

Three-Dimensional Implant Positioning with a Piezosurgery Implant Site Preparation Technique and an Intraoral Surgical Navigation System: Case Report

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This case report describes new implant site preparation techniques joining the benefits of using an intraoral navigation system to optimize three-dimensional implant site positioning in combination with an ultrasonic osteotomy. A report of five patients is presented, and the implant positions as planned in the navigation software with the postoperative scan image were compared. The preliminary results are useful, although further clinical studies with larger populations are needed to confirm these findings. INT J ORAL MAXILLOFAC IMPLANTS 2017;32:e163–e165. doi: 10.11607/jomi.5800

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Piezoelectric bone surgery procedures have commonly been used for osteotomies for alveolar bone crest expansion, maxillary sinus elevation, and dental implant removal, which can be performed accurately and safely, providing excellent clinical and biologic results.

A recent application of Piezosurgery (Mectron Srl) in dental implantology has been the preparation of implant sites¹ for a large number of implants. The outcome of this clinical study showed 97.7% success in all anatomical situations (ridge expansion, sinus elevation, bony block, and guided bone regeneration). The advantage of preparing crestal cortical bone separately from the underlining cancellous bone (differential implant site preparation) is to optimize the primary stability in a difficult anatomical situation. In particular, such differential preparation allows widening of a socket

wall by a three-dimensional (3D) cutting action that includes lateral movements. Studies^{2,3} showed the maintenance of primary stability due to early osteogenesis, promoted by ultrasonic stimulation of stem cells, as demonstrated by an increase in growth factors.

Multiple factors contribute to this result. Among them, there is reduced mechanical and thermal trauma, improved washing of smaller bone debris, and improved efficacy of debridement by cavitation versus the regular irrigation action using normal drill bits.

As a consequence, both primary and secondary stability are improved, and the risk of postoperative necrosis is reduced.^{4,5}

Other studies have examined how ultrasonic drilling can be more accurate than conventional rotary instruments in terms of uniformity of the osteotomy cut.^{2,6} Mixed traditional and ultrasonic techniques for implant site osteotomies have been evaluated clinically for implant placement, revealing that implant stability might develop more rapidly.^{7,8}

Because of the nonaxial cutting action, it is ideal if the implant socket is prepared through live tracking of the piezosurgery tip. However, since it is based on ultrasonic vibrations, the piezoelectric surgical technique avoids the macrovibrations generated by conventional drilling, allowing greater intraoperative control with higher safety when cutting in difficult anatomical regions.^{9,10} In this context of reduced vibrations, if applied, a tracking system could facilitate access to deeper cortical areas of the surgical site, guiding the cutting action, for example, in thin bony crests, near the mandibular nerve, or close to the maxillary sinus.

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The ImplaNav Navigation System consists of a software interface running in Microsoft Windows (Microsoft), which processes positional data obtained from a stereoscopic camera. In each frame, the firmware of the camera (NDI Polaris Vicra; Northern Digital) identifies the 3D coordinates of a predefined geometric pattern of reflective spheres, which are segmented on-the-fly in the two-dimensional (2D) image obtained from the frame. The software-hardware system is modular, so that the assembly of the main components—the camera, reflective tools with relative supports, and the processing unit—can be customized to facilitate operations in a dental facility.

Surgical planning is performed with the ImplaNav software on a 3D model reconstructed from a cone beam computed tomography (CBCT) scan. Image-to-world registration is performed using radiopaque markers embedded in a calibration plate manufactured in biocompatible plastic, which can be tooth-supported for partially edentulous patients or bone-supported via a provisional mini-fixture for full-arch reconstructions. Both the patient and the surgical handpiece are equipped with a minimally invasive optical reference frame supporting markers that reflect infrared light from the stereoscopic camera.

Given the multiple axes of symmetry of the Piezosurgery inserts, in contrast to the straight tips used for contra-angle handpieces, a specialized tool has been designed to allow the calibration, and thus, correct virtualization of the tips in the 3D-rendering environment. Because of its complex internal design, a prototype of the calibration tool was manufactured via selective laser sintering using an EOS P380 machine (Advanced Manufacturing Services).

