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Piezosurgery in Dentistry: A Versatile Tool In Bone Management.

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ABSTRACT

Piezoelectric surgery applied to bone, also known as the Piezosurgery® technique, is a new option for osteotomies and ostectomies, using an ultrasound device. This device produces specific ultrasound frequency (25-29 kHz), and has been designed to secure increased precision in application to bone surgery. This instrument produces selective sectioning of the mineralized bone structures causing less intra- and postoperative bleeding. The principle of piezosurgery is ultrasonic transduction, obtained by piezoelectric ceramic contraction and expansion. Furthermore, with piezoelectric surgery it has been possible to perform precise osteotomy lines, micrometric and curvilinear with absolute confidence, particularly in close proximity to the vessels and nerves and other important facial structures. This new ultrasound cutting method will, no doubt, in the future, be increasingly used in oral surgery, particularly with improvements in power and geometry of the inserts, with possible applications also in neurosurgery, paediatric surgery and orthopedics, branches in which a selective action upon the mineralized tissues is of fundamental importance.

INTRODUCTION

Within the field of dentistry, Ultrasound was first applied in dentistry in 1952, specifically for preparing dental cavities, which was subsequently displaced by the introduction of high-speed rotary instruments. This was based on the reports on cutting effects of high-frequency sound waves on dental hard tissue by Catuna in 1953 [1]. Traditional rotating instruments gave generally good results, however their action is always more traumatic; moreover, their action is strictly related to the surgeon's capability, giving less predictable results over the treated surfaces. Drillers are the most common bone cutting instruments and until few years ago, they were the sole devices used to cut bone tissue. In recent years, Piezosurgery and erbium lasers were introduced in bone surgery [2].

Piezoelectric bone surgery, also simply known as piezosurgery, is a new technique developed by Italian oral surgeon Tommaso Vercellotti in 1988 utilizing an innovative ultrasonic surgical apparatus, known as the Mectron piezosurgery device [3].

Piezosurgery was developed in response to the need to reach major levels of precision and intraoperative safety in bone surgery, as compared to that available by the traditional manual and motorized bone cutting instruments. It is a promising, meticulous and soft tissue sparing system for bone cutting, based on ultrasonic microvibrations. It was developed to overcome the limits of traditional instrumentation in oral bone surgery by modifying and improving conventional ultrasound technology.

Piezosurgery's accuracy and selectivity render it superior to conventionally rotating instruments in operations where the area of interest is adjacent to nerves, such as when strongly displaced and impacted wisdom teeth are located in close proximity to the inferior alveolar nerve, in osteotomies performed close to the mental foramen, or in lateral nerve displacements. The advantages of the piezo osteotomy can also be applied to preimplantologic surgery for augmentative purposes [1].

Not only is this technique clinically effective, but histological and histomorphometric evidence of wound healing and bone formation in experimental animal models has shown that tissue response is more favourable in piezosurgery than it is in conventional bone-cutting techniques such as diamond or carbide rotary instruments [3].

Unit

The unit consists of *handpiece, foot switch, ultrasound, control, dynamometric wench and peristaltic pump.*

Each piezosurgery unit is supplied with two handpieces. It is connected to the main unit, which has holders for the handpiece and irrigation fluids. The liquid is drawn from a bag hanging from the provided rod. All the parts of the unit through which the liquid passes, including the handpiece cord and the handpiece itself, are fully sterilizable. The insert tips are tightened to the handpiece with the dynamometric wrench, applying a pre-defined force to obtain optimum energy transmission. High-frequency oscillations of 24,000 and 29,500 Hz, modulated with a low frequency between 10 and 60 Hz, enables efficient and controlled use. The unit is controlled solely by means of the keyboard. Each command selected is shown on a display. The sterile tube inserted into the pump contains the liquid. It is used 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 the cutting area [4].

