REVIEW ARTICLE

# PIEZOELECTRICITY: BOON FOR BONE SURGERY

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## ABSTRACT

Piezoelectricity is one of the most significant innovations in implant dentistry in the last few decades. It is primarily used in bone surgery. It has overcome the disadvantages of laborious and time consuming bone surgeries associated with conventional ways of surgeries, at the same time maintains less heat which is a disadvantage of motor driven instruments. This instrument is manageable as there is no macro vibration and allows more intra-operative control during surgical procedure. In addition, there is increase cutting efficacy even in difficult anatomical zones. Bone healing rate is also favourable with piezo-electric bone surgery. This review describes piezo-electric surgical unit, its mode of action, biological effects on tissues, and applications in dentistry, advantages and disadvantages.

## KEY WORDS

**Piezo-electricity, Piezo surgical unit, Bone surgery, Implant dentistry.**

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## INTRODUCTION

Over the past few decades dentistry has seen many changes in its different fields, which ranges from microsurgery to bio-mimetic restorations and smile make over to prosthetic rehabilitations. Among all these innovations dental implant is one which impact mostly in terms of chewing ability and patient's quality of life. Inadequate bone volume restricts implant placement in the jaw bone.

Bone surgery is an integral part of implant dentistry as well as other field of dentistry including oral surgery, periodontics and orthodontics. Conventional ways use manual and motor driven instruments. These instruments have some advantages and disadvantages over each other. Manual instruments are laborious and time consuming but generate less heat during their use whereas motor driven instruments are faster in performance but generate more heat and may injure adjacent soft tissues[1].

Piezo-surgical unit is a device which overcomes all the drawbacks of conventional instruments and combines all the benefits of manual and motor driven instruments[2]. It is faster, precise and kind enough to adjacent nerves and vessels. It generates very little heat and produces a blood less field during its operation.

## History of ultrasonic's:

The definition of sound given by the oxford dictionary is "vibration in an elastic medium at a frequency and intensity that is capable of being hard by the human ear" [3]. The frequencies, audible by human ear ranges from 20 Hz to 20 KHz. Sound waves that are beyond audible range of human ear are often referred as infra sound (below 20 Hz) and above 20 KHz are ultra sounds. The science of sounds was cultured way back in 6th century BC at the time of Pythagoras, who wrote the mathematical properties of stringed instruments. In history the first article on ultrasound was written in 1948 during the first word war[4]. The ultrasonic device basically has a transducer which converts electrical energy to mechanical energy. Transducer contain active material such as a ferromagnetive rods with wrap around coil which produce magnetostrictive effects

or piezoelectric disc which changes it`s physical properties by application of electricity. In dentistry Catuna first introduced ultrasonic drilling machine to cut cavities in extracted tooth[5]. In 1955 Zimmer first use ultrasonics in periodontal treatment as oral prophylaxis [6].

## Piezoelectric surgical device:

Piezoelectricity derives its name from the Greek word piezein means to squeeze or press, French physicists Jacques and Pierre Curie discovered piezoelectricity in 1880[7].

In the year 1988 Tomaso Vincentti with the collaboration of Mectron Italy first introduced piezoelectric surgical device which was first used clinically in the year 1988 in the field of oral and maxillofacial surgery, cranial and spinal surgery [8]. In dentistry piezoelectric ultra sonic scaler is a well known device from very long back, but in bone surgery it is the new addition [9,10]. It makes the surgery safer and more convenient than ever. The frequency of the surgical device ranges from 25 to 35 KHz (Hertz = vibrations / seconds). By changing the frequency it is possible to cut the tissue selectively. Low frequency enables cutting through mineralised tissue like bone whereas soft tissue cuts over 50 KHz of frequency[11,12]. The power typically can be adjusted from 5 watt to 15 watt[13,14] whereas the latest machine shows power output up to 90 watts[15].The cutting efficiency not only depends on the power but it influenced by the bone density, working pressure and the tip characteristics[16] (i.e. shape, size and kind of material used to fabricate the tip) Tip vibration ranges from 60 to 200 micrometer. Piezo scaler which is used for oral prophylaxis typically shows power output of 2 watt

## Mode of action:

Piezoelectricity is a quality of material that leads to conversion of mechanical energy to electrical energy and vice-versa. In medical science it is employed to monitor many body signals and changes of dynamic pressure.

