Dynamic Navigation Guidance for Bone Reduction in Maxilla: Case Report

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This case report demonstrates the use of dynamic navigation guidance for bone reduction. Information about smile line position incorporated in a virtual plan and accurate transfer to the surgical field enhances the predictability of the treatment. A virtual wax-up was made, and implant positions along with bone reduction were planned accordingly. Residual teeth in the maxilla were extracted, and bone reduction and zygomatic implant placement were assisted by surgical navigation, while conventional implants were placed using the surgical template, followed by immediate loading. When surgical navigation is used for implant placement, navigated bone reduction can easily be incorporated in the workflow. The accuracy of bone reduction was evaluated together with the accuracy of two zygomatic implants assisted by a navigation system and four conventional implants assisted by a static template. The mean deviation between planned and performed bone reduction was 1.3 ± 0.39 mm (range: 0.8 to 1.7 mm). The accuracy of this procedure corresponds to the accuracy of guided implant placement and can be considered reliable after confirmation through clinical trials. Int J Oral Maxillofac Implants 2021;36:e1–e6. doi: 10.11607/jomi.8555

Keywords: accuracy, bone reduction, dynamic navigation, full-arch rehabilitation, immediate loading, zygomatic implant

The position of the smile line must be taken into consideration when full-arch implant-supported fixed prostheses are planned. Bone reduction for implant-supported fixed dental prostheses is often necessary to provide adequate restorative space, ensure that the prosthetic-tissue junction is not visible during smiling, and create a more cleansable surface. Under-reduction of bone can lead to prosthetic and esthetic failure, while over-reduction may result in insufficient bone height for an implant of preferred length, or enlarged risk of injury of vital anatomical structures.1 The extent of bone reduction is directly dependent on the smile line position; therefore, having smile information incorporated in virtual implant planning represents valuable data for clinicians. Different techniques have been proposed to accurately transfer the position of the smile line into the implant planning software. Measuring smile line exposure of the central incisor and drawing a line of the same length on the CBCT scan can help clinicians include this information in the planning procedure.2 A radiographic smile guide can be fabricated prior to CBCT imaging,1 or a CBCT scan can be taken while the patient is smiling.3 The latter is called a smiling scan; the patient is asked to display a broad smile on their face for the duration of the scan while residual teeth are kept in contact during the smile in order to record the patient’s occlusion. Another option is to take a face scan of the patient in a smiling position, although this technique requires an additional extraoral scanner.4

While computer-aided static surgery is routinely used in implant surgery, dynamic navigation is showing rapid development and an increasing range of indications in craniomaxillofacial surgery.5 In dentistry, navigation systems are mainly used in implant dentistry to obtain a prosthetically driven implant position according to a presurgical virtual plan.6 Dynamic navigation systems demonstrated promising results regarding their accuracy in model-based and clinical studies.7–9 The accuracy of dynamic navigation has been shown to be superior to freehand drilling and similar to static computer-assisted surgery.9,10 In addition to placement of conventional implants, computer-aided dynamic navigation systems have been shown to be a reliable tool for accurate placement of zygomatic implants.11,12

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This case report demonstrates the use of a dynamic navigation system for bone reduction in the maxilla, together with a classic zygomatic implant approach followed by immediate loading. The accuracy of bone reduction was evaluated together with the accuracy of two zygomatic implants assisted by a navigation system and four conventional implants assisted by a surgical template.

**CASE PRESENTATION**

**Case Description**

A female patient 44 years of age, who was healthy and a nonsmoker, reported to Second Dental Center of Shanghai Ninth People’s Hospital, Shanghai Jiao Tong University School of Medicine, requesting rehabilitation of a failing dentition in the maxilla.

The patient was diagnosed with severe generalized periodontitis of residual teeth. Clinical examination revealed excessive gingival display and overeruption of periodontally affected anterior teeth (Fig 1). Panoramic image analysis showed pneumatization of maxillary sinuses and severe bone resorption in the posterior maxilla (Fig 2). According to division of the edentulous maxilla into three radiographic zones by Bedrossian et al., sufficient bone volume for placement of implants was found in zone 1, while zones 2 and 3 did not have enough bone for implant anchorage without extensive bone grafting.

