CLINICAL ORAL IMPLANTS RESEARCH

Paolo Viganò
Daniele Botticelli
Luiz A. Salata
Michael T. Schweikert
Joaquin Urbizo Velez
Niklaus P. Lang

Healing at implant sites prepared conventionally or by means of Sonosurgery®. An experimental study in dogs

Authors' affiliations:
Paolo Viganò, Daniele Botticelli, Michael T. Schweikert, Joaquin Urbizo Velez, Faculty of Dentistry, University of Medical Science, La Habana, Cuba
Daniele Botticelli, ARDEC, Ariminum Odontologica, Rimini, Italy
Faculdade de Odontologia de Araçatuba, UNESP – Univ Estadual Paulista, São Paulo, Brasil
Daniele Botticelli, Niklaus P. Lang, The University of Hong Kong, Prince Philip Dental Hospital, Hong Kong, China
Luiz A. Salata, Faculty of Dentistry, São Paulo University USP, Ribeirão Preto, São Paulo, Brazil
Niklaus P. Lang, University of Zurich, Zurich, Switzerland

Corresponding author:
Daniele Botticelli, MD/DDS, PhD
Avenida Salvador Allende y G
Vedado, La Habana, Cuba
Tel.: 537-879-3360
Fax: 537-870-3312
e-mail: daniele.botticelli@gmail.com

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Abstract

Objective: To compare peri-implant tissue healing at implants installed in sites prepared with conventional drills or a sonic device.

Material and methods: In six Beagle dogs, the mandibular premolars and first molars were extracted bilaterally. After 3 months, full-thickness muco-periosteal flaps were elevated and recipient sites were prepared in both sides of the mandible. In the right side (control), the osteotomies were prepared using conventional drills, while, at the left side (test), a sonic device (Sonosurgery®) was used. Two implants were installed in each side of the mandible. After 8 weeks of non-submerged healing, biopsies were harvested and ground sections prepared for histological evaluation.

Results: The time consumed for the osteotomies at the test was more than double compared to the conventional control sites. No statistically significant differences were found for any of the histological variables evaluated for hard and soft tissue dimensions. Although not statistically significant, slightly higher mineralized bone-to-implant contact was found at the test (65.4%) compared to the control (58.1) sites.

Conclusions: Similar healing characteristics in osseointegration and marginal hard tissue remodeling resulted at implants installed into osteotomies prepared with conventional drills or with the sonic instrument (Sonosurgery®).

An atraumatic osteotomy preparation that avoids an increase in temperature is essential to achieve optimal healing outcomes in implant therapy (Eriksson & Alberksson 1983). Increasing the temperature above 47°C in fact may produce necrosis and hence may inhibit bone repair (Eriksson & Alberksson 1983). The temperature produced during drilling with conventional instruments may be influenced by the thickness of the cortical bone (Eriksson et al. 1984), the depth (Wiggins & Malkin 1976; Ercoli et al. 2004; Sener et al. 2009) and the speed of drilling (Costich et al. 1964), the sharpness of the drills(Lavelle & Wedgwood 1980), and the pressure applied to the drills (Matthews & Hirsch 1972). Consequently, irrigation for cooling is considered to be an important prerequisite to maintain the temperature to a proper level aiming to avoid damage to the hard tissue structures (Eriksson et al. 1984; Brägger et al. 1995; Benington et al. 2002).

A comparison on heat production was made among different osteotomy preparations: conventional drilling, Piezosurgery® and SONICflex® (Heinemann et al. 2012). The Piezosurgery® is an instrument that uses ultrasonic frequencies of 25–29 kHz, while the SONICflex® is an instrument that uses sound frequencies of 6 kHz at maximum. This *in vitro* experiment was performed in porcine mandibles under similar conditions of cooling with saline. An increased temperature of about 1.5°C, 18.2°C, and 2.3°C was found during osteotomy preparations for conventional drills, Piezosurgery® and SONICflex®, respectively.

