A comparative study of bone densitometry during osseointegration: Piezoelectric surgery versus rotary protocols

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Objectives: To date, there have been no studies on the outcome of osseointegration of alveolar bone around dental implants inserted with piezoelectric osteotomy versus conventional osteotomy. The aim of this study was to compare the radiographic differences, through evaluation of peri-implant bone density, between implant insertion using traditional surgical technique and piezoelectric technique. Method and Materials: Forty patients were selected whose treatment consisted of a minimum of two implants placed in non-pathologic native bone. A single type of implant surface (SLA) was chosen. The implants were placed following the manufacturer protocol for traditional surgical technique and piezoelectric technique. Radiographs were taken following surgery and 30, 60, and 90 days after surgery. The bone density was studied with the densitometry application. Results and Conclusion: All patients completed the study period with success. Despite a limited number of treated patients, the results of this pilot study demonstrated that (1) piezoelectric implant site preparation promotes better bone density and osteogenesis, and (2) the piezoelectric technique is predictable, with a 100% success rate in this study. (Quintessence Int 2010;41:639-644)

Key words: bone density, implants, osseointegration, surgery, ultrasound.

Osseointegration of dental implants is highly predictable when implants are completely embedded in bone.1 In recent years, numerous efforts have been made to make implant therapy safer and with certain clinical results for potential patients by simplifying clinical procedures. One of these efforts has been the reduction of the healing period using new implant surfaces that may shorten and improve the osseointegration process. Albrektsson et al2 recognized in the early age of implantology that the implant surface, including topography, chemistry, surface charge, and wettability, is one of the important factors influencing osseointegration.

Piezoelectric osteotomy is a technique based on piezoelectric vibration of an osteotomic device that permits precise cutting of bone structures without damaging adjacent soft tissues.3 Ultrasonically moved knives have the ability to cut hard tissues, such as teeth and bone. In contrast, soft tissues (eg, gingiva, blood vessels, nerves, and sinus membranes) are preserved from injury because they vibrate with the tip. This makes piezoelectric surgery particularly suitable for a broad spectrum of surgical applications, including apicectomy, bone block sectioning, sinus lifting, split-crest technique, nerve lateralization, resesective bone surgery, bone scraping, and biopsy sampling.4-9 The Piezosurgery instrument, first developed in 1988, uses a modulated ultrasonic frequency that permits highly precise and safe cutting of hard tissue. Nerves, vessels, and soft tissue are not injured by the micovibrations (60 to 200 mm/s), which are optimally adjusted to target only mineralized tissue. The selective and thermally harmless nature of the

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piezoelectric instrument results in a low bleeding tendency. In addition, the instrument can be used in operations requiring either local or general anesthesia.\textsuperscript{3}

The precise nature of the instrument allows exact, clean, and smooth cut geometries during surgery. The difference in time requirement for surgical procedures using the piezoelectric instrument in comparison with the conventional drill is negligible. Postoperatively, excellent wound healing of soft tissue injuries could be observed. The range of application of piezoelectric surgery is not limited to minor oral surgery procedures. Because of its highly selective and accurate nature, with its cutting effect exclusively targeting hard tissue, its use may be extended to more complex oral surgery cases, as well as to other interdisciplinary problems.\textsuperscript{10}

The application of ultrasound is emerging as a potent therapy for the treatment of complex bone fractures and tissue damage. Ultrasonic stimuli accelerate fracture healing by up to 40% and enhance tendon and ligament healing by promoting cell proliferation, migration, and matrix synthesis through an unresolved mechanism.\textsuperscript{11–15}

To date, however, there have been no studies on the outcome of osseointegration of alveolar bone around dental implants inserted with piezoelectric osteotomy versus conventional osteotomy. The present study evaluated piezoelectric versus conventional osteotomy in alveolar bone osseointegration processes.

The aim of this study was to compare the radiographic differences, through evaluation of the peri-implant bone density, between implant site preparation with traditional surgical technique burs and piezoelectric technique with implant tips (Piezosurgery, Mectron, Genova, Italy; EMS, Nyon, Switzerland).

**METHOD AND MATERIALS**

**Patient selection**

Forty patients (22 males, 18 females) were selected to be enrolled in this study. The age range was 38 to 47 years (mean age 42.5).

All patients were healthy, not taking medications that could alter bone metabolism or bone calcification, and needed a minimum of two implants placed. All implant sites were in nonpathologic native bone. Extraction sites were implanted at least 6 months after tooth extraction.