After different treatment options were presented to the patient, it was agreed to proceed with a full-arch fixed prosthesis supported by two zygomatic implants in the posterior and four conventional implants in the anterior maxilla.

**Treatment Planning**

The smiling CBCT scan (Planmeca, scanning with a resolution of 0.33 mm/pixel and 0.4-mm slice thickness) was taken. Digital Imaging and Communications in Medicine (DICOM) data were imported in coDiagnostiX (Dental Wings) implant planning software and merged with a standard tessellation language (STL) file from an intraoral scanner. The patient’s bite was recorded with an intraoral scanner (Trios, 3Shape), so the occlusion could be transferred to a virtual articulator. A virtual wax-up was made, and the extent of bone reduction was determined accordingly. Implants were planned at a new bone level, following a virtual wax-up (Fig 3). A preliminary plan for zygomatic implants was also made at this stage. A stereolithographic guide for placement of conventional implants with sleeves for three anchor guide pins was fabricated together with a silicone index for guide fixation. Models of the maxilla with virtually extracted teeth and the mandible were printed, positioned in a printed articulator using digital bite registration, and a silicone index for surgical guide was made accordingly.

Placement of zygomatic implants was performed using dynamic navigation. Eight bone-anchored mini titanium screws (CIBEI) were used as fiducial markers and broadly spread in a polygon arrangement across the maxilla. Positions of the markers were meticulously planned to avoid overlapping with the surgical guide, implants, or anchoring pins. On the other hand, the surgical template had a hollow palate design so that it could be fixated after fiducial markers were placed at the palate. These markers are used for intraoperative point-to-point registration to establish a coordinate between the navigation system image and the patient. An intraoperative CBCT scan was made with fiducial markers, and data were imported to planning software for navigation surgery (iPlan Navigator, Brainlab). Data from the initial plan made with coDiagnostiX software, which contains implant information and bone reduction information, were exported as an STL file and overlapped with the new DICOM file in iPlan Navigator software. Trajectories of implants and new bone level were created in navigation software following a virtual plan imported from coDiagnostiX. The procedure for zygomatic implant planning and placement using real-time navigation was previously described in detail.

**Surgical Procedure**

After general anesthesia, the skull reference base was rigidly secured within the hairline with a single self-tapping titanium screw of 1.5 × 6 mm. The remaining teeth in the maxilla were extracted. The surgical template was guided in an appropriate position using a silicone index fabricated in a laboratory and secured with three anchoring pins (Fig 4). The drilling sequence for conventional implants was completed using the surgical template.

A midcrestal incision and vertical releasing incisions at the maxillary tuberosity region were made. Prior to mucoperiosteal flap elevation, the navigation system (VectorVision2, Brainlab) was registered by using a navigation probe to contact the surface cavity of miniscrews. A custom-made rigid bracket integrating the reference array was connected to the zygoma drilling handpiece, enabling constant visualization of the drill on the screen in real time. A small round bur (1.4 mm in diameter) was connected to the handpiece and calibrated. With this bur, a bone reduction line was marked (Fig 5). During this procedure, the position of the bur was actively followed on a display with a 3D image of the patient and marked line for bone reduction, allowing the surgeon to adjust the position and angulation of the tool (Fig 6). After the line was marked, cutting was finished using a Piezosurgery device (Piezotome...
Solo, Acteon). Positions and depth of prepared osteotomies as well as the level of bone reduction were once again verified using paralleling pins with depth indicators, and four implants were placed without a template (NobelActive, Nobel Biocare).