Following the calibration procedure, the position of the implant site is registered with the 3D model that the surgeon used to plan the surgery virtually. During the surgical planning stage, the optimal position for the implants is evaluated according to the virtual representation of the prosthetic restoration, which can be scanned with an optical laser or as a radiographic template via CT data. Alternatively, the prostheses are loaded from an internal software library and superimposed on the CT data. The registration procedure consists of touching three points with the tip mounted on the handpiece. Because of the curved nature of the tips, axis calibration is performed by identifying the axis of the distal end of the ultrasonic tip. This set-up allows the surgeon to follow in real-time, via an LCD display, the increasing depth of the cutting action of the tip.

MATERIALS AND METHODS

In this preliminary clinical study, five patients referred to the Oral and Maxillofacial Department, University of

Bologna, Italy, in need of implant-born prosthetic rehabilitation were included. The patients were all in good health and between 25 and 60 years of age. No patient had contraindications for implant surgery. After being briefed about the surgical treatment plan, all patients signed an informed consent for the procedure.

Two maxillae and three mandibles were treated; five implant sites were considered. The patient cases were chosen for their complexity and difficulty due to reduced bone support in the horizontal or vertical direction during preparation of the implant site.

For two patients, a full ultrasonic implant site preparation was performed, and in one case, flapless surgery was performed. In the remaining cases, implant preparation was performed using ultrasonic tips and completed using progressively larger standard drills up to the planned implant diameter. The mandible cases included the selective preparation of the lingual cortical wall in the thin-crest posterior mandible, performed using both a full piezoelectric procedure and a combination of Piezosurgery and traditional drilling. It is known that, in this anatomical region, “traditional” socketing procedures often result in a shifting of the implant due to contact between the drill tip and the lingual wall (Fig 1a).

Technique One: Combined Piezo-drill–Navigated Implant Site Preparation

In these cases, using the piezo-navigated technique, the surgeon could perform a combined differential preparation (Fig 1b), consisting primarily of the selective preparation of the lingual cortical wall using IMS1 and IM2P inserts, with a real-time monitoring of the tip position (Fig 2a). With the ultrasonic tip, the surgeon could keep the right trajectory and better instrument control. This procedure proved to be more accurate and safer than using rotary instruments, which were instead only used as part of the final step to refine the implant socket (Fig 2b). The same method was also used in a maxillary case with flapless surgery.

Technique Two: 3D Piezo-Navigated Implant Site Preparation

In one mandibular case, flapless surgery was performed, following a full piezo-navigated preparation (Fig 3). Using only two Piezosurgery inserts, IMS1 and OT4 (Fig 4), the socketing procedure was completed via a 3D approach, visualizing the live tracked position of the ultrasonic tip and the virtual volume of the planned implant on a digital display. While using an insert with a 3D cutting edge, the software guides the progressive circumferential border preparation to the desired depth. The surgeon shapes the socket to the virtual volume that will be occupied by the planned implant by way of radial extensions according to feedback from the navigation system.

Fig 1 (a) Conventional implant shift due to contact between the tip and the lingual cortical wall. (b) Different preparation using a combined piezoelectric and traditional drilling process.

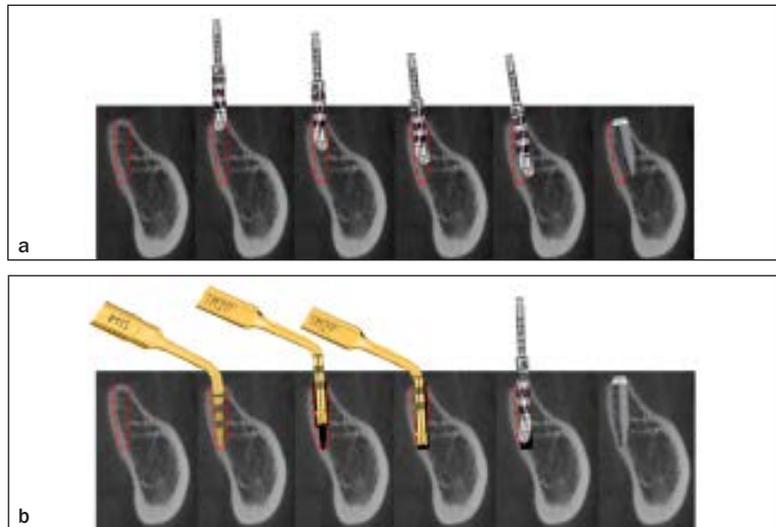


Fig 2a Selective preparation of the lingual cortical wall using IMS1 and IM2P inserts.

