A Novel Application of Dynamic Navigation System in Socket Shield Technique

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INTRODUCTION

Achieving osseointegration after dental implant placement has been proven to be a predictable process, and implant restorations can maintain adequate function for many years.[1,2] Obtaining optimal long-term esthetic results in implant therapy, however, remains a challenging task. One of the main reasons for this difficulty is alveolar bone resorption after tooth extractions, which leads to significant reduction in the horizontal and vertical dimensions of the hard and soft tissues.[3,4]

The socket shield technique has been developed to overcome the tissue resorption process.[5] By retaining the buccal and/or the proximal portions of the root to be extracted, the periodontal ligament and surrounding bone can be maintained. This leads to the preservation of soft tissue contour; hence, a natural-appearing esthetic result can be achieved.

The socket shield technique, however, is technique-sensitive. Preparing the socket shield to the correct shape, thickness, and length without damaging the surrounding tissues can be challenging because the socket has limited visibility and access, and the root anatomy varies. It is difficult to visualize the root during preparation and know exactly how much structure to reduce or remove.

The image-guided dynamic navigation system was developed to have real-time visualization of anatomical structures such as bone and teeth, as well as drill tips during implant surgical procedures. This type of system has advantages in placing implants in a pre-planned, prosthetically driven position, avoiding crucial anatomical structures such as the inferior alveolar nerve and maxillary sinus. Since the system provides real-time feedback, any malpositioning or false alignment of the drills can be immediately corrected.

The present report describes a novel method in applying the image-guided dynamic navigation system in the socket shield preparation and immediate implant placement.

CLINICAL CASE REPORT

Part I—The dynamic navigation workflow

A 23-year-old female with noncontributory medical history presented with a non-restorable maxillary left first premolar due to severe caries. Clinical photographs and a cone-beam computerized tomography (CBCT) scan were taken (Veraviewepocs 3D R100, J Morita Mfg Corp, Kyoto, Japan) (Figures 1 and 2), and a preliminary impression was made with polyvinyl siloxane material. A diagnostic wax-up of tooth #12 was made on the preliminary study cast from the impression. The study cast was then scanned and transferred into standard tessellation language (STL) files. Both the DICOM dataset (CBCT scan) and the STL files were imported into the Navident software (Navident R2.0.1, ClaroNav Inc, Toronto, Canada) for case analysis and treatment planning. The two files were merged and mapped together on the software to obtain an accurate image of the bone, teeth, roots, and soft tissue.

On the Navident software, a 1-mm diameter osteotomy was planned from the buccal border of the root canal chamber to the root apex with a slight tilt towards the buccal side (Figure 3). The osteotomy was planned buccal to the root apex and passed the periapical lesion area. This osteotomy would indicate the apico-coronal direction of the mesiodistal cut and ensure the complete removal of the root apex and any periapical pathology.

To accurately guide the drilling process, the navigation system must map the drill tip to a CT scan image of the jaw. This was done in three steps: registration, calibration, and tracking.

Registration was the process of mapping the CBCT image to the patient's physical jaw structures. First, on the preliminary study cast, the wire portion of the Jaw Tracker, which was a tag used for real-time tracking of the patient's jaw, was bent and fitted onto the occlusal surfaces of the maxillary right premolar and molars. Then the Jaw Tracker was attached to the maxillary right premolar and molars with flowable composite resin (Figure 4). The system's tracking camera (Micron Tracker, ClaroNav Inc) tracked the Jaw Tracker in the physical 3D space, thereby allowing for a continuous tracking of the patient's maxillary anatomical structures.

Next is the trace registration procedure. The Tracer Tool with a TracerTag attached was calibrated on the Calibrator (Figure 5a and b). The tracking camera tracked both parts, the Calibrator and the TracerTag, so when the Tracer Tool was placed in the dimple of the Calibrator, the computer calibrates the Tracer Tool's tip in relation to the TracerTag. Then the Tracer Tool was used to trace the surfaces of four pre-selected teeth around the maxillary arch. As the Tracer Tool's ball tip slid over the tooth surfaces, the system continuously sampled its position in space, creating a virtual "cloud of points" or a 3D mesh, in relation to the Jaw Tracker attached to the patient's jaw (Figure 6). This virtual 3D mesh was then matched by the software to the outer surfaces of the traced teeth in the CT