Piezoelectricity works by transformation of mechanical energy to electrical energy and electrical energy to mechanical energy. It has a both way relationship[17]. Piezo-electricity is a process of making some mechanical energy to electrical energy and vice versa. Some crystalline materials like quartz, Rochelle salt and piezo ceramics such as barium titanate and lead ziroconate titanate shows piezoelectricity. These materials exhibit electric charge on application of a force. Apart from these certain body parts like bone, DNA and various proteins also exhibits piezoelectricity[18]. For example if these materials are kept in between two piece of metal they will not show any electrical impulse, but if pressure applied on them from outside which causes their shape alteration there will be generation of electricity and that will flow through the metal plates. Alternatively in static phase if some electrical impulse induced through the metal plates to those materials it deforms and changes from its original shape and the effect is known as inverse piezo-electric effect.

The inverse piezoelectric effect is used in a variety of applications. For example a speaker, in which a voltage is applied to a piezoelectric ceramic, causes the material to vibrate the air as sound waves.

The discovery of piezoelectricity shows many useful applications like cell phones, music system, vibration sensor, ultrasonic transducer and many more in our daily life.

In surgical fields use of piezoelectricity was first introduced by Fernando Binchetti, Domenico Vercellotti and Tomaso Vercellotti[19]. Power ultrasonics devices basically consists two fundamental components one is generator and other transducer. Transducer converts electrical energy to mechanical energy and mostly tuned to operate within a narrow frequency range, whereas the generator transforms main power supply from a specific frequency range to the tuned frequency of transducer and simultaneously altering the voltage or current to optimise performance.

## Parts of piezo surgical unit:

## Control panel:

It is the control unit of whole system (Fig.1) consist of different programme setting based on the application in different field of dentistry. Bone, Perio and Endo are the different programme modes and scheduled for different power output during operation. Nowadays there are various models available in the market by different manufacturers who provides some added function of the device for better functioning (Fig.2). Apart from programme button it has one power control knob and one water control knob specified for controlling power output and water flow respectively.

**Figure 1. Piezo surgical unit**

 


**Figure 2. Control panel**

**Figure 3. Hand piece with surgical insert**

## Hand piece:

It is the part which joins the main control unit with different surgical inserts (Fig3). It is autoclavable and attaches with main control unit with a cord that carries power, water and light to the hand piece.

## Foot switch / Foot control:

This is basically additional control switches that is operated by foot of the operator and allow operator to control the whole unit hands freely during operation.

## Peristaltic pump:

It is a delivery device of irrigation solution through the various surgical inserts. The flow rate varies from 0 to 60 ml / minute and in some higher models it is even 0 to 120 ml /min. Irrigation solution serve two purposes, it produce cooling effects and provides cavitation effects. Irrigation solution generally cooled at $4^0$ C for better cooling effects.

## Surgical inserts:

Mectron originally the manufacturer of ultrasonic scaling device first introduced a specified hard tissue cutting device and it is reported successfully during a sinus filling procedure[20]. The first designed surgical insert OT1 & OT2 resembles the original scaling version. OT1 and OT2 both have very similar design characteristics with OT1 having diamond coated tip where as OT2 missed it. Trial shows OT1 insert was less efficient at cutting and produce more heat on hard tissues in compare to OT2 insert. However it is still used for finishing tool on freshly cut bone edges. In view of increasing cutting efficiency of OT2 insert under gone through several modification over a period of time and resulting in OT6 and OT7. OT 6 with saw like edges and OT7 with same design characteristics with elongated blade (Fig 4) which provides better depth[21]. Apart from various cutting tips (Fig.5) there are various non cutting blunt edged tips are also available depending on their specific applications on various tissue sites and mode of operation (Fig 6). These tips can be diamond coated or titanium nitrate coated depending on their specific use .Unlike rotary instruments and surgical saw piezo tips use high frequency vibration to cut the bone. Pressure prevents vibration, generates heat and reduces efficiency. The optimum force varies from 1.5 -3 N[22,23]. Beyond 3N pressure cutting efficiency does not improved but thermal damage increased[24].

