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Ultrasonic Bone Cut Part 1: State-of-the-Art Technologies and Common Applications

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The ultrasonic lancet is a surgical device able to cut out hard tissue with precision and to facilitate the cleavage of solid interfaces. It uses microvibrations of intermediate frequency generated by a piezoelectric transducer and applied to titanium nitride-hardened or diamond-coated inserts. With its vast range of inserts, it finds many applications in oral and maxillofacial surgery, such as nontraumatic dental avulsions, root surfacing and bone defect debridement, or cyst removal. It also proposes a simplified protocol for the sinus lift surgery. Last, it offers a true revolution in the bone grafting surgery by allowing precise and nontraumatic graft harvesting. This article presents its physical, technologic, and clinical aspects and discusses its most promising applications. Indeed, although the ultrasonic lancet remains a safe and powerful tool in many circumstances, it is, however, significant to define a reasoned application field to it.

The development of adequate instruments is a crucial step in the validation process of any surgical technique. Oral surgery has long been considered as low risk surgery because of the high healing potential of the oral sphere and the absence of vital risk during these interventions. Surgeons must often face maxilla surgery with rudimentary instruments that do not enable meticulous, precise work. In fact, few of these tools are really fit for nontraumatic surgery in difficult anatomic situations.

The ultrasonic lancet brings many solutions to this issue because it has been developed by maxillomandibular surgeons for specific surgery procedures. Using piezoelectric technology (that is usually used in ultrasonic detartrating devices), they have built this innovative tool. The clinical indications of this lancet have guided all the steps of its conception and fabrication.

A Little Bit of Physics

ULTRASOUNDS AND INVERSE PIEZOELECTRICITY

Ultrasounds are mechanical waves that are inaudible and biologically harmless. Nevertheless, by a simple phenomenon of agitation, they may induce the disorganization and the fragmentation of all interfaces between bodies of different nature: the ultrasonic vibrations easily enable the cleavage of solid-solid interfaces (by differential vibration) and solid-liquid interfaces (by cavitation). The medical applications of such properties are numerous, from the fragmentation of clots of dental tartar to the fragmentation of renal stone. Finally, as any intense energetic phenomenon, ultrasounds may cause thermal effects: it is possible to burn biologic tissues with ultrasounds, which explains the need to couple up ultrasonic instrumentation with an adequate irrigation to cool down the working parts of the tissue.

Pierre Curie discovered piezoelectricity in 1881. Piezoelectricity is a physical phenomenon that is specific to certain crystals (eg, quartz) and is defined by the appearance of electrical charges on the crystal surface when submitted to mechanical constraint. Therefore, inverse piezoelectricity is the opposite phenomenon: when an electric current is applied to a crystal a mechanical deformation is induced. If the current is alternative, the crystals extend and retract alternatively. Finally, if the current is alternative and of an intermediate frequency, the crystals are then sub-

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FIGURE 1. The Piezosurgery ultrasonic lancet from Mectron is made of a generator of intermediate frequency current, an irrigation pump for physiological saline solution, a shaft containing piezoelectric ceramic chips, and an important panel of inserts.

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ject to mechanical oscillations of medium frequency: these intermediate frequency microvibrations create ultrasonic waves in gases and liquids.

Practically, quartz crystals have long been abandoned in medical applications of piezoelectricity. Today we use piezoelectric ceramic chips made of Barium titanium or its equivalent. Indeed, its resistance to vibrations and resonance frequencies are more adequate for clinical applications.

CAVITATION

Cavitation is a 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 vapor until they form bubbles about to implode. This phenomenon occurs in all acoustic transitions between vibration of solids and ultrasounds in liquids, whatever the transmission direction is.