Several clinical and experimental studies on the healing after using Piezosurgery® for implant recipient site preparation have been published (Preti et al. 2007; Di Alberti et al. 2010; Bengazi et al. 2014; Stacchi et al. 2013). Only clinical studies (Agabiti 2011; Geminiani et al. 2011, 2013; Papadimitriou

et al. 2012; Agabiti et al. 2014; Schmidt et al. 2013) have been published on the use of sonic devices. Yet, there is a lack of histological documentation of healing in recipient sites prepared with instruments applying sound frequencies.

Hence, the aim of this was to compare peri-implant tissue healing at implants installed in sites prepared with conventional drills or with a sonic device.

Material and methods

The research protocol was submitted to and approved by the local Ethical Committee for Animal Research at the University of São Paolo (protocol number 06.1.573.53.9).

Clinical procedures

Six Beagle dogs, each approximately 13–14 kg and 1 year old, were selected. The animals were pre-anaesthetized for any surgical procedures with Acepran® 0.2% (0.05 mg/Kg – Univet-vetnil, São Paulo, Brazil), sedated with Zoletil® 10 mg/Kg (Virbac, EUA), and the maintenance of the anesthesia was performed with inhalation of Isoflurane® (Baxter Hospitalar Ltd.,).

The mandibular premolars and first molars were extracted bilaterally, and 3 months after tooth extraction, a crestal incision was bilaterally performed, and full-thickness mucoperiosteal flaps were elevated. Two experimental sites were selected, in both sides of the mandible. In the right side (control site), the cortical bone was first perforated with a guide drill, and then, osteotomies were prepared using the first two drills of the preparation set (Medentis Medical GmbH, Dernau, Germany). Finally, a stop drill was used to widen the coronal portion of the recipient sites (Fig. 1). In the left side, the Sonosurgery® system (Dr. Ivo Agabiti, Pesaro, Italy) was used (test site). The system for implant sites preparation includes the use of a sonic instrument (Sonosurgery® Air Power, TKD, Calenzano, FI, Italy; Fig. 2a), and of six sequential inserts (Komet, Lemgo, Germany; Fig. 2b). After having perforated the cortical bone with a guide drill, the preparation was performed using sequentially all inserts (Fig. 3 a-d).

Time of preparation of the recipient sites from the first perforation to the end of the site preparation including changes of drills/inserts was recorded.

In both sides of the mandible, two implants (ICX-Gold®, Medentis Medical GmbH, Dernau, Germany) were installed with the rough/smooth interface (M) flush with the buccal bony crest (Fig. 4a). In a low-pressure plasma process, ICX-Gold implants are equipped with a super-crystalline titanium oxide layer. This ultra-thin nanostructured layer provides the ICX-Gold implants with a super-hydrophilic surface with a contact angle of 0–5°.

Titanium healing cups (Bottle size, Medentis Medical GmbH, Dernau, Germany) were

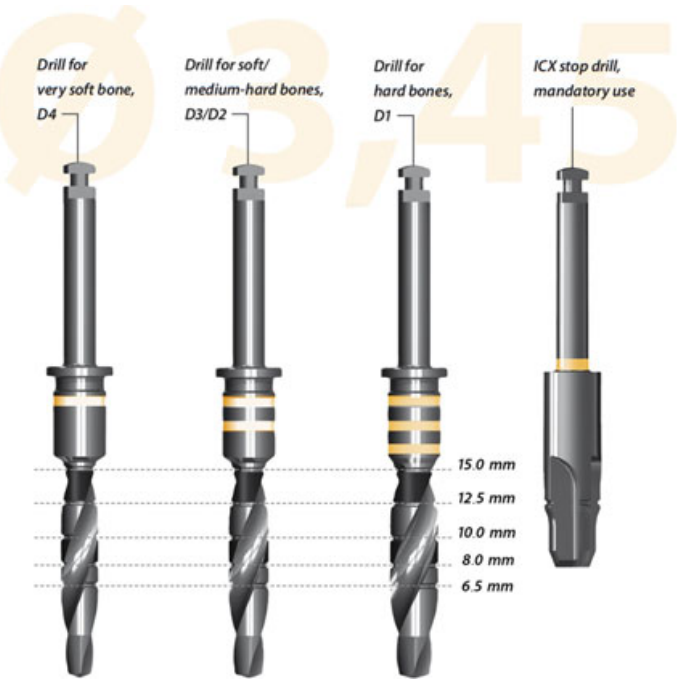

Fig. 1. The preparation set of drills. The first two drills on the left were used to prepare the osteotomies at the control sites.