**Implant selection**

To better define and restrict this clinicoradiological study, a single kind of implant surface was chosen: sandblasted, large grit, acid-etched (SLA). Also, all implants used were Seven and Biocom (MIS, Shlomi, Israel). The implant lengths used were 10 mm, 11.5 mm, and 13 mm.

**Traditional surgical technique**

The implant insertion with traditional surgical technique was performed following the manufacturer’s protocol, which includes this drilling procedure: a round bur was used first, followed by 2- and 3-mm-diameter burs. A single-use drill, specific for the implant diameter and present in the implant packaging of the company, was used to make the final osteotomic bone preparation for implant insertion.

**Piezoelectric technique**

The implant insertion with piezoelectric technique was performed using the new implant tips kit made by EMS (Nyon, Switzerland) for 20 patients and the new implant tips kit for anterior and posterior maxillary jaws made by Mectron (Genova, Italy) for the other 20 patients.

The manufacturer protocols define the use of the following tip sequence: MB1 to MB6 for EMS protocol and OP5, IM2, OT4, and IM3 for Mectron protocol. The surgical perforation was rinsed with sterile double-distilled water using the perfusion from the tip of the Piezosurgery or Piezon Master Surgery after every use of the tips.

After the use of the last tip, the implants were inserted using the surgical micromotor without the final single-use drill of the implant manufacturer.

**Radiological follow-up procedure**

Periapical radiographs were taken using the same x-ray apparatus (Image Rx System, De Gotzen, Legnano, Italy) and the Kodak 6000 RVG as a digital sensor (Kodak Carestream
Health, NY, USA). The exposure time was the same for all radiographs. The radiographs were taken immediately after implant insertion and 30, 60, and 90 days after surgery.

Using RVG software analysis, the bone density was studied with the densitometry application. For every implant, four defined and repeatable points were chosen: the microthreads area, the first coronal thread, the middle part of implant, and the last apical thread of the implant. The values were evaluated mesially and distally for every implant.

Every data point was converted into a data value, which was correlated with the same data point/value over the follow-up period to create a histogram of the bone density during the osseointegration process. All data points/values were recognized in every implant placed using both surgical procedures. Then, all data points/values of a single implant surface, mesially and/or distally, were summarized. The mean and the median values were compared between the traditional surgical procedure and the piezoelectric procedure.

RESULTS

All patients successfully completed the study. All implants were stable and osseointegrated at the end of the study period, and no inflammation was recorded during the healing time (Figs 1 to 9).

The mean bone density value of all implants after piezoelectric implant insertion (bone density at T0 = 167 for the Mectron group and 160 for the EMS group) was higher than the traditional drilling procedure (bone density at T0 = 135 and 137 for traditional groups) and did change after a 3-month period (bone density at T1 = 168 for the Mectron group and 175 for the EMS group vs 142 and 140 for the traditional groups).

Bone quality was categorized according to the classification by Norton and Gamble⁶ (Table 1), who correlated their findings of bone density of alveolar bone with the subjective quality classification described by Lekholm and Zarb.⁷ In Lekholm and Zarb’s classification, quality 1 describes homogeneous compact bone of high quality. Quality
Fig 4  Bone densitometry 1 week after surgery and at 4-week follow-up with traditional site preparation. A good bone implant contact is present.

Fig 5  Bone densitometry 1 week after surgery and at 4-week follow-up with EMS ultrasonic site preparation. Presence of a more dense bone at 4 weeks.

Fig 6  Bone densitometry 4 weeks after surgery and at 12-week follow-up with traditional site preparation. The cementoma lesion is still present and with same volume.

Fig 7  Bone densitometry at 12-week follow-up with traditional (left implant) and piezosurgical site preparation (right implant).

Fig 8  Bone densitometry 4 weeks after surgery and at 12-week follow-up with EMS ultrasonic site preparation. A high density bone is present at 12 weeks and resembles the histological bone canalicular view of a calcified bone.

Fig 9  Bone densitometry after 12-week follow-up with EMS ultrasonic site preparation. A definitive presence of highly dense bone is present, and the implant appears fully osseointegrated.