This phenomenon is used in many applications such as tanks of ultrasonic cleaning, in which the appearance and the implosion of these bubbles on the surface of the instruments enable their cleaning. In the case of detartrating tools, cavitation occurs when the water spray comes in contact with the insert vibrating to intermediate frequencies.[1]

Materials and Methods

ULTRASONIC LANCET TECHNOLOGY

Ultrasonic detartrating tools are the most common devices for dentist surgeons. Most of the present systems use inverse piezoelectricity created from Barium titanium chips or their equivalent. However, none of these systems enable us to cut through soft tissues, let alone hard tissues. On the contrary, systems that are efficient but not very sharp are desireable, so as to keep the gum undamaged,[2] and moderate vibrations are used to avoid a "pneumatic drill effect," which is particularly harmful to the amelodental junction.[3-5]

With these tools, conventional inserts enable, in the best cases, 1 to 2 mm-deep notches in the bone. In addition, these attempts often end up provoking a bone necrosis due to considerable heating.

On a technical level, the ultrasonic lancet looks like any other ultrasonic detartrating piezoelectric tool: a shaft, an insert, a generator of intermediate frequency periodic current (Fig 1). Inside the shaft, the piezoelectric ceramic chips are piled up to generate intermediate frequency vibrations (Figs 2, 3). If adequate inserts are plugged on it, it may even serve as a conventional detartrating tool. However the ultrasonic lancet differs from these conventional tools by 4

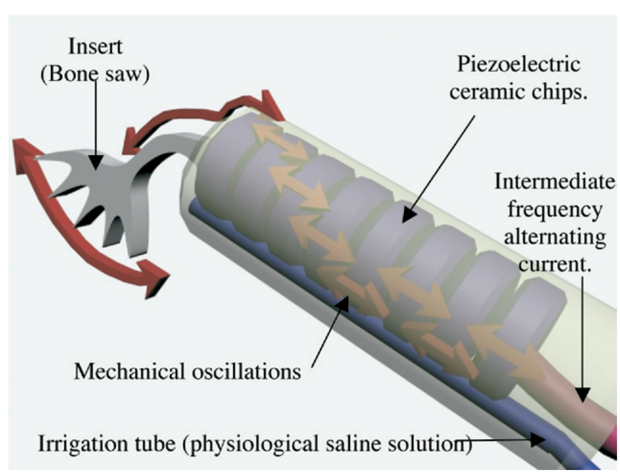

FIGURE 2. Schematization of an ultrasonic lancet device. Under an intermediate frequency current, the piezoelectric ceramic chips in the shaft will undergo dimensional alternating variations (extension then retraction in intermediate frequency oscillations [*red arrows*]) and transmit these vibrations to the insert connected to the shaft. The oscillations of the insert induce ultrasound waves in gas and liquids.

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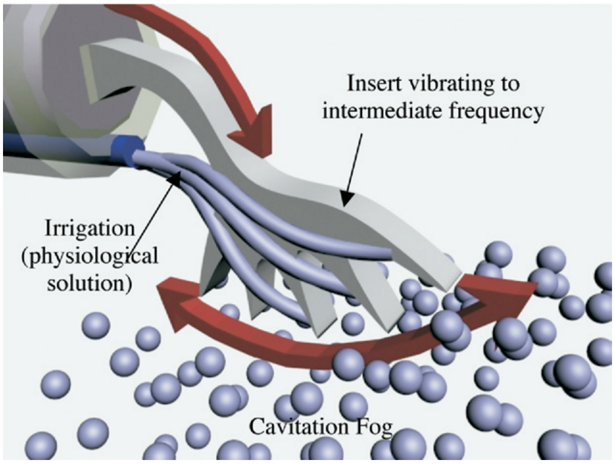

FIGURE 3. Cavitation is a microboiling phenomenon occurring in liquids on any solid-liquid interface vibrating to intermediate frequencies. When the water jet comes in contact with the insert vibrating to intermediate frequencies, it is sprayed in a cavitation fog (ie, in irrigation bubbles exploding on surfaces to cleanse).

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parameters: the generator's frequencies, and the insert's weight, hardness, and form.

The Piezosurgery system constructed by Mectron (Carasco, Italy) was the first ultrasonic lancet on the market.[6] It is made of a generator of intermediate frequencies and a pump enabling the irrigation during the operation.

Conventional inserts are used for detartrating. To obtain the cut effect looked for, modified inserts are used, whose vibrations can enter in resonance with the piezoelectric ceramic chips of the shaft. This resonance enables us to increase the energetic output, making the insert more efficient. The hardness of the insert is increased by a superficial layer of titanium nitride sometimes diamond-coated, enabling the insert to face the hardest materials without breaking. Finally, the different forms of inserts permit a cut effect when the cutting edge transforms into a micrometric oscillating saw under the effect of ultrasonic vibrations.