Fig. 2. The Sonosurgery® system composed of (a) a hand-piece (Sonosurgery® Air Power) and (b) a set of six conical inserts of increasing diameter.

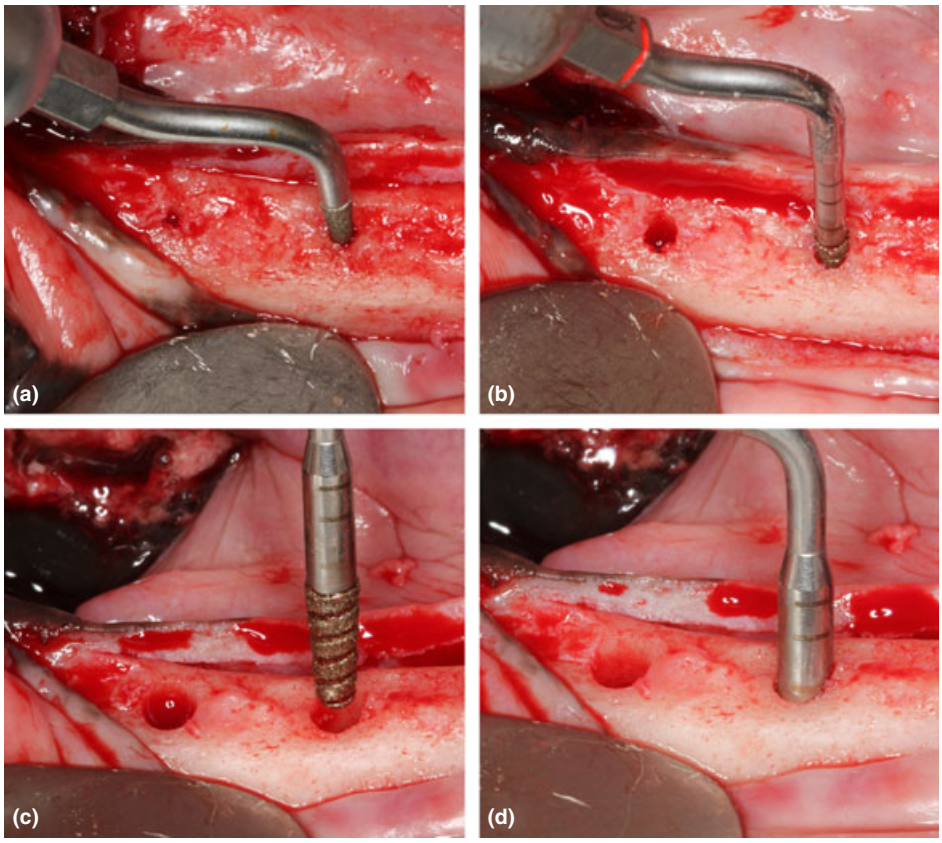

Fig. 3. Clinical view of some steps of site preparation using the Sonosurgery® system. (a) Pilot insert used immediately after the perforation of the cortical bone layer performed with a drill. (b) The osteotomy was widened using sequential inserts with an increasing diameter. (c) Last insert used. (d) Osteotomy prepared to the needed depth.

