Review Article

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ULTRASOUND BONE SURGERY: A BOON FOR THE BONE

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ABSTRACT

Piezoelectric ultrasonic units have been used to power periodontal scalers and endodontic instruments for many years. Piezoelectric bone surgery known simply as piezosurgery is a new technique of osteotomy and osteoplasty which requires the use of micro-vibrations of ultrasonic frequency scalpels. The principle of piezosurgery is ultrasonic transduction obtained by piezoelectric ceramic contraction and expansion. The vibrations thus obtained are amplified and transferred onto the insert of a drill which then has mechanical cutting effect exclusively on mineralized tissues. With piezoelectric surgery it has been possible to perform precise osteotomy lines, micrometric and curvilinear particularly in close proximity to the vessels and nerves. Though this new ultrasound cutting method involves a different learning curve compared to other techniques, it has been increasingly used in various fields of dentistry with improvements in power and geometry of the inserts which has a selective action upon the mineralized tissues.

KEYWORDS: Ultrasound; Piezosurgery; Bone surgery

INTRODUCTION

The ultrasonic or ultrasound frequency, as the name implies, is a frequency above the audible range for humans, usually above 20 kHz. In dental applications the ultrasound frequency used ranges from 24 kHz to 36 kHz the frequency range capable of cutting mineralized tissue. Ultrasound has been used for decades to cut tissue. At present, the use of power ultrasonics is becoming very popular in the field of dentistry. Ultrasonic scalers driven by magnetostrictive, or piezoelectric ultrasonic transducers have been used to remove tartar and plaque on teeth. In the last decade; a revolutionary surgical technique, known as piezosurgery, was invented by Professor Tomaso Vercellotti in 1998. The Piezosurgery device consists of a novel piezoelectric ultrasonic transducer powered by an ultrasonic generator, capable of driving a range of resonant cutting inserts. This innovative device was first designed and commercialised by Mectron® Medical Technology.[1] Piezosurgery was invented and developed to reach increasingly higher levels of precision, safety and rapidity in recovery in bone surgery.

MECHANISM

With piezoelectric ultrasonic the frequency is created by driving an electric current from a generator over piezoceramic rings, which leads to their deformation. The resulting movement from the deformation of the ring sets up a vibration in a transducer and/or amplifier, which creates the ultrasound output. These waves transmitted to the handpiece tip, also called an insert, where the longitudinal movement results in cutting of osseous tissue by microscopic shattering of bone. The active element is basically a piece of polarized material with electrodes attached to two of its opposite faces. Application of electric field to this material causes electrostriction of molecules. The active element of most acoustic transducers used today is a piezoelectric ceramic, which can be cut in various ways to produce different wave modes. Early 1950's, piezoelectric crystals made from quartz crystals and magnetostrictive materials were primarily used. Piezoeletric ceramic soon became the dominant

material for transducers due to their good piezoelectric properties and their ease of manufacture into a variety of shapes and sizes. They also operate at low voltage and are usable about 300°C. Cavitation - It is the microboiling phenomenon occurring in liquids on any solid-liquid interface vibrating to an intermediate frequency. It corresponds to a rupture of the molecular cohesion in liquids and the appearance of zones of depression that fill up with vapour until they form bubbles about to implode. In case of detartrating tools, cavitation occurs when the water spray comes in contact with the insert vibrating to intermediate frequencies.[1-3]

INSTRUMENT

Piezoelectric device is with a functional frequency of 25-29 kHz and the possibility of 30 Hz digital modulation and a series of inserts of different forms with a linear vibration ranging from 60 to 200 µm. The power of the device is 5 W (Ultrasonic scaler 2 W). Each part of the instrument (Fig. 1) is described below.[1,4,5]

1. Control Panel

There are two basic programs BONE and ROOT. In the BONE program, it is possible to adapt the power to any of four levels depending upon bone quality. In the ROOT program, the power can be set to either PERIO or ENDO. The CLEAN function is activated by pressing a button and the footswitch together to start the cleaning cycle of the unit's main tubes.

2. The Dynamometric Wrench

The insert tips are tightened to the handpiece with the dynamometric wrench.

3. The Liquid

Liquid is drawn from a bag or bottle which hangs from the rod provided. All parts of the unit through which the liquid passes, including the handpiece cord and the handpiece itself, are fully sterilizable.

