A systematic review compared the outcomes of implant site preparation performed with a piezoelectric device and drills. Both technical approaches presented similar results regarding implant failure and marginal bone level changes. However, a longer time for site preparation was required for the piezoelectric device compared with the drills.

The use of piezoelectric or sonic devices has become widespread during recent years due to the precision offered in the cutting procedures of these devices, the reduced risk of damaging soft tissues, and the clear view of the surgical sites offered by these devices during the preparation. The healing of implants positioned in osteotomies made using drills on sites prepared using either a piezoelectric instrument or a sonic device was studied in animal experiments. No differences in osseointegration were found in either study.

Piezoelectric devices have been studied and compared with the use of drills for implant site preparation. In a randomized controlled clinical study, gain in implant stability was faster in sites prepared with piezosurgery compared with twist drills, while no differences in survival rates were found. In support of this finding, an experimental study in minipigs showed that sites prepared with piezosurgery presented a more advanced osteogenesis compared to those prepared with drills.

Compared with the piezoelectric devices, less clinical and experimental research has been performed to evaluate the sonic devices. Nevertheless, similar advantages to the piezoelectric instruments are offered by the sonic devices. Both provide surgical precision, clear views of the surgical field, and a low risk of possible damage to the surrounding soft tissues. Moreover, sonic devices are claimed to produce...
a similar increase in temperature during the procedure compared with that produced by drills, and lower than that produced by piezoelectric instruments.\textsuperscript{19}

Experimental histologic data comparing sonic devices and conventional drills are still scarce, and histologic data from humans are not available. Hence, the aim of the present study was to perform a histomorphometric evaluation of the early healing of implants placed in sites prepared with either a sonic device or conventional drills. The hypothesis was that preparation of an implant recipient site using a sonic instrument will produce different osseointegration compared with conventional site preparation using drills.

**MATERIALS AND METHODS**

**Patient Selection**

In the present split-mouth histomorphometric randomized controlled trial, 16 patients were included. The Helsinki Declaration was followed. The protocol was authorized by the Ethical Committee of the University Corporation Rafael Nunez of the city of Cartagena de Indias, Colombia (protocol #05-2014; October 8, 2014). In the same institution, all treatments were performed during the period from May 2016 to August 2017. After exhaustively illustrating the surgical procedures and the possible complications, a written informed consent was signed by the patients. The study was reported according to the CONSORT guidelines.

To calculate a suitable sample, data from an animal experiment in dogs performed by the same research group were used.\textsuperscript{6} In that experiment, implant site preparations were carried out either with a similar sonic device used in the present study or drills, and a difference of 7.3% in bone-to-implant contact was seen in favor of the sonic groups with \( n = 6. \) Considering a possible higher variability in humans and possible dropouts, a sample of \( n = 8 \) pairs of subjects was considered sufficient to reject the null hypothesis with a power of 0.8 and \( \alpha \) set to .05, as evaluated using PS Power and Sample Size Calculations. Two groups of eight volunteers were randomly formed and planned for biopsy specimen retrieval after either 2 or 6 weeks of healing.

The patients included in the present study satisfied the following inclusion criteria: (1) good general health; (2) presence of an edentulous zone in the distal region of the maxilla; (3) sinus floor height \( \geq 10 \) mm; (4) \( \geq 25 \) years of age; (5) smoking \( \leq 10 \) cigarettes per day; (6) no contraindication for oral surgery; (7) not being pregnant.

The following exclusion criteria were adopted: (1) presence of systemic disorders; (2) chemotherapy or radiotherapy; (3) smokers \( \geq 25 \) cigarettes per day; (4) previous bone augmentation procedures in the same region.

Moreover, caries and periodontal conditions were evaluated, and if any of these pathologies were present, they were treated before starting the study.

**Device**

Titanium screw-shaped mini-implants, 2.5 mm in diameter and 4 mm long (Fig 1a) with a moderately rough surface (ZirTi, Sweden & Martina, Due Carrare) were used. Surface features of the implants were previously reported.\textsuperscript{20}

**Randomization and Allocation Concelalment**

Each patient received two mini-implants that were placed in sites prepared in the distal regions of the maxilla either with a sonic device or drills. The two recipient sites were selected prior to the surgery, while the type of site preparation was randomly decided. A researcher (D.B.), who neither selected the patients nor was involved in the surgical and prosthetic treatments, electronically carried out the randomization (at randomization.com). Sealed, opaque envelopes were prepared and unsealed at the time of surgery and reported the position of the sonic sites. This was indicated as mesial or distal position if the two sites were in the same quadrant of the maxilla, or as right or left if they were in opposite quadrants of the maxilla.

