OP3-OP3A- Pp1
6. Endodontic Surgery- 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

Osteotomy, osteoplasty and extraction technique inserts are used in combination with each other in the surgical protocol for each technique.

INSERT TIPS[10]

1. *Sharp Insert Tips*

- Sharp insert tips are used in osteotomy and/or harvesting bone chips along with osteoplasty techniques
- Fine and well-defined cut in the bone structure can be placed.

2. Smoothing *Insert Tips*

- Precise and controlled work has been made possible with smoothing diamond surfaces inserts.
- Smoothing insert tips are used where difficult and delicate structures to be preserved on osteotomy site. For example, those preparing for a sinus window or access to a nerve.
- The final bone shape is obtained by using these smoothing insert tips during osteotomy.

3. *Blunt Insert Tips*

- Blunt insert tips are used for elevating Schneider's Membrane or for lateralizing nerves i.e. specially for preparing the soft tissue.
- In periodontology, these tips are used for root planning.

INSERT TIPS COLOR
Gold colour is used for all insert tips used to treat bone. A coating of titanium nitride provides gold color to the insert tips for improving the surface hardness which means a longer working life of instrument. Steel colour is used for all insert tips used to treat soft tissue or delicate surfaces such as the roots of teeth.[10]

PROCEDURE
The hand piece can be fitted with different tips for osteoplasty, osteotomy, separating soft tissue from bone and cutting bone. Micro movements depends upon the insert and are in the frequency range of 25 to 29 kHz with amplitude of 60 to 210µm. Thus only mineralized tissue is selectively cut. A frequency of above 50 kHz is used for cutting Neurovascular tissue and other soft tissue. While using conventional microsaws, a certain degree of pressure is must to apply for its action which is in contrast to the piezosurgery device which needs only a very small amount of pressure for a highly precise cut. There are limitations for use of too much pressure as it causes heat generation and restricts the movement of the tip.

The device uses power of 5 W. With the increase in power cutting ability increases but is demanding for thicker tips, which cause thicker and more imprecise cuts. The 5-w power is ideal compromise between speed and precision. Tip width and thickness vary according to

the density of the bone being operated on and adjustments in the power setting being used.[11]

INDICATIONS IN VARIOUS BRANCHES OF DENTISTRY

The application of piezosurgery in medical fraternity is a new and highly acceptable technique. Its use extends from department of Oral and maxillofacial Surgery to Orthopedics, Periodontics, traumatology, Ophthalmology as well as plastic and reconstructive surgery.[2]

PERIODONTOLOGY

Piezosurgery has improved and simplified the soft and hard tissue management. Not only the invasiveness of traditional surgery has been reduced with the use of this technology but the workflow has also improved along with thorough cleaning of the periodontium. It also favours tissue healing by using bone removed in the osteoplasty procedure as a graft for small osseous defects, thus preserving bone architecture.[12]

This technique is used in following procedures:

1. Osteotomy and osteoplasty techniques
2. Reconstructive operations
3. Bone harvesting for regenerative surgery
4. Root debridement
5. Scaling and root planning
6. Curettage
7. Crown lengthening procedure

IMPLANTOLOGY

1. Bony window osteotomy in sinus lift
2. Elevation of schneiderian's membrane
3. Ridge expansion /augmentation
4. Bone harvesting: chips/ blocks
5. Osteoplasty
6. Implant site preparation
7. Extraction for immediate implant positioning
8. Resective and regenerative surgery
9. Guided bone regeneration

ORAL AND MAXILLOFACIAL SURGERY

1. Root/tooth extraction
2. Apicoectomy
3. Cystectomy
4. Osteogenic distraction
5. Sinus lift
6. Surgically-assisted rapid maxillary expansion (SARME)

ORTHODONTICS

1. Palatal impacted teeth removal
2. Orthodontic corticotomy/ Periodontal Accelerated Osteogenic Orthodontics (PAOO)
3. Orthognathic surgery
4. MIRO technique; minimally invasive rapid orthodontics{Jofre et al 2013}

ENDODONTICS

Piezosurgery instruments for endodontic surgery includes osteotomy, root end resection, and root-end preparation techniques.[13]

1. Retrograde root canal preparation
2. Hemisection,
3. root amputation
4. apical resection

ADVANTAGES

Since then, the piezosurgery device has gained a widespread use in dental and Oral Surgery and implantology because of the following advantages:

1. Micrometric cutting action:

The micrometric cutting through ultrasonic devices depends on the micro-oscillation of the handpiece smaller than the width achievable with rotary instruments and varies from 20 µm to 200 µm. Thus offering superior precision in cutting with no bone loss. Precise incision with no damage to adjacent structures and precise bone cutting due to microvibrations and maintains the bone constantly clean.