4. The Peristaltic Pump

The peristaltic pump is for cooling with a jet of solution that discharges from the insert with an adjustable flow of 0 – 60 ml/min and removes detritus from cutting area. For cooling effect, the solution is refrigerated at 40°C.

5. The Handpiece

The handpiece is connected permanently to the handpiece cord and the two are sterilized together. Each Piezosurgery unit comes with two handpieces.

From a clinical point of view, the piezosurgery system offers three different power levels:

1. Low mode indicated for apical endocanal cleaning, in orthodontic surgery;
2. High mode, useful for cleaning and smoothing the radicular surface;
3. Boosted-mode, indicated in bone surgery, necessary in performing osteotomy and osteoplasty.

The Ultrasonic bone surgery device differs from conventional tools by 4 parameters: the generator frequencies, and insert's weight, hardness and form. It is made of a generator of intermediate frequencies. Inserts used are those whose vibrations can enter in resonance with the piezoelectric ceramic chips of shaft. This resonance enables us to increase the energetic output, making the insert more efficient.

Inserts Available Can Be Classified As

- **Sharp,** covered with titanium nitrate (gold colour), which offers a harder surface, and, in turn, maximum efficacy in cutting;
- **Diamonds,** which are used in the case of thin bone osteotomy or to complete osteotomies, close to important anatomical structures. These offer a clinically less efficacious cut, are histologically more traumatic than the cutting inserts, but much safer.

INSERT TIPS COLOR

- **Gold** For all insert tips used to treat bone.
- **Steel** For all insert tips used to treat soft tissue or delicate surfaces such as the roots of teeth.

Many different tips are available for different purposes. Four major categories of tip kits depending on the type of surgery are Implant Kit (Fig. 2), Periodontal kit (Fig. 3), Extraction Kit (Fig. 4), Sinus lift Kit (Fig. 5). Tips for Ridge expansion, Corticotomy technique, Bone block grafting, Bone chip grafting, Scraper, Apicectomy and retro surgical procedures, Osteotomy close to nerves are also available.

BIOLOGICAL EFFECTS ON BONE CUT BY PIEZOELECTRIC DEVICE

UBS provided more favourable osseous repair and remodeling when evaluated at day 14 and day 56 than carbide bur (Fig. 6a) or diamond bur (Fig. 6b)when surgical ostectomy and osteoplasty procedures were performed. Therefore, UBS (Fig. 6c) could be regarded as being efficacious for use in osseous surgery.[6] Histomorphological analyses done to compare UBS and traditional

Fig. 1: Ultrasound Bone Surgery Unit

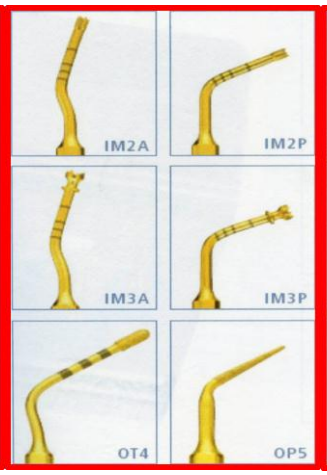

Fig. 2: Implant Kit

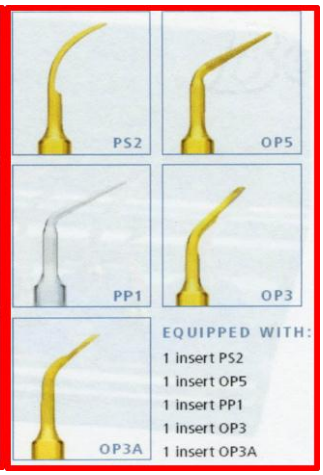

Fig. 3: Periodontal Kit

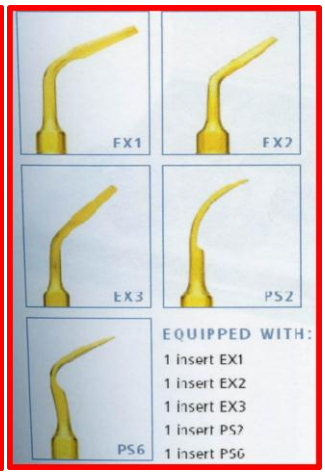

Fig. 4: Extraction Kit

drills demonstrated that more inflammatory cells were present in samples from drilled sites. Also, neo-osteogenesis was consistently more active in bone samples from the implant sites that were prepared using piezoelectric bone surgery. It was also noted that bone around the implants treated with piezoelectric bone surgery technique showed an earlier increase in BMP-4 and TGF-β2 proteins as well as a reduction in proinflammatory cytokines.[7]

APPLICATIONS

Ultrasonic instruments are used for soft tissue incisions.

