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Micromorphometric analysis of bone blocks harvested with eight different ultrasonic and sonic devices for osseous surgery

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ABSTRACT

Objectives: The aim of this study was to analyse *in vitro* the main features of osteotomies performed by means of different ultrasonic and sonic systems for bone surgery.

Materials and methods: Six ultrasonic and two sonic devices for osseous surgery were evaluated during block harvesting on bovine bone. After measuring cutting speed, images of the blocks were acquired by light stereo-microscope and E-SEM, in order to measure the osteotomy thickness and to evaluate the presence of intra-trabecular bone debris and signs of thermal injuries on the bone. Roughness evaluation was performed using a profilometer.

Results: All the ultrasonic instruments required a shorter time than sonic systems to perform the block harvesting ($p < 0.05$). Piezomed was found to be the most efficient in terms of cutting speed (20.5 mm^2/min), even if not significantly different from most of the devices here tested ($p > 0.05$). K-Bisonic and Variosurg 3 showed the smallest percentage variance between tip thickness and osteotomy width. Intra-trabecular debris was found to occur in inverse proportion with the width of the osteotomy: the tighter the track, the higher the amount of debris. Sonicflex Bone, Piezotome 2 and Sonosurgery showed almost no signs of thermal injuries on the osteotomised surfaces.

Conclusions: No single ultrasonic or sonic device combined all the best features of speed, precision and bone micro-architecture preservation.

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1. Introduction

The piezoelectric osteotomy is the result of bone micronisation produced by mechanical shock waves with a linear vibration ranging from 24 to 36 kHz and with an amplitude varying from 20 to 200 μm: these properties produce a peculiar cutting action on hard tissues, which was extensively studied in the last decade (Vercellotti, 2000; Eggers et al., 2004; Stübinger et al., 2005; Cardoni et al., 2006; Beziat et al., 2007; Nordera et al., 2007). Main features of ultrasonic bone surgery are represented by the micrometric cut (leading to a precise and controllable surgical action) (Vercellotti, 2004; Alam et al., 2013), the selective activity on the mineralised tissues (Schaeren et al., 2008), the cavitational effect (Walmsley et al., 1990), and the positive influence of the ultrasonic cut on bone healing if compared to rotary instruments (Preti et al., 2007). Many clinical applications of piezoelectric bone cutting were described both in oral surgery (*e.g.,* maxillary sinus floor elevation (Vercellotti et al., 2001)), ridge expansion (Anitua et al., 2013), bone block harvesting (Stübinger et al., 2008), tooth extraction (Rullo et al., 2013), implant site preparation (Stacchi et al., 2013) and in other surgical fields (maxillofacial surgery, otorhinolaryngology, orthopaedics, neurosurgery).

Recently, the use of air-driven sonic osteotomes with a vibration ranging from 3 to 6 kHz and an amplitude varying from 200 to 300 μm has been proposed for applications in oral surgery and reported in some clinical and experimental studies (Agabiti, 2011; Papadimitriou et al., 2012; Viganò et al., 2015). Sonic tips rotate with a circular tapping motion, and are oriented by the friction into the osteotomic line: inserts are active on all sides, permitting work in any direction without changing the position of the handpiece.

Nowadays, the number of sonic and ultrasonic osteotomes available on the market had remarkably increased. *In vitro* and animal studies (Maurer et al., 2008; Hollstein et al., 2012; Rashad et al., 2013) demonstrated differences in the micromorphology of

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osteotomised bone surfaces between rotary and oscillating instruments, ultrasonic osteotomes, and among some piezoelectric devices themselves. Bone cut with microvibrations preserves the osseous architecture, especially the integrity of the trabeculae of the cancellous bone which, on the contrary, loses its typical structure after conventional osteotomies performed with burs or saws (Maurer et al., 2008). In these cases, the cancellous spaces are condensed with osseous debris, which represents a mechanical obstacle for the centrifugal blood supply (Schweiberer et al., 1974; Simonetti et al., 2013). Many authors underline that the preservation of the cancellous bone structure enhances the quality and the speed of the bone healing process, due to the high osteogenic potential of the spongious bone (Soldner and Herr, 2001; Rundle et al., 2006).

Hence, the objectives of this *in vitro* study were to analyse and compare the bone cutting performance of eight different sonic and ultrasonic devices when harvesting bovine bone blocks, in terms of cutting speed, surgical precision and micromorphology of the osteotomised bone surfaces.

2. Materials and methods

2.1. Investigational devices

Between February and April 2014, thirteen manufacturers and distributors of sonic and ultrasonic devices for osseous surgery were invited to join this study. An e-mail containing the study protocol was followed by direct phone calls from one investigator (CS), in order to thoroughly illustrate the project and its objectives to the invited companies. Eight manufacturers agreed to participate in this investigation, while five companies decided to decline the invitation (the complete list was reported in Table 1). Six ultrasonic devices [K-Bisonic (Kirmed, Italy); Piezomed (W&H, Austria); Piezosurgery Touch (Mectron, Italy); Piezotome 2 (Acteon Satelec, France); Surgysonic Moto (Esacrom, Italy); Variosurg 3 (NSK, Japan) and two sonic systems Sonicflex Bone (Kavo, Germany); Sonosurgery (Komet/TKD, Germany/Italy)] were enrolled in this study. Companies were asked to select the most appropriate tip and device settings, in order to harvest bone blocks with the following characteristics: i) minimal percentage variance between osteotomic track thickness and tip thickness ii) osteotomised bone surface as smooth as possible with conservation of trabecular microarchitecture integrity, limiting the presence of bone debris and avoiding thermal injuries to the bone iii) surgical time as short as possible.