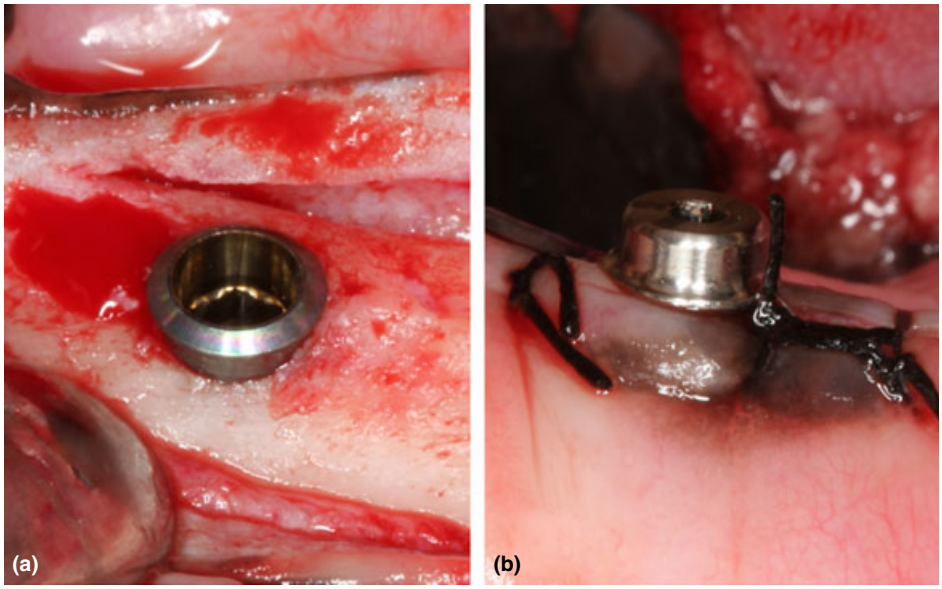

Fig. 4. Clinical view. (a) The implants were placed with the rough/smooth coronal margin flush to the buccal bony wall. (b) Healing abutments were applied to the top of the implants, and the flaps were sutured to allow a non-submerged healing.

affixed to the implants, and the flaps were sutured to allow a non-submerged healing in both sides of the mandible (Fig. 4b).

After the surgeries, the animals were given antibiotics for 10 days (Stomorgyl 10®, one tablet/10 Kg daily – Merial Saude Animal Ltd., Paulinia, Brazil); anti-inflammatory drugs were administered for 5 days (Maxicam® 2.0 mg, one tablet/20 Kg daily – Ouro Fino Saude Animal Ltd., Cravinhos, Brazil); and analgesics were given for 3 days (Tramal 50 mg®, 4.0 mg/Kg subcutaneous, every 8 h – União Quimica Farmaceutica Nacional S/A, Pouso Alegre, Brazil). The animals were kept on concrete runs in kennels at the university's field facilities with free access to water and feed of moistened balanced dog's chow.

A daily inspection of the wounds for clinical signs of complications and healing abutment cleaning was performed. The sutures were removed after 2 weeks. The animals were euthanized 8 weeks after the surgery applying overdoses of Thiopental® (Cristalia Ltd., Campinas, Brazil).

Histological preparation

Individual blocks containing the implant and the surrounding soft and hard tissues were fixed in 4% formaldehyde solution followed by dehydration in a series of graded ethanol solutions and finally embedded in resin (LR White® hard grade, London Resin Company Ltd, Berkshire, UK). The blocks were cut in a bucco-lingual plane using a diamond band saw fitted into a precision slicing machine (Exakt®, Apparatebau, Norderstedt, Germany) and then reduced to a thickness of about 50 μm using a cutting–grinding device (Exakt®, Apparatebau).

From each block, one or two histological slides from the central part of the implants were prepared and then stained with Stevenel's blue and alizarin red and examined under a standard light microscope for histometric analysis.

Histometric evaluation

In an Eclipse *Ci* (Nikon Corporation, Tokyo, Japan), equipped with a digital video-camera (Digital Sight DS-2Mv, Nikon Corporation) connected to a computer, the following landmarks were identified (Fig. 5): the abutment/fixture connection (AF), the most coronal bone-to-implant contact (B), the top of the adjacent bony crest (C), and the top of the peri-implant mucosa (PM).