The generator is composed of 3 settings in frequency:

- The first setting passes on 29,000 Hz frequencies to the insert, enabling conventional detartrating when used with the adequate inserts.
- The second setting uses 29,000 Hz modulated in 50,000 Hz every 30 ns to get a moderate cut effect. It remains inefficient for bone surgery, but is an excellent compromise for periodontal surgery.
- The third setting uses 29,000 Hz frequencies modulated in 50,000 Hz every 10 ns to obtain a maximum cut effect. This setting is the most interesting for us as it enables us to have a maximum resonance between the piezoelectric chips of the shaft and the inserts of corresponding weight, implying a maximum energetic output and an optimum cut efficiency.

Each frequency setting may be associated with a different power depending on the work.[7-9] In bone incisions, however, maximum power is needed to have a sufficient cut effect.

DIFFERENT INSERTS

There is an important panel of inserts, classified in 4 categories depending on the type of surgery. Theoretically, numerous applications are possible. However, if ultrasonic vibrations easily enable a cleavage of solid interfaces, with these instruments bone incision is slower than with a turbine or a hand piece.

The first kit gathers all the inserts for periodontal surgery. It is composed of conventional inserts for detartrating and their hardened versions with titanium nitride. The latter can be coupled with higher frequency and power to get a moderate cut effect for high-performance and an in-depth debridement of periodontal lesions.

The second kit is dedicated to dental avulsions. It is composed of a series of thin scalpels covered with a layer of titanium nitride enabling us to trace trenches of passage around the teeth.

The third kit is dedicated to the opening of the maxillary sinus and lifting of its membrane. It is composed of an insert recovered by titanium nitride- and diamond-coated (for the osteotomy of access to the sinus), a large plane insert (to lift the membrane by ways of vibrations on the bone window), and 2 spatula formed inserts (to slide between bone and membrane to make the lifting easier) (Fig 4).

The last kit is composed of all the inserts necessary to cut through bone and remove fragments. All are covered with titanium nitride, giving them a sufficient hardness to cut through the bone with great power. It has a series of bone saws with 5 points and large scalpels that can become real micrometric oscillating saws under the impulsion of intermediate frequency vibrations (Fig 5). A few of these are also diamond-coated to enlarge bone trenches.

Some secondary inserts have also been developed: for example, scraper spatula for bone harvesting or cylindrical osteotomes for final osteotomy of the implanting site (Fig 6).

Results

The use of the ultrasonic lancet during dental avulsions presents numerous advantages.[6] The thinness of

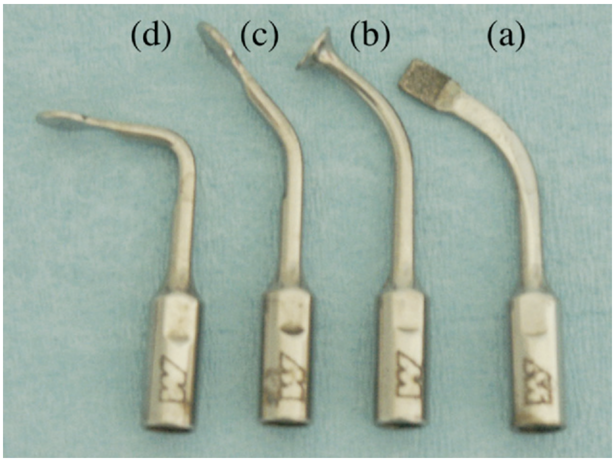

FIGURE 4. The kit of inserts for sinus-lift is composed of a diamond-coated insert (for the osteotomy of access to the sinus) (*A*), a sinus membrane separator (*B*), and 2 ultrasonic spatula (*C, D*).

