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Ultrasonic osteotomy as a new technique in craniomaxillofacial surgery

J.-L. Beziat[1], J.-C. Bera[2], B. Lavandier[2], A. Gleizal[1,2]
[1]Department of Maxillofacial Surgery, University Lyon-Nord, Lyon, France;
[2]INSERM U556, Cours Albert Thomas, Lyon, France

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Abstract. Ultrasound osteotomy is a new surgical technique used in dentistry to section hard tissues without damaging adjacent soft tissues. It was hypothesized that this could also be useful in craniofacial and orthognathic surgery. An ultrasonic device was employed in the following craniofacial surgical procedures: 144 Le Fort I osteotomies, 140 palatal expansions after Le Fort I osteotomies and 140 bilateral sagittal osteotomies; 2 Le Fort III osteotomies for treatment of Crouzon syndrome in two patients; 12 cases of unicortical calvarial bone grafting; removal of superior orbital roof in 25 cases of craniofaciostenosis; removal of external wall of the orbit in 10 cases of orbital cavity tumour; removal of anterior and posterior walls of the frontal sinuses in four cases of orbital cavity tumour. Integrity of soft tissues and surgical time were evaluated. Functional results were good without any soft-tissue damage being observed, but the overall operative time was increased. Ultrasound osteotomy is a new technical procedure that is advantageous for bone cutting in multiple situations, with minimal to no damage in adjacent soft tissues such as brain, palatal mucosa and the inferior alveolar nerve.

Key words: craniofacial surgery; orthognathic surgery; ultrasound; bone cutting; piezosurgery.

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In maxillofacial surgery, bones are cut with mechanical instruments such as saws or drills. Efforts have been made to create and develop better bone-cutting instruments in response to the need for greater precision and safety[14]. Rotating bone-cutting instruments are potentially injurious because of the production of excessively high temperatures during osseous drilling. Such temperatures can engender marginal osteonecrosis which ultimately impairs bone regeneration[6].

In 2000, Vercellotti and co-workers presented a novel technique for osteotomy without damage to adjacent soft tissue: ultrasound osteotomy[18,19]. Piezoelectric substances have the capacity to be deformed when placed into an electric field. If the polarity of the field changes periodically, these materials start vibrating. Ultrasonic vibrations can then be transmitted to diverse solid, liquid or gaseous materials[16]. This property is used in ultrasonic scalers with a functional frequency of around 20 kHz. Addition of a 50 kHz pulse every 10 ns to this basal frequency increases the power of the receiver device, allowing it to cut bones without damaging soft tissues[13]. In this study is reported the authors' experience with piezosurgery in various craniofacial and orthognathic procedures using an ultrasound piezoelectric system (Mectron).

Patients and methods

The ultrasonic device is composed of a 16-W generator attached by a flexible cord to a hand piece (Fig. 1). Different inserts can be attached to the top of the hand piece, but only one (ref: OT7) was used in this

Fig. 1. Hand piece of Mectron Piezosurgery ultrasonic device.

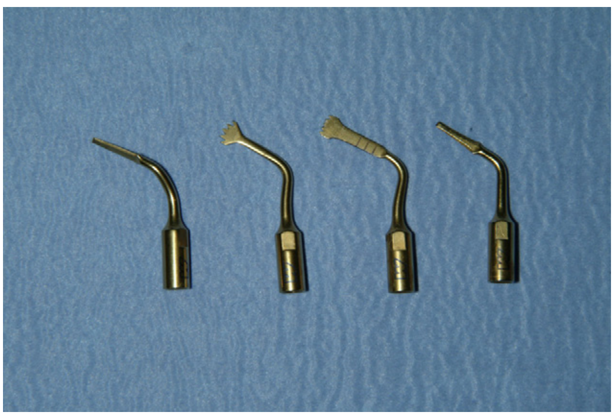

Fig. 2. Different inserts can be screwed on to the top of the hand piece.

study, and this was easily adapted to various maxillofacial procedures (Fig. 2). An automatic irrigation system was connected to the generator. A digital box controls both frequency variations between 25 and 29 kHz and the water flow. A standard pedal controls the whole set. The apparatus contains a peristaltic pump for jet cooling with a physiologic solution (0.9% normal saline). This discharges the solution from the inlet with an adjustable flow rate of 0–60 ml/min and removes detritus from the cutting area during the entire surgical procedure. The settings for power and frequency modulation of the device can be selected on a control panel with a digital display and keypad according to the planned task. The ultrasonic device provides three different power levels (low, high, boosted), the highest of which was used in bone surgery. The amplitude of the working tip ranges from 60 to 200 μm, with variable ultrasonic frequencies.

For every vibration, the head of the insert moves from 60 to 200 μm horizontally and from 20 to 60 μm vertically, working like a micro pneumatic drill. The cavitation effect of the irrigation solution is physically reduced to the formation of very small gas bubbles as a result of ultrasonically induced pressure changes. Such cavities may be present in aerated media, or they may develop through the process of rectified diffusion. The bubbles grow and may oscillate in the sound field, increasing and decreasing in volume. This motion gives rise to a localized liquid flow in the fluid around the vibrating bubble, called microstreaming, which in turn may alter cellular processes[2].

The goal of this study was to evaluate the power of ultrasonic bone cutting, with attention paid to effects on adjacent soft tissue including the dura mater, palatal mucosa and inferior alveolar nerve. To accomplish this, ultrasound osteotomy was used:

- to cut the anterior wall of the maxillary sinus during 144 Le Fort I osteotomies;
- to perform 140 palatal expansions after Le Fort I osteotomies;
- to split the mandible during bilateral sagittal osteotomies (140 cases);
- to remove 25 orbital roofs during surgery for craniofaciostenosis: the whole bandeau was removed including the roof of the orbit and forehead bone;
- to remove 15 external orbital walls and 4 walls of frontal sinuses during surgery for orbital tumours;
- to perform 2 Le Fort III osteotomies for treatment of Crouzon syndrome;
- to perform 12 cases of unicortical calvarial bone harvesting.

All the patients were treated in one centre by two different surgeons.

Different types of data were collected including:

- the duration of time for each bone cut;
- the condition of the palatal mucosa following palatal section;
- the size of the split in osteotomies of the mandible;
- any injury to the dura mater and globe following removal of the roof or external wall of the orbit;
- sensation in the distribution of the inferior alveolar nerve, with testing performed on days 5, 10 and 60 after surgery – see below.

All results were compared to those observed in cases using mechanical bone sectioning (150 Le Fort I osteotomies, 140 palatal expansions, 140 sagittal split osteotomies, 25 orbital roofs for craniofaciostenosis, 15 removals of external orbital walls, 4 removals of frontal sinuses, 2 Le Fort III osteotomies).

Clinical neurosensory testing

This was performed on all patients preoperatively, at days 5 and10 postoperatively, and at the second month postoperatively. The same person performed all tests, which were carried out in a calm room with the patient relaxed and comfortable, eyelids closed, in a semi-sitting position, after explaining and performing on the hand (free from any sensory disturbance) the different tests used. Reference points were determined over the inferior lip and chin. Right and left sides were examined separately. Patients were given a few minutes' break between the different tests.

Light touch sensation

This test examines the myelinated A-alpha fibers and would reflect large axonal neuropathy[17]. Inspired by the Semmes-Weinstein aesthesiometer, a battery of monofilaments was devised using 20-mm-long nylon monofilament suture material (Ethicon, Inc., Johnson & Johnson, Somerville, NJ, USA) of four differ-