2. Cavitation effect

Maximum intra-operative visibility and surgery is performed in bloodless field. The cavitation effect created by the interaction between the irrigant solution and the oscillating tip has enhanced the visibility of surgical site.

3. Surgical stress

The less collateral tissue damage. Results in excellent tissue healing with less invasive cutting action.

4. Asepsis

Sterile coolant provides an aseptic environment (free from contamination).[13]

5. Selective cutting and minimal operative invasion

The selective cutting limited to the mineralized structures– bone and reduces the risk of perforating the Schneider membrane and only.

6. Controlled movement of the surgical devices

Safe and enable osteotomy to be performed even in close proximity to delicate structures such as vasculo-nervous structures without damaging them.

7. Enhanced visibility and Blood less field

Cutting with the ultrasound unit creates bloodless field providing good visibility of the operating site and enables one to conduct the procedure very precisely because of the cavitation effect. This effect creates bubbles from the physiological salt solution leading to implosion and generation of the shock wave which results in micro coagulation.

Block grafts harvesting has become easy with clear visibility of the surgical site using straight and angled piezosurgery tips, with less tissue damage to adjacent

oral soft tissues and bone. The harvested bone can then be modified and shaped to fit accurately to the recipient site using piezosurgery tips, before being stabilized with a fixation screw.

8. Faster bone regeneration and healing process
An antiseptic effect is produced during cutting as a result of generation of oxygen molecules and stimulation of cell metabolism through ultrasonic vibration. Moreover, bone regeneration activity is accelerated because of lack of necrosis.

9. Reduced traumatic stress
The device produces less noise and only micro vibrations in comparison with a conventional motor, so the fear and psychological stress of the patient are reduced.[6]

10. No risk of emphysema
The aerosol effect through the ultrasonic device has reduced the subcutaneous emphysema unlike the effect of air-water spray generated during osteotomy with rotary instruments.

11. Reduced sensitivity and faster recovery of the tissues with less postoperative pain.

DISADVANTAGES[13]
Piezosurgery has certain disadvantages:-
1) The main disadvantage of the procedure using the piezosurgery unit is the increased operation time that is required for bone preparation.
2) The ultrasonic waves have mechanical energy, and this energy can be converted into heat and pass into adjacent tissues. This necessitates the use of irrigation, not only to avoid the the effect of cavitation, but also to avoid overheating.
3) Adequate dexterity and gentle touch is required for this type of procedure with a different learning curve. More practice is needed for clinicians in using piezosuregry device.
4) difficulty or impossibility to perform the deeper osteotomies (eg: maxillo-pterygoid disjunction), due to lack of inserts of the appropriate length.
5) Piezosurgery inserts get worn away very rapidly. It is recommended never to go beyond ten little uses in bone surgery. Despite their hardness, inserts may break or cause damage to the tissues by uncontrollable heat.
6) Cost of a device may initially be a financial load.

Figure 1: Jacques and Pierre Curie.

Figure 2: Dr. Thomas Vercelloti.

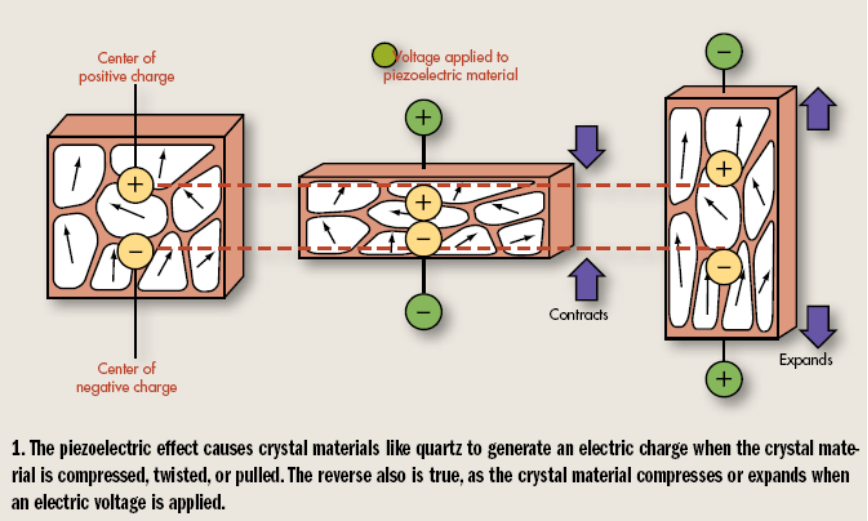

Figure 3: Piezoelectric effect.