Applications of Piezosurgery devices[1,8- 23]

1. Cranial Osteoplasty
2. ENT surgery, neurosurgery, paediatric surgery and orthopaedics
3. Rhinoplasty
4. Otologic surgery
5. Orthodontic Applications
   - Corticotomy.
   - Exposure of impacted canines.
6. Oral surgery
   - To treat TMJ ankylosis.
   - Nerve mobilization or nerve transposition procedures.
   - Atraumatic extractions.[24]
7. Periodontology
   - Resective surgeries.
   - Regenerative surgeries - To obtain autogenous grafts for treatment of periodontal intrabony defects (Fig. 7a).
8. Implantology (Fig. 7b, Fig. 7c, Fig. 7d)
   - For harvesting block (bone) grafts and eventually implant placement in the recipient sites.
   - Osteotomy procedures.
   - Distraction osteogenesis followed by Implant placement.
   - For Retrieval of blade implants.
   - Ridge Expansion and implant placement.
   - Maxillary sinus elevation procedures.
   - Drilling hole in the bone for implant placement.
   - For insertion of implant.

ADVANTAGES

UBS device have the advantages of being[3,22,23]

1. **Safe**
2. **Selective** for the mineralized tissues
3. **Micrometric** - the insert vibrates with a range of 60-200 µm at a modulated US frequency which while cutting maintains the bone constantly clean, thus avoiding excessive temperatures;
4. Surgical control with piezosurgery is maximum as the **strength** required by the surgeon to affect a cut is far less compared to that with a drill or with oscillating saws.
5. It is possible to have **direct visibility** over whole osteotomies since there is minimal intra-operative bleeding.
6. The **slightly increased time** for operation using the Piezosurgery instrument, compared with that of the conventional drill, is negligible.

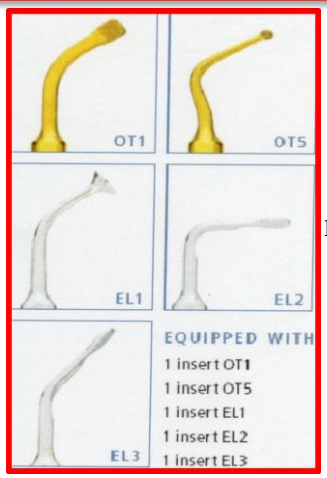

Fig. 5: Sinus Lift Kit

Fig. 6a: Osteotomy with carbide bur

7. Reduced sensitivity and faster recovery of the lower Lip and Chin following Mandibular Bilateral Sagittal Split Osteotomy Using Piezosurgery.

Comparision of Piezosurgery Device with Conventional Micromotor Instruments and Oscillating Saw[5,22]

1. Burs controlled by a micromotor require greater strength that is obtained by applying increased pressure by hand. As a result, surgical sensitivity is reduced, especially when there are structures presenting different mineralization.
2. Oscillating saws though guaranteeing excellent linearity, they do not allow control of the depth of the cutting, at the sides or in the centre, and, therefore, it is often necessary to complete the incision with a scalpel and hammer.
3. When it is necessary to perform an osteotomy starting from the cortex, clearly the strength necessary to make use of the "torque", in the more mineralized bone structure, this suddenly becomes excessive when passing to the spongiosum or when the cortical bone is finished. This causes an immediate loss of control of the surgical instrument, a condition which may be very dangerous in close proximity to delicate anatomical structures, such as vessels and nerves.
4. The traditional motorized instruments produce macrovibrations while the piezoelectric drill produce linear microvibrations of an ultrasound nature thus increase the surgical safety.
5. The effects of the increases in temperature on the surfaces of the cut were examined. In the bone sections examined, obtained with the piezoelectric drill, no phenomenon of necrosis was revealed, but on the contrary, nucleated osteocytes and a peak in growth factors was observed, in particular of the biomorphogenetic proteins, one hour after the operation, signs indicating early bone regeneration. Instead, in those patients in whom the oscillating saw was employed, but, particularly, in those in whom the diamond burrs had been adopted, phenomena such as changes in the protein structures and protoplasmatic lipids, modifications in enzymatic activity resulting in bone damage, were observed.