**Clinical Procedures**

All surgical procedures were performed by an expert surgeon (M.F.). Local anesthesia was provided, and incisions were performed on the alveolar crest. The flaps were elevated, and the alveolar bone was exposed. The sites were prepared either with a lanceolate drill (FS 230, Sweden/Martina), with a maximum diameter of 2.3 mm (Figs 1b and 2a) or conical diamond inserts of increasing diameter (SFS99, Komet-Brasseler) applied on a sonic-air instrument (Sonosurgery TKD). This is shown in Figs 1c and 2b. The dimensions of the final drill and of the final sonic device allowed the preparation of recipient sites of similar dimensions (approximately 2.3 mm in the coronal aspect). The mini-implants were subsequently placed (Figs 2c and 2d), a cover screw was placed on the mini-implants, and sutures were applied to close the flaps in a fully submerged mode.

Amoxicillin 875 mg and clavulanic acid 125 mg (twice a day for 6 days), ibuprofen 400 mg, if needed, and mouthrinses with 0.12% chlorhexidine three times a day for 10 days were prescribed. The patients were enrolled in a maintenance recall. The sutures were removed after 7 days. Biopsy specimens including the mini-implants were retrieved (Fig 3a) by the
surgeon after 2 or 6 weeks of healing, paying attention to keep the implant in an eccentric position within the trephine (Fig 3b) to reduce the dimension of the biopsy specimen and maintain sufficient tissue for analysis (Fig 3c), as previously described.\textsuperscript{21}

**Histologic Process**

The biopsy specimens were washed in saline solution and stored in 10\% buffered formalin. The histologic process was performed in the laboratory facilities at the University of Chieti-Pescara. The biopsy specimens were not removed from the trephine. They were dehydrated and consequently included in a glycolmethacrylate resin (Technovit 7200 VLC, Kulzer). Once the polymerization was finalized, a section was performed following the long axis of the mini-implant using a disk. Specimens of \textasciitilde 150 microns were obtained, and subsequently, they were reduced to \textasciitilde 30 microns. Acid fuchsine and toluidine blue were used for staining.

**Histomorphometric Evaluation**

The histomorphometric evaluation was performed twice by a blinded author (D.B.), and mean values were used. A code was reported on the histologic slides so that no indications were available on the site preparation procedures and period of healing. All histologic analyses were carried out in the ARDEC Academy, Italy, using an Eclipse Ci microscope (Nikon Corporation) that was connected to a digital video camera (Digital Sight DS-2Mv, Nikon Corporation). To carry out measurements, the software NIS-Elements.
D 4.10 (Laboratory Imaging, Nikon Corporation) was used. The percentages of newly formed bone (new bone), preexisting bone (old bone), bone debris/clot remnants (debris), and marrow spaces (soft tissue) in contact with the implant surface were evaluated at ×200 magnification from the most coronal contact of the bone to the implant surface (B) to the apical extension of osseointegration (A). The total mineralized bone was calculated as a sum of new and old bone.

Morphometric measurements (tissue density) were performed, identifying the same tissues indicated earlier plus vessels, in a region included between B and A, and at a distance from the implant surface of approximately 0.4 mm. For this purpose, a point-counting procedure was used, applying a lattice with squares of 50 microns superposed over the histologic slides using a magnification of ×200.

The interception point for new and preexisting bone in contact with the implant surface was calculated and expressed in days of occurrence and bone-to-implant percentage.22

Data Analysis
Mean values ± standard deviations are reported in the text. In the tables, 25th, 50th (median), and 75th were also added. Means, standard deviations, and 95% upper and lower confidence intervals of the difference between the means of sonic and drill sites were calculated for each variable analyzed for both histometric and morphometric analyses.

The primary variable was the newly formed bone (new bone) in contact with the implant surface. Total mineralized bone in contact with the implant surface was considered as a secondary variable. A Wilcoxon test was used to analyze the differences between the sonic and drill groups. The level of significance was fixed at \( \alpha = .05 \). With an explorative aim, a Mann-Whitney test was used to analyze the difference in new bone and total mineralized bone between 2 and 6 weeks of healing.