The following measurements were performed in μm at a magnification of ×100 using the NIS-Elements 4.1 (Nikon Corporation): the vertical distance parallel to the long axis of the implant between AF and B (AF-B), AF and C (AF-C), and PM and AF (PM-AF). The rough/smooth coronal interface (M) was located 1.7 mm apically to AF. Consequently, M-B and M-C were calculated

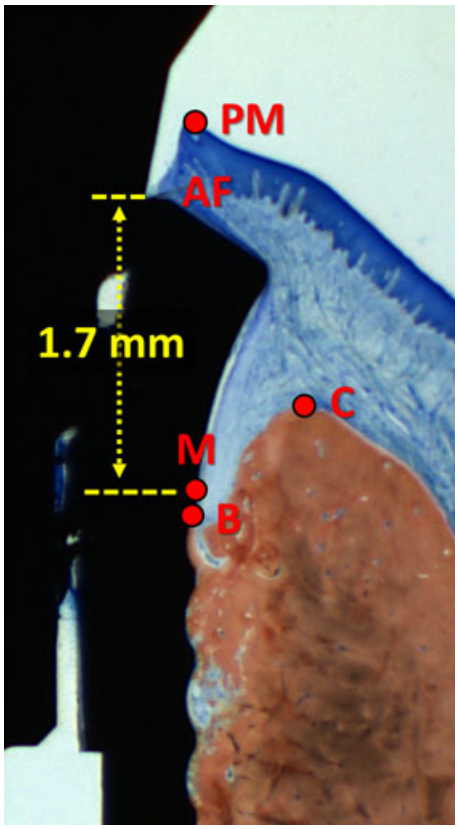

Fig. 5. Diagram illustrating the landmarks for the histological evaluation. PM, top of the peri-implant mucosa; AF, abutment/fixture connection; C, top of the adjacent bony crest; M, coronal margin of the rough/smooth limit; B, most coronal bone-to-implant contact. The neck of the implant (between AF and M) was 1.7 mm high.

subtracting 1.7 mm (height of the neck) from AF-B and AF-C, respectively.

Mineralized bone-to-implant contact (MBIC%) was also measured at a magnification of ×200 from B to the apex of the implant.

Data analysis

Mean values and standard deviations as well as 25th, 50th (median), and 75th percentiles were calculated for each outcome variable. A mean value per dog was used for the two implants installed. The primary variables were AF-B, AF-C, and MBIC%. Differences between test (sonic device) and control (drills) sites were analyzed using Wilcoxon signed rank test using IBM SPSS Statistics V.19 (SPSS Inc. Chicago IL, USA). The level of significance was set at $\alpha = 0.05$.

Results

In one dog, only one instead of two implants was installed in the right side of the mandible. After 8 weeks of healing, none of the implants were lost or mobile, and no complications occurred during the healing period. No artifacts were generated during histological processing, nor were any tissue blocks destroyed. Hence, test and control sites yielded an $n = 6$.

The time for the preparation of the two osteotomies was 315 ± 44 s. (5′15″) for the test and 147 ± 45 s. (2′27″) for the conventional drill sites, the difference being statistically significant (Table 1).

Histological evaluation

Figures 6a-b illustrate histological outcomes after 8 weeks of healing. Table 1 also reports data regarding hard tissue levels.

All implants appeared to be embedded into bone, and no major sings of inflammation were seen within the peri-implant soft tissues. The distance M-B was 0.7 ± 0.7 at the test and 0.5 ± 0.3 at the control sites. M-C was 0.3 ± 0.3 and 0.5 ± 0.3 at the test and control sites, respectively. None of the differences were statistically significant.

The MBIC% at the test sites was 65.4 ± 11.4%, while, at the control sites, it was 58.1 ± 10.1%, the difference not yield statistical significance.

The distance PM-B was 3.1 ± 0.4 mm at the test sites and 3.6 ± 0.3 mm at the control sites. Again, no statistically significant difference was identified.

Discussion

The aim of the present study was to compare peri-implant tissue healing at implants installed in sites prepared with conventional drills or a sonic device.

The time to prepare the osteotomies was more than double for the Sonosurgery® compared to the conventional using a preparation set of the implant system used. This outcome is in agreement with another experiment in dogs (Bengazi et al. 2014), in which the time required for site preparation applying a Piezosurgery® instrument or conventional drills was compared. The time needed was 4–5 times longer for the Piezosurgery® compared with the conventional drill preparations. However, it has to be emphasized that, in that experiment, the time included also the change of the Piezosurgery® inserts. Furthermore, no drills were used to perforate the cortical bony layer at the Piezosurgery® sites.