2/3 describes a “straightforward therapeutic situation,” providing the implant with good primary fixation. Caution is warranted over the placement of implants into inadequate quality bone. Quality 4 describes a “failure zone.” There was no statistically significant difference in resorption rates between implants inserted in the maxilla and in the mandible with the piezoelectric technique. The statistical significance was $P = .042$ (ANOVA).
Table 1  Bone quality according to the classification by Norton and Gamble\textsuperscript{16}

<table>
<thead>
<tr>
<th>Quality (Lekholm and Zarb\textsuperscript{3})</th>
<th>Bone density range (HU) (Norton and Gamble\textsuperscript{4})</th>
<th>Region of interest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality 1</td>
<td>&gt; + 850</td>
<td>Anterior mandible</td>
</tr>
<tr>
<td>Quality 2/3</td>
<td>+ 500 to + 850</td>
<td>Posterior mandible/anterior maxilla</td>
</tr>
<tr>
<td>Quality 4</td>
<td>0 to + 500</td>
<td>Posterior maxilla</td>
</tr>
<tr>
<td>Quality 4*</td>
<td>&lt; 0</td>
<td>Tuberosity region</td>
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</tbody>
</table>

DISCUSSION

Piezoelectric osteotomy is a technique based on ultrasonic vibration of an osteotomic device that permits precise cutting of bone structures without damaging adjacent soft tissues.\textsuperscript{3} The application of ultrasound is emerging as a potent therapy for the treatment of complex bone fractures and tissue damage. The ultrasonic devices transform the vibrations of the tips into motion energy and heat. The motion energy produces the cutting action, and the heat produced is reduced with irrigation. Some devices are capable of transforming most of the vibrations into energy and will not produce heat on the end of the tip. Other devices may become too hot and can cause burns on the soft tissues, while other devices remain cold during use.

Ultrasonic stimuli accelerate fracture healing by up to 40% and enhance tendon and ligament healing by promoting cell proliferation, migration, and matrix synthesis through an unresolved mechanism.\textsuperscript{9-15} Ramil and al\textsuperscript{17} investigated the effect of short-wave (1-MHz) and long-wave (45-kHz) ultrasound on the vascularity of the chorioallantoic membrane (CAM) of a fertilized egg and demonstrated that ultrasound methods showed evidence of an angiogenic effect compared to controls. The most effective results were seen with direct application of a 45-kHz wave at an intensity of 15 mW/cm\textsuperscript{2} and indirect application of the media of fibroblasts ultrasonicated at 1 MHz with an intensity of 0.4 W/cm\textsuperscript{2}. This model has confirmed that ultrasound can induce neoangiogenesis in vivo.\textsuperscript{15} Low-intensity pulsed ultrasound (LIPUS) is commonly used in the treatment of fractures and nonunion-promoting acceleration of healing fractures, and it induces osteoblastogenesis via the release of purines, such as adenosine triphosphate, activating P2Y receptors, mainly the P2Y(1) receptor.\textsuperscript{12} Research on LIPUS in animal fracture models has demonstrated promising results for acceleration of fracture healing and for promotion of fracture healing in compromised tissue beds. A large body of cellular and animal research exists, which shows that LIPUS may be beneficial for accelerating normal fracture healing or for promoting fracture healing in compromised tissue beds.\textsuperscript{12-15}

Scheven and colleagues postulate that low-frequency, low-intensity ultrasound may stimulate endogenous coronal tooth repair by stimulating dentin formation from existing odontoblasts or by activating dental pulp stem cells to differentiate into new reparative dentin-producing cells. They also believe that ultrasound therapy could promote dentin formation and repair and that it may have the potential benefit of alleviating dentin hypersensitivity by inducing occlusion of dentinal tubules. It is envisaged that therapeutic ultrasound may be used in the future to facilitate dental tissue engineering and stem cell therapy applications for dental tissue regeneration.\textsuperscript{15}

As ultrasound is able to promote biological effects on odontoblast-like cells,\textsuperscript{15} on osteoblasts, and on osteogenic cells, we have postulated that ultrasound could have potential benefits in osseointegration. Our results, based on radiological findings, denote promising results on bone density surrounding implants. Since this density measurement is based on the pseudo-color visualization of the digital imaging software, a future study for revalidation of the density measurements with another type of analysis, such as cone beam computed tomography, is indicated. The short follow-up period is exclusively associated with the time in the market of the two ultrasonic implant kits.
CONCLUSIONS

Considering the importance of bone quality in implant surgery or related integration, the need for an accurate and reliable clinical tool for quantifying this is evident.

Despite a limited number of treated patients, the results of this pilot study demonstrated that (1) piezoelectric implant site preparation promotes better bone density and osteogenesis, and (2) the piezoelectric technique is predictable, with a success rate of 100% in this study.

A longer follow-up study is needed to confirm the promising preliminary data. Further histological and animal studies are needed to evaluate the fate of the newly formed bone over time.

REFERENCES