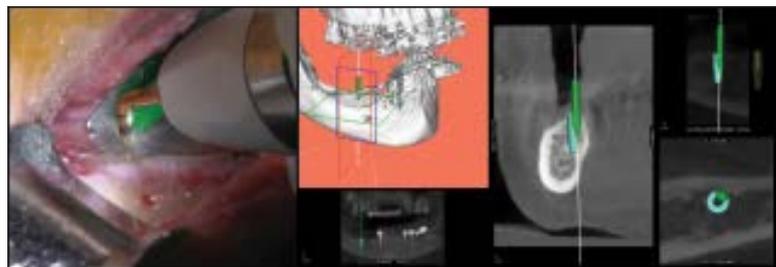


Fig 2b Rotary instruments, which are only used to refine the implant socket.

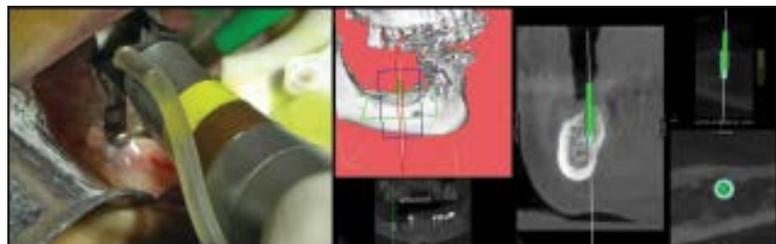
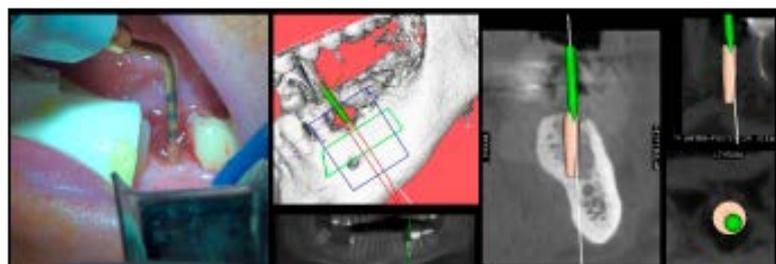


Fig 3 Different steps of a full piezo-navigated implant site preparation using only two Piezosurgery inserts, IMS1 and OT4, and a 3D approach.



Fig 4 Contextual visualization on a digital display of the live tracked position of the OT4 Piezosurgery tip and the virtually planned implant.



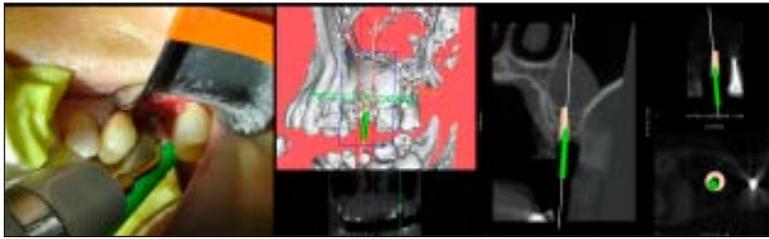


Fig 5 Vertical ultrasonic implant site preparation checking in real-time, on the navigation system display, the tip depth.



Fig 6 Superposition of preoperative surgical plan with postoperative segmentation of the inserted implant.

Technique Three: Full Piezo-Navigated Implant Site Preparation

In a left first molar area of the maxilla, a short implant had to be placed avoiding the maxillary sinus in which a thickening of the membrane appeared. Following the standard procedure for a vertical ultrasonic implant site preparation, the tip depth was checked in real-time, on the navigation system display, allowing the surgeon to keep the sinus floor intact (Fig 5). This method could be considered suitable in similar cases in which there is the need of a highly sensitive implant site preparation, due to close anatomical structures.

After socket preparation, the implants (three, Southern Implants and two, BioSafin) were positioned with a contra-angle handpiece at 40 rpm with 40-Ncm maximum torque. The depth of the implant insertion could also be tracked on the software against the final virtually planned implant position.

Accuracy Evaluation

For all patients, a postoperative CBCT scan was taken within 3 months after the implant surgery, according to the research protocol approved by the S. Orsola-Malpighi Hospital Ethical Committee, University of Bologna, Italy.