In the present experiment, instead, two hand-pieces were used. While the surgeon was proceeding with the osteotomies using one hand-piece, an assistant was changing the insert in the other hand-piece hereby saving time. Furthermore, an initial drill was used to perforate the cortical layer at the test sites (Sonosurgery®). Both these procedures have speeded up the time for site preparation in the present study. In the aforementioned study (Bengazi et al. 2014), the time was taken for the preparation of a single site, while in the present study, the procedures were timed for multiple sites. This, in turn, means that the change of the inserts substantially prolonged the time spent for site preparation.

The use of the two different site preparations did not yield statistically significant differences in buccal bony crest resorption and in the location of the coronal level of osseointegration. This means that the use of the two systems did not affect the biological aspects of osseointegration. In the study mentioned above (Bengazi et al. 2014), a similar bony crestal resorption was observed between the two site preparations (Piezosurgery® and conventional drills). However, a statistically significant difference was found for the buccal coronal level of osseointegration,

Table 1. **Time of preparation for two recipient sites and histological measurements of hard and soft tissue dimensions**

		Time (s)	M-B buccal (mm)	M-C buccal (mm)	MBIC%	PM-B buccal (mm)
Test (Sonic device)	Mean (SD) 25th; 50th; 75th	315 (44) * 284; 314; 335	0.7 (0.7) 0.4; 0.5; 0.8	0.3 (0.3) 0.3; 0.3; 0.4	65.4 (11.4) 62.6; 67.9; 72.4	3.1 (0.4) 2.8; 3.1; 3.4
Control (drills)	Mean (SD) 25th; 50th; 75th	147 (45) * 123; 135; 146	0.5 (0.3) 0.4; 0.5; 0.6	0.5 (0.3) 0.3; 0.5; 0.5	58.1 (10.1) 51.3; 57.2; 64.7	3.6 (0.3) 3.5; 3.7; 3.8

Mean values, standard deviations (SD) and percentiles 25th, 50th (median), and 75th in millimeters. M, coronal rough/smooth limit; B, coronal end of osseointegration; C, top of the bony crest. MBIC mineralized bone-to-implant contact; PM, peri-implant mucosa.
*$P < 0.05$ between test and control.