RESULTS
Sixteen volunteers, including 11 women and 5 men with a mean age of 48.7 ± 10.5 years, were recruited. Eight patients were randomly assigned to the 2-week group and eight to the 6-week group. No dropouts of patients were registered.

Two implants were placed in each patient in recipient sites prepared either with a sonic instrument or conventional drills. The bone quality registered in the 2-week patients was type 3 in five sites and type 4 in five sites, in both the sonic and drill groups. In the 6-week patients, the bone quality was type 3 in seven sites and type 2 in one site, in both the sonic and drill groups. The insertion torque never exceeded 25 Ncm in any site. Two mini-implants were not integrated in one patient from the 2-week group, and one histologic slide presented too few tissues to be examined from a test site of a patient from the 6-week group. These patients were excluded from the study, so \( n = 7 \) was obtained for each period group (Fig 4).

Two Weeks of Healing
At the 2-week period, new bone was found within the threads of the implants and on the implant surface (Fig 5). New bone in contact with the implant surface was 5.5% ± 7.3% at the sonic sites, and 3.8% ± 10.0% at the drill sites (Table 1; Fig 6a). Preexisting bone (old bone) was present at proportions of 27.8% ± 7.8% in the sonic group, and 29.4% ± 9.0% in the drill group. The total amount of mineralized bone in contact with the implant surface was 33.3% ± 12.6% and 33.1% ± 15.4% in the sonic and drill groups, respectively. No statistically significant differences were found for any of the variables using a Wilcoxon test (Table 2).

The tissue density showed new bone, old bone, and total mineralized bone at percentages of 3.5% ± 3.9%, 43.1% ± 9.1%, and 46.5% ± 10.2% in the sonic group, and 6.3% ± 13.0%, 37.9% ± 12.2%, and 44.2% ± 14.9% in the drill group, respectively (Table 3; Fig 6b). No statistically significant differences were found using...
No inflammatory infiltrates were seen.

Six Weeks of Healing
After 6 weeks of healing, new bone in contact with the implant surface increased in percentages compared with the previous period of healing (Fig 7), reaching 46.9% ± 15.5% in the sonic group, and 46.4% ± 14.9% in the drill group (Table 5; Fig 6a). Approximately 14% to 15% of old preexisting bone in contact with the implant surface was present, so the total amount of mineralized bone was 60.8% ± 15.5% and 61.4% ± 14.3% in the sonic and drill groups, respectively. No statistically significant differences were found for any of the variables using the Wilcoxon test (Table 2).

New bone, old bone, and total mineralized bone densities were 48.1% ± 8.6%, 20.1% ± 5.7%, and 68.2% ± 7.4% in the sonic group, and 47.5% ± 4.4%, 20.0% ± 4.3%, and 67.4% ± 6.4% in the drill group, respectively (Table 6; Fig 6b). No statistically significant differences were found for tissue density between the sonic and drill groups using a Wilcoxon test (Table 4).
The differences in new bone and mineralized bone percentages between 2 and 6 weeks of healing were both statistically significant using a Mann-Whitney test. No inflammatory infiltrates were seen.

The intersection point occurred after 25.3 days at 22.2% of bone-to-implant contact for the sonic group, and after 26.6 days at 22.9% of bone-to-implant contact for the drill group (Fig 8).

**DISCUSSION**

The aim of the present study was to compare the histomorphometric outcomes of retrieved mini-implants placed in recipient sites prepared with either a sonic device or drills. After 2 and 6 weeks of healing, similar amounts of newly formed bone were found in both groups.
In a similar preclinical study in dogs, the healing of implants placed in osteotomies prepared with either a sonic instrument or drills was evaluated. A difference in bone-to-implant contact of 7.3% in favor of the sonic group was seen; however, this did not reach a statistically significant difference compared with the drill group. This showed that the preparation of the recipient site using a sonic instrument not only did not endanger osseointegration but might be beneficial. The present study also confirmed that in humans, the use of a sonic instrument for recipient site preparation may yield predictable results like those obtained using drills.