The Insert Kits

Kit containing the insert tip can be used for various procedures. The tips have been classified as sharp, smoothening and blunt tips. Sharp insert tips are used in osteotomy and osteoplasty, whenever a fine and well-defined cut in the bone structure concerned is required. The smoothing insert tips have diamond surfaces enabling precise and controlled work on the bone structures. Smoothing insert tips are used in osteotomy when it is necessary to prepare difficult and delicate structures, for example those for preparing a sinus window or for access to a nerve. Blunt insert tips are used to prepare the soft tissue, for example for elevating Schneider's membrane or for lateralizing nerves. In periodontology, these insert tips are used for root planning [4].

The tips are either gold or steel colored. The gold tips are used to treat bone whereas the steel tips are used to treat soft tissues or delicate surfaces such as the roots of teeth. The golden colour of the insert tips is obtained by the titanium nitride coating to improve the surface hardness, which means that their working life may be longer [4].

Mechanism

Piezosurgery is based on the piezoelectric effect, first described by Jean and Marie Curie in 1880. 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, when rapidly applied, with slight pressure, upon the bony tissue, results, in the presence of irrigation with physiological solution, in the *cavitation* phenomenon, with a mechanical cutting effect, exclusively on mineralized tissues [5].

In this device, the electrical field is located in the handle of the saw. Due to the deformation caused by the electrical current, a cutting – hammering movement is produced at the tip of the instrument. These micro movements are in the frequency range of 25 to 29 kHz and, depending on the insert, with amplitude of 60 to 210 μm. This way only mineralized tissue is selectively cut. Neurovascular tissue and other soft tissue would only be cut by a frequency of above 50 kHz [6].

Modes

Several forms of modes are available [5]:

- *Low Mode*: is useful for apical root canal treatment in dentistry.
- *High Mode:* is useful for cleaning and smoothing bone borders.
- *Boosted Mode*: is most often used in oral and maxillofacial surgery in osteoplasty and osteotomies.

In the boosted mode, digital modulation of the oscillation pattern produces alternating high-frequency vibrations, with pauses at frequencies up to 30 Hz; this prevents the insert from impacting bone and thus avoids overheating, while maintaining optimal cutting capacity [7].

This modality of work is further divided into *a*, *b*, *c*, according to the modulation of the correct frequency for the quality of the bone to be treated. As far as concerns the parameter of choice, this is based upon the sound produced by the insert during the cutting process [5].

Features

- It allows for micrometric sectioning, offering superior precision in cutting and with no bone loss [8].
- The instrument selectively sections mineralized structures, without damaging the adjacent soft tissues, which remain intact even in the case of accidental contact with the device [8].
- The physical cavitation phenomenon produced by the device ensures less bleeding [8].

An important feature of the piezoelectric device, according to unanimous agreement among the authors who have used it, is the selective cutting of only mineralized structures, without damaging soft tissues. This characteristic is due to the low frequency of the ultrasonic waves and the shape of the tip used. It is especially important when performing delicate surgeries that involve proximity to nerve tissues, such as, for example in the inferior alveolar nerve lateralization technique or even in the removal of autogenous grafts from the skull cap [9, 10].

INDICATIONS

Oral surgery

- Root extraction
- Apicectomy
- Cystectomy
- Osteogenic distraction
- Sinus lift

Specific oral surgery indications include osteogenic distraction (distraction osteogenesis), ridge expansion (crestal splitting), endodontic surgery, inferior alveolar nerve decompression, cyst removal and dental extraction—mainly impacted teeth [11]. A bone cut by piezosurgery appears to heal more efficiently.

During sinus lift with piezosurgery, the loss of bone tissue is generally lower [12]. The mucosa can be peeled off the bone with a cone compressor without any damage. Barone et al., in their randomized controlled clinical trial of thirteen patients, observed no significant differences in the diameter of necessary bone window, bone thickness, time needed or incidence of Schneiderian membrane perforation [13].