The lateral sinus wall and a part of the zygomatic complex were exposed, a window of $5 \times 10$ mm was made in the lateral aspect of the sinus wall, and the sinus membrane was reflected. The entry points for zygomatic implants were located by a navigation probe. Two zygomatic implants (Bråemark System Zygoma, Nobel Biocare) were placed using navigation, and the complete drilling procedure followed the trajectories from the entrance point to the exit point as planned (Fig 7). After implant placement, multiunit abutments and healing caps were respectively placed on implants, and the incision was sutured. All implants were placed with an insertion torque of more than 35 Ncm.
Five days of antibiotic (amoxicillin 500 mg, metronidazole 600 mg) therapy was prescribed to the patient, together with mouthwash solution (chlorhexidine 0.12%).

**Immediate Loading**
Prior to surgery, a polymethyl methacrylate (PMMA) provisional restoration was milled from a 3D virtual wax-up, with sleeves for anchor guide pins in predetermined positions that match the surgical guide. The provisional prosthesis was delivered 24 hours after surgery (Fig 8). All implants healed uneventfully.

**Table 1 Deviation of Navigation-Assisted Bone Reduction**

<table>
<thead>
<tr>
<th>Point position</th>
<th>Deviation (mm)</th>
</tr>
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<tbody>
<tr>
<td>13</td>
<td>1.2</td>
</tr>
<tr>
<td>11</td>
<td>0.8</td>
</tr>
<tr>
<td>21</td>
<td>1.5</td>
</tr>
<tr>
<td>23</td>
<td>1.7</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>1.3 ± 0.39</td>
</tr>
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</table>

**Accuracy Measurements**
For accuracy measurements, the patient was rescanned after the surgery with the same CBCT machine and the same exposure parameters. Implant and bone reduction accuracy analysis were performed using iPlan Navigator software, where the preoperative trajectory images were fused with the postoperative images (Fig 9). Three-dimensional distances between the entry centers and apical centers of the corresponding planned and placed implants were calculated. The angle of deviation of the axes (angular deviation) was calculated as the 3D angle between the longitudinal axes of the planned and placed implants. The deviation of bone reduction was defined as the difference between the preoperatively drawn line and the new bone level. The line was stretched between four points, marked at the buccal aspect of the alveolar ridge at the corresponding implant sites. The deviation of bone reduction was calculated as the 3D distance between the preoperatively marked points and points marked at the corresponding implant sites postoperatively. The mean deviation between the planned and performed bone reduction was 1.3 ± 0.39 mm (range: 0.8 to 1.7 mm; Table 1). Accuracy of the navigation system and static guide for implant placement is given in Table 2.

**DISCUSSION**
Full-arch rehabilitation of the maxilla with a fixed implant-supported prosthesis is very often accompanied by bone reduction. Ostectomy can be performed freehand or guided. A windowed denture or acrylic bone reduction guide are used to help clinicians in transferring information of the extent of bone removal from the presurgical plan. However, CAD/CAM-generated surgical guides are most often used to prevent complications associated with under-reduction or over-reduction of the alveolar ridge. During treatment planning, the extent of bone reduction is calculated,
and if a guided surgery protocol is used, a stereolithographic guide for bone reduction is fabricated. This procedure usually involves a combination of two guides: an osseous recontouring guide, which is used for bone reduction, and an implant placement guide. Bone reduction requires extensive opening of a flap and guide support by the underlying bone tissue, which negatively affects accuracy. The drilling sequence for implants was finished prior to bone reduction, which was aided by surgical navigation, and implants were placed freehand, avoiding misfit of the implant placement guide and inappropriate vertical position of implants if the error occurred during bone reduction.

Although dynamic navigation is becoming popular in implant surgery, only static computer-assisted surgery has been reported for bone reduction. Accuracy of navigation surgery is related to several factors; registration is one of the most important procedures, and multiple factors may affect the total error. In this case, invasive fiducial markers, which can achieve acceptable accuracy for zygomatic implant placement, have been well distributed in the intraoral area. However, to the authors’ knowledge, no research has focused on the effectiveness of number and distribution of fiducial markers in bone reduction. The validity of this method suggests that it could be accepted for bone reduction in clinical practice after further research. It is advised that fiducial markers in the bone reduction area should not be inserted lower than the new bone level. Also, the area of the implants and maxillary sinus should be avoided; thus, comprehensive planning for fiducial markers in complex cases is needed.