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the inserts enables us to trace very thin trenches that are scarcely harmful to the periodontal bone. In addition, the ultrasonic vibrations favor the rupture of solid interfaces: by dispersing in the periodontal ligament, in the contact zones between tooth and bone or in any interface of different density, these vibrations enable an almost nontraumatic cleavage.[10] The ultrasonic lancet will therefore enable us to extract more easily some ankylosed teeth and decreases the risk of fracturing the alveolar wall. The neatness of the bone incision and the security of the procedure will facilitate the immediate implantation on the avulsion site and therefore enable a more favorable prognosis.[6]

FIGURE 5. Bone saws are titanium nitride-coated inserts: it makes them hard enough to cut bone with the maximal power of the generator. These are 5-tipped saws and large-edged scalpels that can become real micrometric oscillating saws under the impulsion of intermediate frequency vibrations.

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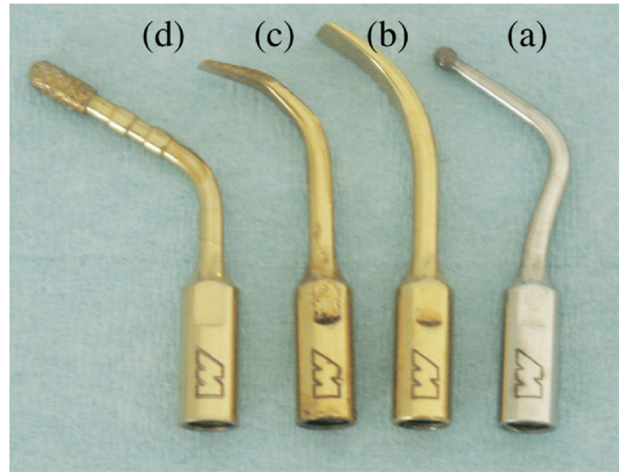

FIGURE 6. Many secondary inserts are found on the market: small diamond-coated balls for thin incisions (*A*), scraper spatula for bone harvesting (*B, C*), and cylindrical osteotomes for final osteotomy of the implanting site (*D*).

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Thanks to a vast panel of inserts and frequency settings, the ultrasonic lancet also makes debridement of bone defect and root surfacing an easy process.[10] The diamond-coated inserts enable us to draw securely and with precision the layout of periodontal bone festoons. The detartrating inserts hardened with titanium nitride and the spatula-formed inserts turn the ultrasonic lancet into a precious aid for cyst removal and the periapical debridement during endodontic surgery.

During sinus-lift surgery, the ultrasonic lancet enables a meticulous approach of the site thanks to its insert dedicated to the osteotomy of access to the sinus.[10-12] The instruments that lift the membrane are also interesting, but less efficient than a set of spatulas that are adapted perfectly to this type of intervention.

Finally, the ultrasonic lancet brings a true revolution in bone surgery by enabling thin and nontraumatic incisions while facilitating the cleavage of bone plans with ultrasonic vibrations.[13] As a matter of fact, during bone incisions, it has been histologically observed that the cut out tissue remained perfectly vital[14]: by coupling the adequate insert and the suitable frequencies, this neutralizes the thermal effect that causes necrosis and which may have been feared with such a system.[15,16] In addition, clinical observation shows that the insert's ultrasonic vibrations seem sufficient to facilitate the cleavage of bone fragments.

These properties are used successfully in numerous bone surgeries of the maxilla. In orthognathic surgery, the ultrasonic lancet enables us to trace the incision outline with great precision and the cleavage of bone blocs while using lesser hitting instruments, which gives a better control of fracture lines during the separation of maxilla or mandible portions.[17-19] In grafting surgery, the use of the ultrasonic lancet for tracing the incision outline and collecting the graft renders scissors useless, thus decreasing the patient's trauma and the risk of bone fracture.[20]

The ultrasonic lancet brings great ease in all surgical applications because of the security it gives: it only attacks tissues facing the tip of the insert, which enables us to work in zones of difficult access, with limited visual contact, and limited risk of lesions on the adjacent tissues.[21]

Discussion

AN EFFICIENT AND SECURE TOOL

Besides the neatness of the incisions and vibrations that facilitate the cleavage of solid interfaces, the ultrasonic lancet also offers a considerable advantage in terms of security and control in difficult surgeries. There is practically no risk of damaging anatomic structures during the passage of the instrument because its cut effect can only be obtained when its working end is positioned with a precise axis.[22] As opposed to rotating systems, the risk for damaging the surrounding tissues is totally nil in piezoelectric surgery.[21]