Another histomorphometric study in humans evaluated the sequential osseointegration processes in the earliest periods of healing at mini-implants placed in the posterior segments of the mandible. Mini-implants with two different surfaces were placed, and biopsy specimens were retrieved after 1, 2, 4, and 6 weeks. After 2 weeks, approximately 12% to 14% of new bone and approximately 28.8% of preexisting bone were observed. After 6 weeks of healing, approximately 61% to 62% of new bone was reported, while approximately 8% to 14% of old bone was still found. In the present study, lower percentages of new bone were reported both after 2 and 6 weeks of healing, with approximately 4.5% after 2 weeks and 46% to 47% after 6 weeks of healing. The differences in osseointegration percentages in these two studies may be due to several factors. One of these factors might be related to the different regions used for implant placement: the distal regions of the mandible in that study and the distal segments of the maxilla in the present study.
present study. As a matter of fact, in a review, a higher amount of osseointegration was reported in the mandible compared with the maxilla in implants retrieved in humans. The time allowed for healing should also be considered as a factor that may influence osseointegration in the earliest periods of healing. In fact, when longer intervals of healing (3 to 4 months) were allowed at mini-implants that had a surface with similar characteristics as used in the present study, higher percentages of osseointegration were found, reaching values of approximately 63% to 76%. Various histologic human studies reported data on osseointegration during the early phases of healing, and levels of osseointegration ranging from 19% for a machined surface to 76% for a moderately rough surface were found.

It has to be considered that several factors may influence osseointegration, as illustrated in a study that assessed the relationship between old and new bone in various periods of healing. In that report, data on new and preexisting old bone in contact with the surface of the implant were collected from various experiments and a clinical study as well. Lines representing the percentages of new and old bone over time were illustrated in a graph, and the point at which the lines were crossing was defined as the interception point. This point, calculated by a formula, was expressed as bone-to-implant contact percent (BIC%) and time. It was shown that the interception point was strongly influenced by the model used and the density of bone of the recipient site, while surface characteristics, placement in extraction sockets, and immediate loading had a lower effect. It was shown that osseointegration in rabbits was faster compared with other animal models, and in animals, it was faster than in humans. In dogs, the interception point occurred between 13 and 16 days, whereas, in a human study, the interception point was calculated to occur at 18 to 25 days, depending on the implant surface. In the present study, the interception point occurred after approximately 25 to 27 days with an osseointegration of 22% to 23%. It should be considered that implants presenting the same surface as those used in the present study, when used in dogs, provided an interception point of 13 to 16 days. This corroborates the statement that osseointegration in humans is slower compared with that observed in dogs, even though the final results will be similar.

In the present study, after 6 weeks of healing, a high proportion of old bone was present, ranging from 14% to 15%. In other human studies, biopsy specimens of mini-implants were harvested. The mini-implants had a surface with the same characteristics of that used in the present study, but a longer period of healing was allowed. After 3 to 4 months of healing, old bone was found at fractions ≤ 3%. This, in turn, means that old bone takes a few months to be replaced by new bone.

In the present study, the presence of bone debris, particles, and clot was evaluated. After 2 weeks of healing, high proportions of these components were found on the surface of the implants. The presence of debris was considered to be of great importance in favoring osseointegration through the formation of bridges of osteoid tissue and newly formed bone in the earliest stages of healing. Nevertheless, bone debris and particles might represent an obstacle when, instead of being included into newly formed bone, they are absorbed by means of macrophages.

The sonic instrument used in the present study works at low frequencies (approximately 6 kHz), while ultrasonic instruments use higher frequencies (> 25 kHz). The sonic instruments presented several advantages, such as the low increase of the temperature within the prepared sites compared with ultrasonic instruments, and it is considered to be a safe instrument regarding soft tissue damage.

The asymmetric use of the trephine allowed for a reduction in the dimensions of the biopsy specimens. Some of the limitations of the present study are represented by the small sample, the short period of healing that did not allow for evaluation of the long-term outcomes, the absence of load, and the small dimensions of the biopsy specimens that limited the extension of the histomorphometric analyses. Moreover, the use of the sonic instrument requires a longer operative time compared with both the piezosurgery and the drills. Finally, it has to be mentioned that the present study was performed in a region presenting low-density bone (posterior maxilla), and the results should not be generalized to other areas with denser bone. Randomized clinical trials should be performed to assess the long-term outcomes of implants placed in sites prepared with either a sonic device or conventional drills.

CONCLUSIONS

Similar amounts of new bone percentage in contact with the implant surface were observed after 2 and 6 weeks of healing at implant sites prepared with either a sonic instrument or drills.

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