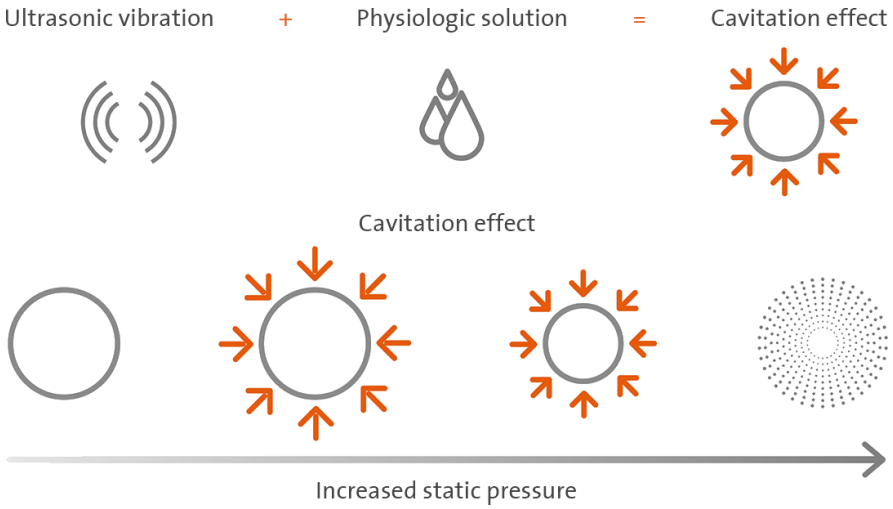

Figure 4: Cavitation Effect.

Figure 5: Piezosurgery Device.

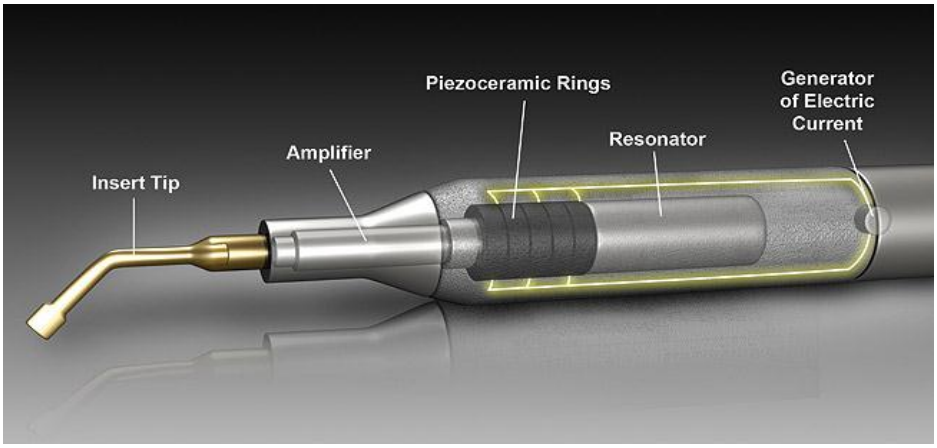

Figure 6: Handle.

Figure 7: Dynamic Wrench.

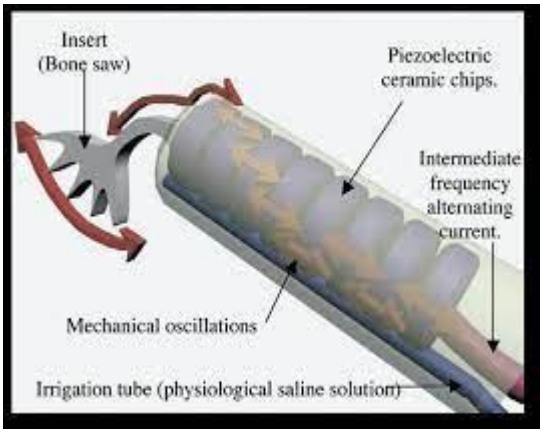

Figure 8: Irrigation tube, cutting saw.

CONCLUSION

With the introduction of this new surgical technique it has numerous restorative features that include a micrometric cut (precise and secure action to limit tissue damage, especially to osteocytes), a selective cut (affecting mineralized tissues, but not surrounding soft tissues), and a clear surgical site (the result of the cavitation effect created by an irrigation/cooling solution and oscillating tip). Because of the vibration of instrument's tip at different ultrasonic frequencies, now it has become possible to cut soft and hard tissues at different frequencies and a very selective cut enables the clinician to spare fine anatomical structures (e.g., Schneiderian membrane, nerve tissue).[13]

Piezosurgery is a relatively new surgical technique based on the novel application of the principle of piezoelectric ultrasonic vibration that can be used to complement traditional Oral Surgical procedures, and in some cases, replace traditional procedures.

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