Saws and drills in electrical motorization systems are a particularly interesting combination in bone surgery, but their inertia when they stop make them dangerous when used next to major anatomic obstacles. This time of latency may be responsible for considerable damage. Pneumatic systems (turbines) bring an answer to this issue: when the practitioner releases the pedal, the pressure immediately disappears in the turbine, and the couple stops. Even if the drill still works for a few moments, its couple is so faint that it cannot cut the neighboring structures. Nevertheless, because of its weak couple, the size of its head (too big to be used in difficult anatomic situations), and its diameter (bigger size = better efficiency = important loss of substance), the turbine cannot be considered an adequate instrument for bone removal.

It is true that electrical hand-pieces with long shafts enable deep interventions. However, the ultrasonic lancet remains the most secure instrument for interventions combining difficulty of access and poor visual control.[6,23]

The ultrasonic lancet possesses 1 last considerable advantage as opposed to rotating instruments[24]: even when the water flow is maintained at a moderate level, to increase the surgical visibility, the drainage remains efficient. Indeed, in piezosurgery, water is not only used to dissipate the calorific energy transferred from the instrument in vibration to avoid burns, it also serves to the acoustic coupling of the insert tip with the tissues, thanks to a cavitation fog that is specific to ultrasonic instruments. This fog is particularly efficient to rinse treated surfaces and drain the remaining debris, as much by the spray pressure as by the abrasive effect of bubbles of cavitation in implosion.

FOR A REASONED APPLICATION

More than any other instrument, the ultrasonic lancet presents the defects of its qualities: its great precision and its efficiency in all circumstances implies an accelerated wear of inserts and a rather modest cutting speed.

Although recovered by titanium nitride and sometimes diamond-coated, inserts in piezosurgery get worn away very rapidly; it is recommended never to go beyond 10 little uses in bone surgery. Despite their hardness, inserts do not resist very long to the violence of the microabrasive impacts and may break or cause damage to tissues by uncontrollable heating. In these circumstances, it remains impossible to bring this system into general use for all types of bone surgeries. This instrument was not conceived for heavy orthopedic surgery, for example.

Because of its microabrasive functioning, the ultrasonic lancet can sometimes be less efficient compared with traditional instruments. It is the case when compared with rotating instruments with a great cutting power, but also in numerous clinical situations when a simple and rapid surgical treatment is needed.

For example, an experienced practitioner knows how to accomplish the avulsion of a tooth with instruments that are less traumatic for the bone tissue. The ultrasonic lancet may therefore be useful in this application only if there is an ankylosis of the tooth, and there is a necessity to trace a peridental trench with a bone drill, or during the disengagement of inclusive teeth. In this situation, the tracing with the ultrasonic lancet is twice as thin as with a bone drill, and therefore twice less damaging. The ultrasonic microvibrations facilitate the cleavage of solid interfaces between bone and teeth that is even more important with an ankylosed tooth, particularly sensible to vibrations.

Also, during the sinus-lift procedure, opening a sinus and lifting the membrane can be accomplished easily with conventional tools, without the ultrasonic lancet.

In all of these situations, using the ultrasonic lancet, even if it is efficient, will slow down the hand of an expert surgeon. It can therefore only reasonably be used by less experienced practitioners to whom the secure aspect of the instrument may prove very important.

These specificities make the true indications of the ultrasonic lancet very dependent on the surgical experience of the practitioner, and only few common clinical situations will truly require such a device.[13,21]

In conclusion, the ultrasonic lancet is an innovating tool that enables a secure and precise execution of many delicate interventions. Although its brute efficiency may be less than that of rotating systems, it remains adapted perfectly to the accomplishment of the majority of oral surgeries. Despite its numerous potential applications, however, it is important to define for this tool a reasoned field of application. Indeed, for an experienced practitioner, using the ultrasonic lancet may slow the surgery down in some cases because it is less invasive than conventional instruments, even though this lack of brute force is, in other situations, its principal advantage.

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