The accuracy of the procedure was evaluated by comparing the software-based surgical plan with postoperative information. The inserted implants were segmented from the tomographic scan using the OpenMAF platform,^{11,12} and the volumes from the preoperative and postoperative models were aligned using a three-point registration module within the ImplaNav software

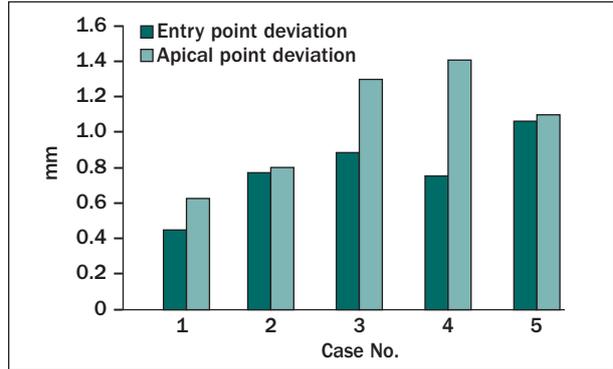


Fig 7 Results of the displacement vector module for entry and apical points for the five clinical cases.

(Fig 6). At this point, the deviation of each planned implant with respect to the segmented postoperative implant profiles was evaluated in two ways. First, the authors used a dedicated function within Geomagic Studio 12.0 (Geomagic), which computes all point-to-point distances and, from them, calculates a mean deviation quantity. The other method was identifying the Euclidean distance between the 3D coordinates of the entry position and the apical point for each pair of implants.

Analysis of the point-to-point distances for the five implant insertions in the five patients showed a mean deviation of 0.87 ± 0.04 mm. The results, summarized in Fig 7, also showed a mean deviation of 0.78 ± 0.20 mm for the insertion point and 1.04 ± 0.29 mm for the apical point.

DISCUSSION

No studies are reported, at the moment, about the combined use of a navigation system and ultrasonic instruments.

Although few significant clinical studies on navigated implant surgery have been reported to date, the performance of the ImplaNav system¹³ seems to be similar to that of the Treon navigation system (Medtronic) and the VISIT navigation system (University of Vienna) for navigated implant insertion.^{14,15}

The application of the piezo-navigation technology¹⁶ seems to facilitate the use of a smaller-diameter insert for the lateral and vertical preparation of an implant socket, possibly leading to more abundant and

deeper irrigation of the osteotomy area. Implant site preparation using a navigated piezosurgery approach may be key to improving the primary stability of the implant. In fact, the ability to access lower trabecular regions of the bone would strengthen deeper implant anchorage while keeping the pressure acting on the upper implant-cortical bone interface low (and where, generally, reabsorption phenomena related to implant buccal-lingual inclination occur¹⁷). If tracked in real-time over the tomographic scan, the surgeon can selectively prepare deeper regions of the cortical walls, such as the mandibular lingual wall or the oblique walls of the maxillary sinus floor, while damage to the surrounding soft and neurovascular tissues is reduced markedly using the Piezosurgery system.^{9,18}

As described in this study, when navigation is combined with ultrasonic drilling and, in particular, a 3D differential preparation, the number of inserts used for socketing can be reduced readily. Indeed, if specifically designed, it is likely that one insert could be used for the entire piezoelectric surgery procedure. Moreover, the possibility of horizontal movement during a lateral preparation allows more control over the socket's geometry in the case of narrow bone crests, according to the morphology of the vestibulo-lingual walls. Additionally, being able to use an insert that is considerably smaller than the socket in both lateral and vertical movements allows more generous irrigation of the socket itself, up to its floor. With the advantages related to the use of an image-guided surgery system that is specialized for oral implantology, it is reasonable to conclude that navigation allows deeper preparation of an implant site, performed according to preoperative virtual surgery planning.

Unlike the use of surgical drill guides, and because of the live feedback from the tracking procedure, the diameter and orientation of the socket can be changed dynamically during the surgery—with respect to the virtual planning—if, for example, poor bone quality or pathologic or anatomical anomalies become evident.

Because this technique can be used with standard drill tips, it becomes more useful for posterior areas, where limited mouth opening may limit access for the extended drill tips, achieved by socketing through drill guides. Finally, because the surgical planning and the live tracking are performed within the same software, the surgeon can decide to modify the optimal position for the implant(s) at any time or even use a free-navigation module that allows inspection of the morphology and density of the surgical site below the tracked surgical instrument.

As a result, the surgeon could perform implant surgery more safely and with the reduced invasiveness that a flapless technique can offer. Clinical studies are underway to further evaluate the efficacy of this procedure.

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