Fig. 6b: Osteotomy with diamond bur

A recent randomized controlled clinical trial done to compare the use of UBS and conventional rotary instruments for the bone removal for impacted third molar removal demonstrated reduced post operative pain, discomfort, trismus and swelling in the UBS treated sites.[24]

Limitations

Limitations of UBS device include[5]

1. Different learning curve.
2. Increasing the working pressure above a certain limit impedes the vibrations of the insert, and the energy is transformed into heat.
3. Increase in the operating time, compared with that with traditional cutting instruments.

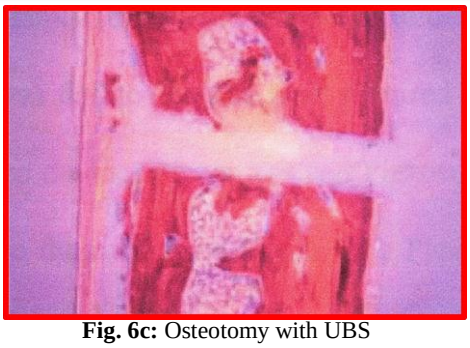

Fig. 6c: Osteotomy with UBS

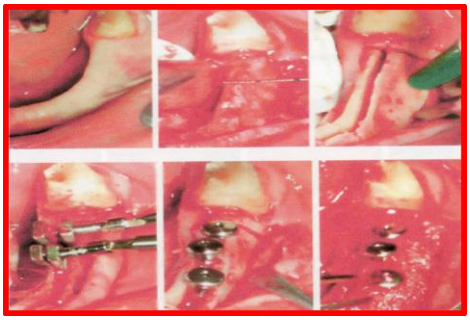

Fig. 7b: Ridge Expansion Followed by Implant Placement

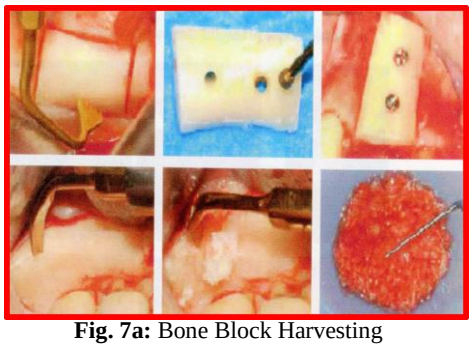

Fig. 7a: Bone Block Harvesting

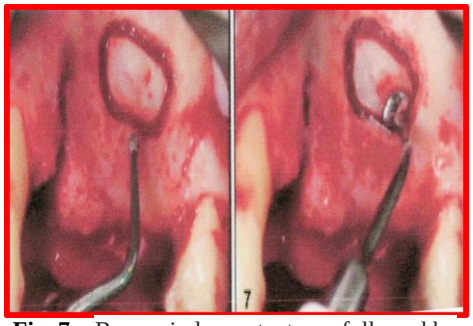

Fig. 7c: Bony window osteotomy followed by

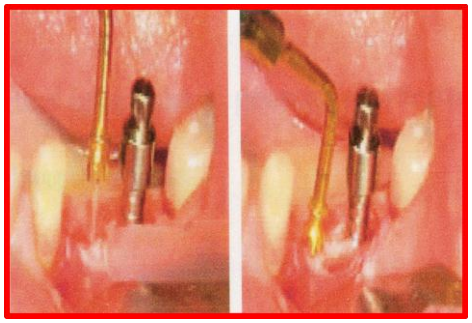

Fig. 7d: Implant Site Preparation

4. The difficulty or impossibility to perform the deeper osteotomies (e.g.: maxillo-pterygoid disjunction), due to lack of inserts of the appropriate length.
5. The economic aspects. Piezosurgery inserts get worn away very rapidly. It is recommended never to go beyond ten uses in bone surgery.

CONCLUSION

Ultrasound Bone surgery provides many advantages over the conventional motorized instruments and oscillating saws. UBS with its various ranges of tips has a variety of applications in Dentistry like in the fields of Periodontics and Implantology and Oral and Maxillofacial surgery. With few limitations this invention of Dr. Tomaso Vercelloti has helped surgeons make the results of bone surgery more predictable, has improved healing, minimized the trauma and provided greater safety for patients. Thus, we conclude that Piezosurgery is an advantageous osteotomy technique for delicate structures in the oral and maxillofacial region. With respect to osteotomies of thin and fragile bones, the application of ultrasound is superior to other mechanical instruments because of the extremely precise and virtually arbitrary cut geometries, easy handling, efficient bone ablation and minimal accidental damage to adjacent soft tissue structures.

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