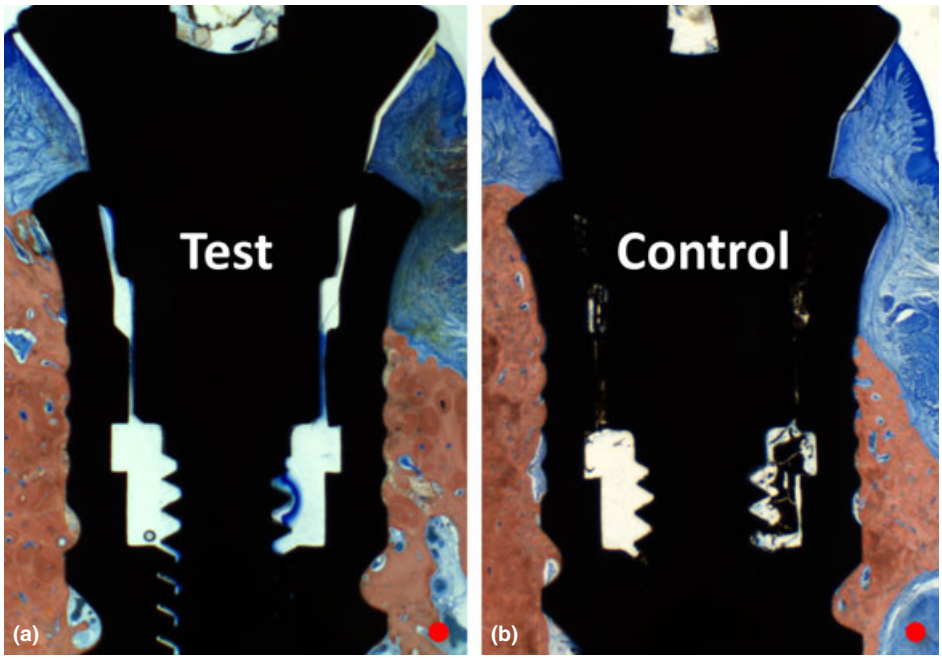

Fig. 6. Ground sections representing the healing after 8 weeks from implants installation. All implants were integrated in mature mineralized bone. Similar vertical levels of the buccal bony crest were found. Original magnification ×16. Stevenel's blue and alizarin red stain. (a) test site; (b) control site. The buccal aspects are on the right of each figure (red marks).

the position being more coronal at the conventional drill compared to the Piezosurgery® sites.

The bony crestal resorption at the marginal aspect of the implants is a healing phenomenon occurring already in the early phases of healing (Rossi et al. 2014) and that may be related both to the surgical trauma for the elevation of the flaps as well as to the establishment of the biological width. The detachment of the periosteum from the bone during flap elevation, in fact, may decrease the capability of the periosteum for deposition of new mineralized bone matrix (Melcher 1969; Melcher & Accursi 1971) and may compromise the blood supply to the bony surface, hereby leading to osteoclast activation and bone resorption (Wilderman 1963; Staffileno et al. 1966; Wood et al. 1972). Moreover, during healing, a biological width will be established within 6–8 weeks, reaching a vertical dimension of about 3.5 mm in 8–12 weeks (Berglundh et al. 2007). At the time of implant installation, the implant surrounding mucosa usually revealed a width that may be thinner in dimension than the biological width established after complete morphogenesis of the soft tissue surrounding the implant. This, in turn, means that at least a part of the marginal alveolar bone may be resorbed to allow the development of proper dimensions of the peri-implant soft tissues (Berglundh & Lindhe 1996; Bengazi et al. 2014, 2014a,b; Baffone et al. 2013).

The MBIC% was slightly higher at the test (65%) compared to the control (58%) sites. However, the difference did not reach statistical significance. This, in turn, means that osteotomies performed with the Sonosurgery® allow adequate osseointegration at implants. This is in agreement with another study (Bengazi et al. 2014), in which no statistically significant differences were found in osseointegration at implants installed in sites prepared conventionally or with a Piezosurgery® instrument. Moreover, the fact of very similar osseointegration outcomes resulted from preparations with conventional drills or Sonosurgery® documented the biological basis for the application of the latter in implant therapy.

Although optimal healing outcomes with high proportions of direct bone-to-implant contact and maintained coronal levels of osseointegration were documented in the present study, it has to be realized that very little is known about the sequential events in the early phases of healing. Such healing sequences were only studied in two animal (Abrahamsson et al. 2004; Rossi et al. 2014) and one human (Lang et al. 2011) histological studies after implant site preparation with conventional drills. It may, indeed, be speculated that during early phases of healing, advantageous events may be identified using sonic or piezoelectric surgery compared with conventional drill site preparation.

The piezoelectric device has been claimed to create favorable conditions for osteotomies (*for a review* see Schlee et al. 2006), such as increased precision and selective sectioning of the mineralized bone structures that minimized a possible damage of the surrounding soft tissues (Vercellotti 2003). Moreover, as result of the cavitation produced by the instrument and by the irrigation, a clear view of the recipient sites has also been propagated (Vercellotti 2003). Furthermore, the use of the Sonosurgery® in the present study also allowed a precise preparation and a sharp vision of the preparation sites.

The use of a sonic instrument for oral surgery has been evaluated in a series of clinical reports, and its application was suggested for several indications, such as tooth extraction, alveolar bone augmentation, and sinus floor elevation (Agabiti 2011; Geminiani et al. 2011, 2013; Papadimitriou et al. 2012; Schmidt et al. 2013).

In conclusion, the present study has documented similar osseointegration and marginal hard tissue remodeling at implants installed into osteotomies prepared with conventional drills or sonic devices (Sonosurgery®).

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Conflict of interests

All the authors declare to have no conflict of interest with the materials used in the present study.

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