Piezosurgery has also been used in orthognathic and reconstructive surgery. Beziat et al. used piezosurgery in Le Fort I osteotomy, palatal expansion after the Le Fort, bilateral sagittal split osteotomy (BSSO), Le Fort III osteotomy for treatment of Crouzon syndrome, segmental osteotomy, osteotomy of the inferior edge of the mandible for facial asymmetry, unicortical calvarial bone grafting, removal of the superior orbital roof in craniofaciostenosis, removal of the frontal bone, removal of the external wall of the orbit or the anterior and posterior walls of the frontal sinuses to approach an orbital cavity tumour and approaching the skull base through the frontal sinus. All the cases healed well without any complications [14].

Piezosurgery presented a low grade cut precision. Cut edges showed poor histological sharpness with irregular cut lines. However, in all samples, no thermal damage was present. Piezosurgery is largely the less traumatic device in our series, however it presents poor depth of incision and several bone debris in the surgical cut margin. The Piezosurgery creates an effective osteotomy, producing less vibration and noise because it uses microvibration, in contrast to the macrovibration and extreme noise that occur with a surgical saw or bur as seen by Sohn et al [15].

Implantology

- Bony window osteotomy in sinus lift
- Elevation of schneiderian's membrane
- Ridge expansion
- Bone harvesting: chips/ blocks
- Osteoplasty
- Implant site preparation
- Extraction for immediate implant positioning

Perforations were eliminated during antrostomy preparation and the initial membrane release phases of the surgery when piezosurgery was employed [16]. Both hinge and complete antrostomies can be performed with piezosurgery using special sinus inserts. When the lateral wall is thin, it may be convenient to use the diamond-ball smoothing insert or the diamond scalpel. If the wall is thick, it is faster to reduce the thickness of the wall first with an osteoplasty insert and then refine the window with the diamond coated smoothing insert. Bone removed by osteoplasty can be harvested and incorporated within the sinus graft. Piezosurgery enables the performance of different techniques of antrostomy with similar results [3].

With the use of piezosurgery the frequency and number of Schneiderian membrane perforations or lacerations is generally lower. Wallace et al. experienced only 7 of 100 cases of Schneiderian membrane perforation in their study when using piezosurgery [16]. Vercellotti et al. observed perforation of the Schneiderian membrane in only 5% of patients [6].

Piezosurgery can also be used to harvest chips or blocks of bone tissue. Bone chips are used as space makers and guides for bone regeneration through osteoconduction, and for support of growth factors at the recipient site to speed up bone healing. Bone blocks should be used when large defects need to be filled or when the immobilization of particulate grafting material is not possible. Piezosurgery is important in bone graft harvesting, which also includes bone separation by burs; bone scrapers; back action, gouge-shaped bone chisels; trephines; ronguers and en bloc harvesting. Berengo et al. have shown that piezosurgery spares a significant amount of surviving osteoblasts and osteocytes [9].

Periodontology

- Osteotomy and osteoplasty techniques
- Reconstructive operations
- Bone harvesting for regenerative surgery
- Root debridement
- Root planning

Piezosurgery enables meticulous preparation of small bone pieces during periodontal surgical procedures, facilitating the removal of small quantities of bone adjacent to exposed root surfaces in order to avoid damaging the tooth surface. It permits inflammatory tissue removal, root surface debridement and root planning [11]. Piezosurgery is targeted mainly at bone removal and soft tissue protection, but the modified setting can be used for excision of soft tissue lesions [3].

The role of piezosurgery in reconstructive surgery is slowly increasing. Crosetti et al. claimed that the main advantages of this technique are: precision in performing osteotomies close to important soft tissues such as the inferior alveolar nerve or the dura mater; minimal bleeding from soft tissues surrounding the osteotomy line; and minimal trauma to the bony part of the flap, necessary for reconstruction [5]. Chiriac et al. did not find any detrimental effects on viability and differentiation of cells growing out of autogenous bone chips derived from intraoral cortical sites [17].