The navigation system used in this case (VectorVision2, Brainlab) is adjusted only for placement of zygomatic implants. Reference array cannot be connected to a standard handpiece used for conventional implant placement. When working with this system, to achieve the highest precision, a static guide for conventional implants can be combined with dynamic navigation for zygomatic implants. A randomized clinical trial compared the accuracy of a static template and surgical navigation for placement of conventional implants, and no significant difference in both entry point and exit point was found. On the other hand, accuracy of static surgical guides seems to be insufficient for placement of zygomatic implants.

The entrance point of drilling for zygomatic implants can be determined by combining the surgical template and navigation guidance. A round bur connected to a zygoma drilling handpiece, used for marking the entrance point for implants, can be used to mark the bone reduction line while monitoring the procedure directly on a 3D image of the patient. In the same manner, the procedure can be done with the use of a navigation system designed for placement of conventional implants. An ultrasonic surgical device can also be connected to a navigation system, and this procedure has been described for implant site preparation.

A high level of accuracy of a real-time surgical navigation system in zygomatic implant placement has been shown in previous studies. The entry deviation, exit deviation, and angle deviation were 1.35 mm, 2.15 mm, and 2.05 degrees, respectively, for 40 zygomatic implants in 10 patients. Similar accuracy was found in this case.

In a case series reporting the accuracy of ostectomy using a surgical template, three sites with three points (buccal, midcrestal, and lingual) at each site were selected for accuracy measurements. The overall deviation was 1.98 mm, ranging from 0.95 to 2.68 mm. In the present case report, four sites at the buccal aspect of the alveolar ridge were selected for accuracy measurements, and the mean deviation achieved with the surgical navigation was 1.3 ± 0.39 mm (range: 0.8 to 1.7 mm). The accuracy of the static guide—assisted bone reduction itself is usually not reported, so there is no standard for the acceptable error, but accuracy of implants placed in conjunction with guided ostectomy seems to correspond to precision of implants placed with a surgical guide. Nevertheless, attention should be paid when a surgical template or navigation is used for bone reduction, since a large deviation in patients with a high smile line can lead to esthetic failure. In navigation surgery, application error affects overall deviation. In the present case, a round bur with a long shank connected to a straight handpiece, designed for zygomatic implants, was used for marking a line for bone reduction (Fig 5). Thus, extensive distance

<table>
<thead>
<tr>
<th>Position</th>
<th>Navigation guidance</th>
<th>Static guidance</th>
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<tbody>
<tr>
<td></td>
<td>Zygomatic implants</td>
<td>Conventional implants</td>
</tr>
<tr>
<td></td>
<td>15 25 Mean ± SD</td>
<td>13 11 21 23 Mean ± SD</td>
</tr>
<tr>
<td>Entry point (mm)</td>
<td>1.1 1.5 1.3 ± 0.28</td>
<td>2.1 1.0 1.1 1.6 1.45 ± 0.51</td>
</tr>
<tr>
<td>Apical point (mm)</td>
<td>2.1 1.9 2.0 ± 0.14</td>
<td>2.0 1.2 1.0 1.1 1.33 ± 0.46</td>
</tr>
<tr>
<td>Angle (deg)</td>
<td>1.6 1.3 1.45 ± 0.21</td>
<td>1.9 1.6 0.9 2.0 1.6 ± 0.50</td>
</tr>
</tbody>
</table>
| "FIDT tooth-numbering system."
between the tip of the bur and the operator’s hand can negatively affect the accuracy. Use of an angled handpiece with a shorter bur or a Piezosurgical device in conjunction with a navigation system could reduce application error. Accuracy of navigated bone reduction corresponds to the accuracy of guided implant placement, and it could be considered reliable after being confirmed through randomized clinical trials.

CONCLUSIONS

To the current knowledge of the authors, this is the first report of clinical application of a surgical navigation system for bone reduction. Predictability and precision of complex implant rehabilitations can be increased by incorporating various digital technologies in surgical and prosthodontic workflow.

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