**Figure 4. Tip with elongated blade length**

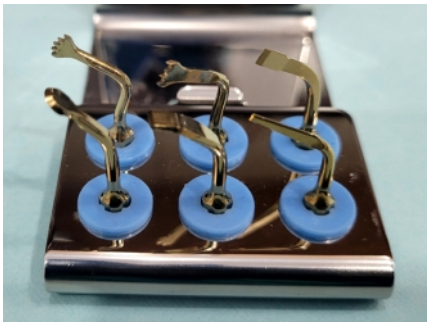

**Figure 5. Surgical inserts with cutting tips**

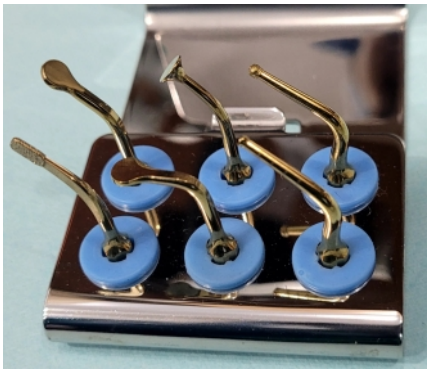

**Figure 6. Non cutting surgical inserts**

## Biological effects on tissues:

Conventional bone cutting instruments produces heat and pressure on bone during their operation. It causes elevation of local temperature and sometimes causes charring of peripheral bone. The critical level of intra osseous hyperthermia is 40 to 41 degree C and bone necrosis occurs over 47°C of temperature. Osteoblast and osteocytes are the bone forming cells which shows apoptosis over these temperature[25]. The thermal damage is directly proportional to the temperature of the cutting site and the time period that the bone exposed to it, more the time heat present over surgical site more damage will occur. To minimize heat built up shorter application cycle, intermittent application with copious irrigation solution should be used[26]. More over rotary instruments produce more ragged and rough edges over the bone surface which eventually delayed healing process. On the other hand piezo-surgical units produce micro vibration ranging from 60 to 200 micron which produces precise cutting and smoother edges in compare to conventional instruments and facilitates healing process[27]. The irrigants used for cooling purpose shows two significant effects, one is cavitation and other is micro streaming. In cavitation micro bubbles are formed, expands and collapse suddenly in a liquid medium. These ultimately release tremendous of energy in a form of shock waves. Micro streaming is the flow of fluid around an oscillating object. In piezo surgery these two effects (cavitation and micro streaming) produce a blood free environment that enhances visibility and working ability. It disrupts the cell wall and cell membrane of microorganisms and creates a sterile operating field. Study shows expression of heat shock protein (HSP 70) a potent bio-marker for stress is lower in m-RNA and protein level in bone cut with piezo surgery device in compared to other conventional bone cutting instruments[28]. There are many studies which compares the bone healing and bone formation between piezo surgery and conventional cutting instruments. Some results with different bone healing time and others with same healing rate with slightly more bone formation with piezo surgery unit. Bone harvesting with piezo unit offers more number of viable bone cells in compare to other rotary instruments.

## Application in dentistry:

1. In the field of Periodontics for osseous surgery.
2. Oral and maxillofacial surgery.
3. Implant dentistry - mainly for sinus lifting, nerve repositioning and ridge split technique.
4. In Orthodontics - Periodontaly accelerated osteogenic orthodontics. and
5. Endo-dontics for periapical surgeries.

## Advantages:

1. The most advantageous part of piezo surgery unit is sparing soft tissues during operation. The frequency range in piezo unit typically ranges from 25 to 35 KHz, in this range it only able to cut hard tissues whereas soft tissue cuts over 50 KHz of frequency, so these instruments can safely be used in areas where vulnerable anatomical land marks like nerves and vessels are presents.
2. Its micro vibration (ranging from 60 to 200 micron) produce smooth cuts, provides better healing.
3. Cavitation effects provides better cooling effects, blood less field with better visibility and enhance working ability. It also produces sterile field.
4. Different surgical inserts allow reaching in inaccessible areas safely.
5. Patient comfort, as less vibration during procedure in compare to other conventional instruments. Better healing and less post operative complications.

## Disadvantages:

1. Costly in compare to other conventional bone cutting instruments.
2. Need different learning curve.
3. Increased operating time.

## CONCLUSION

Piezo-electric surgical unit is an ultrasonic device that uses piezo electric technology to form micro vibration. In compare to other conventional instruments it's safe, comfortable and shows better post operative outcomes. Its soft tissue sparing effects and cavitation creates a visually improved surgical field which make it a clear winner over conventional instrument.

**Conflict of interest:** None

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