Thus piezosurgery provides precise, clean and smooth cutting with excellent visibility. The preparation of bone blocks is generally easier and safer with piezosurgery, but is more time consuming [3]. Piezosurgery can also be used for obtaining a bioptic sample. The main advantage of the specimen thus obtained is that the structures of the surgical bone margins are less impaired by this technique compared with conventional burs [18].

They observed that the slices of autogenous bone harvested with ultrasound contained vital cells which differentiated into osteoblasts, a finding that coincides with the illustrative analysis of this study, in which osteoprogenitor cells and other cells with morphology indicative of osteoblast differentiation were observed [19].

Orthodontics

- Palatal impacted teeth removal
- Orthodontic corticotomy
- Orthognathic surgery

Piezosurgery has been used for minor orthodontic microsurgical procedures, and for orthognathic surgeries such as bilateral sagittal spilt osteotomy (BSSO), surgically assisted rapid maxillary expansion (SARME) and Le Fort I osteotomy [20]. Blood loss decreased from an average 772 ml in conventional orthognathic surgery to an average 537 ml during orthognathic surgery using piezosurgery. Operation time remained the same [3].

Landes et al. performed orthognathic surgery using piezosurgery on 90 patients, where it was reported that, in cases of Le Fort I osteotomy, additional use of chisels was necessary during final separation of the pterygomaxillary suture in 33% of cases, and also during separation of the nasal septum and dorsal lateral nasal cavity walls in all cases, as the piezoelectric tools were unable to reach the desired position [21].

Piezosurgery facilitates separating the pterygomaxillary junction clearly and safely without significant risk of damaging the descending palatine artery. This separation is crucial for the proper execution of the Le Fort I osteotomy, as well as SARME, with the intent of significant future posterior expansion. The cuts between the teeth can be made precisely, with maximum sparing of the adjacent bone and without significant risk to tooth vitality. The safety of piezosurgery is also considerable in terms of reduced indirect thermal damage to the bony surfaces and adjacent structures, such as teeth, because of the copious irrigation with cooled saline solution on the surgical site [20].

The main advantage of piezosurgery during BSSO is the improved protection of the inferior alveolar nerve. Operation time remained the same and blood loss was reduced [21]. Geha et al. observed 75– 80% recovery of inferior alveolar nerve sensory functions, measured by the pinprick test, light touch sensitivity and 2- point discrimination tests 2 months after BSSO performed by piezosurgery [22].

The formation of callus that covers miniplates and screws, making the removal of such devices difficult, is a common problem in maxillofacial surgery. Using piezosurgery, the removal of such callus is quick and safe, without damaging the screw heads for subsequent screwdriver use [12].

Oncological and reconstructive surgery

With carcinoma of the infra-meso-structure, piezoelectric surgery enabled superficial osteotomies to be carried out which were necessary to perform subtotal maxillectomy. 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 [5].

Advantage

The following are the advantages of a peizosurgical unit: [3, 11]

- Allows very precise cutting;
- Avoids bone cutting using an osteotome;
- Spares soft tissue such as brain, dura mater, palatal mucosa, and the inferior alveolar nerve;
- Avoids inadvertent perforation of schneiderian membrane after antrostomy procedures;
- Faster to reduce the thickness of the alveolar wall;
- Losses of bone tissue minimal during sinus lift procedures;
- Reduced indirect thermal damage to the bone surface and adjacent structures , such as teeth;
- Produces less vibration and noise;
- Blood loss is significantly reduced

Disadvantage of piezoelectric surgery [23]:

- According to some authors, the technique demanded longer operative time.
- Another factor is the power of the equipment and the characteristics of the bone to be cut. It is evident that more compact bones require the use of more powerful equipment and suitable parameters.
- Moreover, this new technology demands that the operator must be trained, in order to obtain the maximum benefit of the technological resources available.

CONCLUSION

Piezosurgery appears to be an advanced 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 skill and involves a certain learning curve.

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