Review Article

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Piezosurgery: A Tool of a Trade

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ABSTRACT

Background: Piezosurgery, a promising, meticulous and soft tissue-sparing system for bone cutting, based on ultrasonic microvibrations. To date, it has been indicated for use in Oral and Maxillofacial Surgery, Otorhinolaryngology, Neurosurgery, Ophthalmology, Traumatology and Orthopaedics. Piezosurgery is a revolutionary technical modality for different aspects of bone surgery with a rapidly increasing number of indications throughout the whole field of surgery. It provides an alternative to the mechanical and electrical instruments used in conventional oral surgery. This review summarizes current knowledge about piezosurgery.

Keywords: Osteotomy, Piezosurgery, ultrasonic microvibrations.

INTRODUCTION

The use of manual instruments and motorized devices for hard tissue procedures in Oral and Maxillofacial Surgery has a very long history. Ultrasonic vibrations have been used to cut tissue for more than two decades.[1,2] However, it is only in the recent years that experimental applications have been used routinely for standard clinical applications in many different fields of surgery.

Piezoelectric bone surgery, frequently called Piezosurgery is a promising, precise, bone-cutting system that is based on ultrasonic micro vibrations and spares soft tissue. This allows for the selective cutting of bone and causes minimal trauma at the time of the operation because any cuts are micrometric and selective, and most damage is limited to the surrounding tissues. It also decreases the risk of damage to critical structures like nerves, vessels, and mucosa, particularly during osteotomy.[3,4]

This review describes the current status of the application of Piezosurgery in the field Oral and Maxillofacial Surgery.

Evolution of Tool

The piezoelectric effect was first described by the French physicists Jean and Marie Curie, in 1880. This piezoelectric effect is the creation of electrical tension on some crystal and ceramic materials such as quarts 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 Greek word 'piezein', meaning pressure. The cutting of hard tissue with ultrasonic vibrations that are formed by the piezoelectric effect was first described by Catuna[5] in 1953 followed by Volkov and Shepeleva[6] in 1974. In 1981, its application in Orthopaedic surgery was described by Aro et al [7], and by Horton et al.[8] in Oral Surgery. The first model of current piezoelectric

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devices was developed Italian Oral Surgeon Tomaso Vercellotti [9].

Piezoelectric device (Figure 1) operate on principles that are similar to the piezoelectric dental scaler devices, commonly used in the dental practice, but the ultrasonic dental scalers are not capable of cutting through hard tissues. The most innovative feature of the piezoelectric device is selective cutting. Although piezosurgery cuts mineralized tissues such as bones, it does not cut soft tissues such as vessels, nerves and mucosa[10].

Piezoelectric devices typically consist of a handheld device (handpiece), a base unit and a foot pedal. There are different-shaped inserts (Figure-2) that correspond to different applications that can be screwed into the handpiece. The handpiece is controlled by a foot pedal with settings that can be adjusted on the base unit. A frequency of 25–29 kHz is used because the micromovements (figure-3) that are created at this frequency (ranging between 60 to 210 μm) cut only mineralised tissue; neurovascular tissue and other soft tissue are cut at frequency higher than 50 kHz.[11-14]

Fundamentals of Piezosugery

The cavitation effect of piezoelectric surgery is crucial in bone surgery. Cavitation is the formation and the immediate implosion of cavities within a liquid (i.e. small liquid-free zones, 'bubbles'). These bubbles are formed as a consequence of the forces that are acting upon a liquid. It typically occurs when a liquid is subjected to a rapid change in pressure, leading to the formation of cavities within the liquid where the pressure is relatively low. In piezoelectric surgery, the cavitation phenomenon 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) that will occur in a flowing liquid as a result of the decrease and increase in pressure that is caused by the ultrasonic vibrations. In ultrasonic osteotomy, the cavitation phenomenon helps to maintain good visibility in the operative field by dispersing a coolant fluid as an aerosol that causes the blood to be washed away. Furthermore, the cavitation effect will bring about haemostasis, which results in a bloodless surgery. Walmsley et al.[15] suggested that the cavitation

Fig 1: Piezoelectric device.

Fig 2: Insert Tips for osteotomy.