Table 1
Invited manufactures and distributors (bold type is used for the companies who agreed to participate in the study).

Ultrasonic devices	• **K-Bisonic, Kirmed, Muggia, Italy**
	• MiniUNIKO PZ, Mariotti, Forlì, Italy
	• **Piezomed, W&H, Bürmoos, Austria**
	• Piezon Master Surgery, EMS, Nyon, Switzerland
	• **Piezosurgery Touch, Mectron, Carasco, Italy**
	• **Piezotome 2, Acteon Satelec, Merignac, France**
	• Surgybone, Silfradent, S. Sofia, Italy
	• **Surgysonic Moto, Esacrom, Imola, Italy**
	• Ubsurgery, Resista, Omegna, Italy
	• Ultrasurgery, De Giorgi, Baranzate, Italy
	• **Variosurg 3, NSK, Tochigi, Japan**
Sonic devices	• **Sonicflex Bone, Kavo, Biberach, Germany**
	• **Sonosurgery, Komet Brasseler, Lemgo, Germany and TKD, Calenzano, Italy**

The tested tips (Fig. 1) and the features of each system were listed in Table 2.

This trial was designed as a single-blind study (assessor blinding).

2.2. Experimental phase

Three operators with different levels of expertise were selected: operator A (CS) was an oral surgeon with more than ten years of routine practice in ultrasonic bone surgery, operator B (MF) was an expert maxillofacial surgeon who only occasionally used piezoelectric devices and operator C (FB) was a resident in Oral Surgery, with a still limited practice both in conventional and in ultrasonic osseous surgery. A fourth operator (IA – see acknowledgments), expert in sonic bone surgery, was recruited to test the two sonic devices as operator A: in these two experimental sessions CS worked as operator B and FB as operator C.

Bone-cutting performance of ultrasonic and sonic devices was evaluated during the harvesting of square shaped cortico-cancellous bone blocks (15 mm side length, 10 mm depth, at least 2 mm of cortical bone) from fresh bovine ribs, cleared of soft tissues, at room temperature. Block perimeter was previously marked with a pencil on the surface of the rib, by using a titanium template. Each operator (A,B,C) harvested one bone block with each investigated surgical device: all osteotomies were performed following the manufacturer's instructions, and conducted under irrigation with cooled 0.9% sodium chloride solution. Tests were performed in the presence of a representative for each participating company, who installed and checked the device with the selected tip, adjusted power settings and irrigation, and assisted in the experimental phase.

2.3. Cutting speed and osteotomy thickness measurement

Time required for bone block harvesting was recorded using a digital chronograph, from the beginning to the end of the programmed osteotomies. A time limit of 20 min was fixed to complete the bone cutting procedure and to be included in the subsequent evaluation. The cutting speed (mm^2/min) was obtained dividing the area of the osteotomised cortical bone by the time requested for

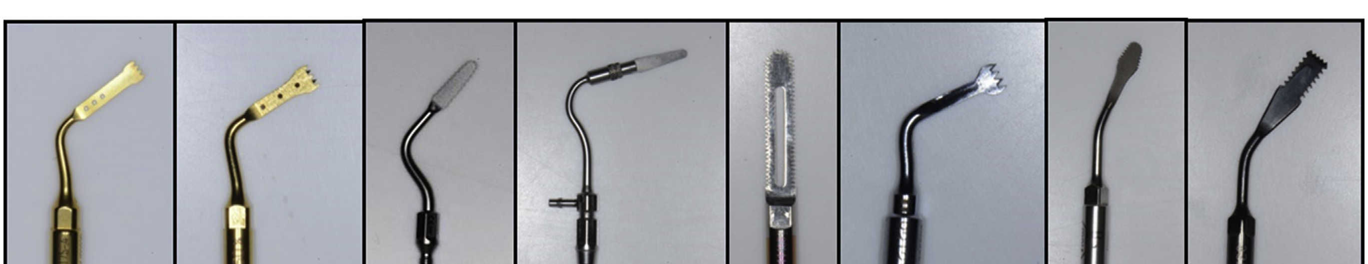

Fig. 1. Tips chosen by the companies to perform the test: left to right Piezosurgery Touch (Mectron); Variosurg 3 (NSK); Sonosurgery (Komet/TKD); Sonicflex Bone (Kavo); K-Bisonic (Kirmed); Piezotome 2 (Acteon Satelec); Piezomed (W&H); Surgysonic Moto (Esacrom).

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