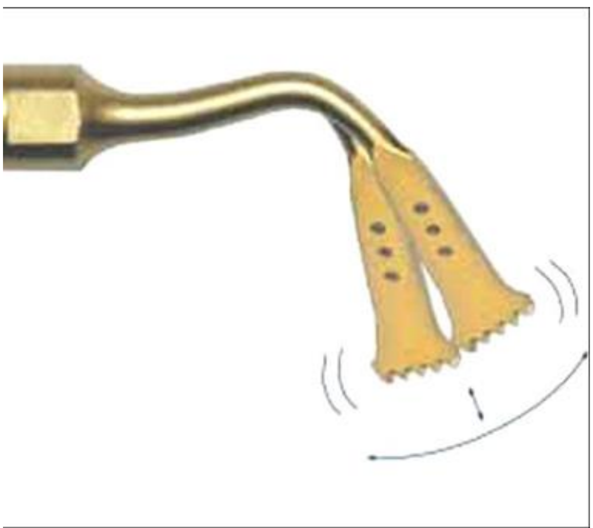

Fig 3: Micro vibration tip.

result in fragmentation of the cell walls of the bacteria, and thus possess an anti-bacterial property.

The cutting characteristics of piezosurgery are dependent upon the degree of bone mineralization (density), the design of the insert, the pressure applied on the handpiece and the speed of movements during use. The frequency of ultrasonic vibrations (Hz), the level of power (W) and the water spray are three adjustable settings that should be set in accordance with the intended procedure.

Biological effects on Bone:

The effects of mechanical instruments on the structure of bone and the viability of cells are important in regenerative surgery. Relatively high temperatures, applied even for a short time, are dangerous to cells and cause necrosis of tissue. There have been several studies about the effect of piezoelectric surgery on bone and the viability of cells.[16,17] Autologous bone that had been harvested by different methods (round bur on low and high-speed handpiece, spiral implant bur on low-speed hand-piece, safe scraper, Rhodes back action chisel, rongeur pliers, gouge shaped bone chisel, and piezoelectric surgery) was examined using microphotography and histomorphometric analysis and evaluated particle size, percentage of vital and necrotic bone, and the number of osteocytes per unit of surface area.[18] The results showed that the best methods for harvesting vital bone are: gouge-shaped bone chisel, back action, enblock harvesting, rongeur pliers, and piezoelectric surgery. Bone that has been harvested with a round bur on low and high speed hand-pieces, a spiral implant bur, or safe scrapers, is not suitable for grafting because of the absence of osteocytes and the predominance of non-vital bone.

Table 1: Relevant clinical studies on the use of Piezosurgery in the Oral and Maxillofacial region[21]

Study	No. of patients	Procedure	Most important results
CROSEITI et al	127	Oncological and reconstructive surgery	Useful in different indications, 20% longer operation time
GEHA et al	20	BSSO	75-80% complete neurosensory recuperation
GLEIZAL et al	57	Orbital tumours	No soft tissue damage, longer operation time
HAPPE	40	Harvesting bone graft	93% donor site success, 96% graft site success
LANDES et al	90	Different orthognathic surgery	Decresed blood loss, unchanged operation time, significant less inferior alveolar nerve damage
STUBINGER et al	60	Bone augmentation	Selective cutting, clear surgical site, lower soft tissue damage, more time consuming
STUBINGER et al	32	Sinus lift	Membrane perforation in 19%, low soft tissue damage, no postoperative swelling
WALLACE et al	100	Sinus lift	7 % membrane perforation rate
BLUS and SZMUKLER	23	Tooth extraction and implantation	Very good osteointegration of implants
BLUS et al	43	Split-crest and immediate implantation	No risk of bone thermonecrosis, decreased risk of soft tissue injury

Recently, Stubinger et al showed that autologous bone from the zygomaticomaxillary region that had been harvested with a piezoelectric device could be used in augmentation for stable and aesthetic placements of oral implants.[19]

In another histomorphological study, porous titanium implants were inserted into minipig tibias. The concentration of morphogenetic protein (BMP)-4; transforming growth factor (TGF)-β 2; tumour necrosis factor α, and interleukin-1 β and -10 were evaluated in peri-implant osseous samples and the analyses showed that neo-osteogenesis was consistently more active in bony samples from implant sites that had been prepared using piezoelectric surgery, and there was an earlier increase in BMP-4 and TGF-β 2 proteins, and fewer pro-inflammatory cytokines in bone around the Implants[20].

CONCLUSION

Compared to traditional rotating instruments, piezoelectric devices are safe and effective for osteotomy or osteoplasty because of the absence of macro vibrations, ease of use and control, and safer cutting, particularly in complex anatomical areas. It has several clinical advantages like precise cutting with micrometric sensitivity, sparing of vital structures like neurovascular bundles, and better visualization of the surgical field due to reduced intraoperative bleeding. 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.[20]

However, there are also few limitations like increased Operating time for osteotomies compared with traditional saws, and increasing the working pressure may impedes the vibration of devices which transform the vibrational energy into heat, resulting in tissue damage.[22,23] Not recommended in particularly for patients with cardiac pacemakers.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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