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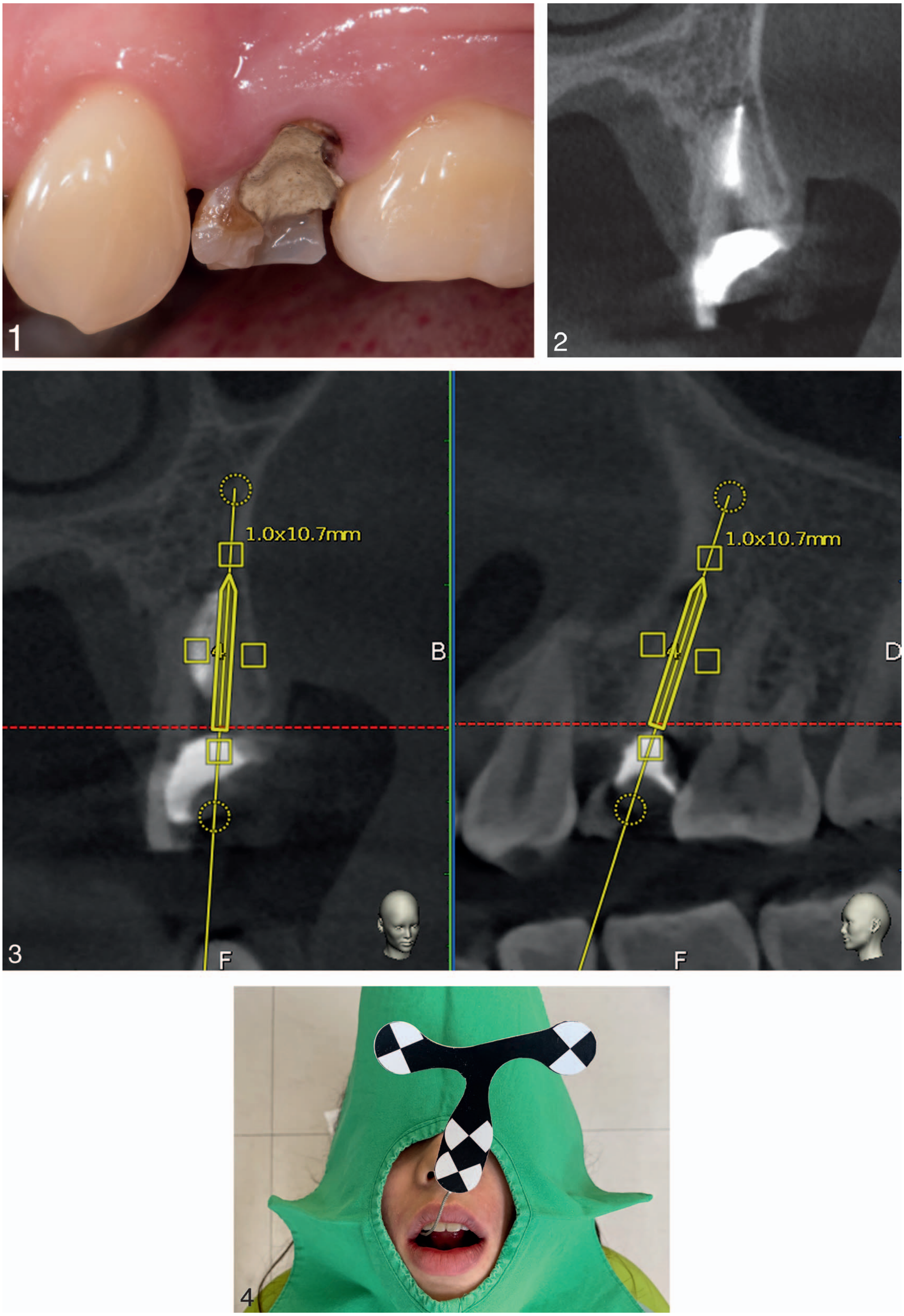


Figures 1–4. Figure 1. Tooth #12 was nonrestorable due to severe caries. **Figure 2.** Pre-operative cone-beam computerized tomography scan image of tooth #12 indicating presence of buccal bone and adequate volume of apical bone. **Figure 3.** Planning of the initial osteotomy for socket shield preparation on the Navident software. The osteotomy was placed in a buccally inclined position. **Figure 4.** The JawTag was attached to the patient's maxillary right posterior teeth with flowable composite.

scan. This tracing step registered the Jaw Tracker position to the CBCT scan images in the Navident software, so the computer can map the patient's actual anatomical structures to the CBCT scan images, maintaining this mapping accurately during the surgery regardless of the patient's possible movement. Once the tracing is completed, its accuracy was verified on the computer screen by touching the surfaces of teeth with the Tracer Tool and evaluating if the corresponding images on the computer screen was correct.

The calibration step related the axis and the tip of the burs or drills to the DrillTag. The DrillTag was first attached to the high-speed handpiece or a contra-angle handpiece (Figure 7a), then the chuck of the handpiece was placed on a pin on the calibrator and rotated around this pin. This identified the axis of the handpiece (Figures 5b and 7b). Next, the bur or the drill to be used was inserted into the handpiece, and the bur or drill tip was placed in the dimple on the Calibrator in the same manner as how the Tracer Tool was calibrated (Figure 7c). The location of the drill tip and its axis were now set relative to the DrillTag.

The last step is the tracking. When the DrillTag and the JawTag were in the tracking camera's field of view, the position of the drill tip and the patient's anatomical structures were mapped together by the software. In other words, this step is relating the drills to the jaw structures, allowing the operator to see them in motion on the computer monitor in real-time.

Part II—The socket shield preparation and implant placement

First, the coronal portion of the tooth was cut off with a chamfer diamond bur. Next, a long, small-diameter diamond bur (Root Membrane Kit, MegaGen Implant Co, Ltd, Daegu, Korea) was placed on a high-speed hand piece and then calibrated. The diamond bur was used to drill through the root following the first planned osteotomy. Once the bur passed the apex and reached the planned position, the same bur was used to cut the root in a mesiodistal direction. When the diamond bur approached the mesial and distal borders of the root, an ultrasonic instrument (Newtron P5, Acteon Satelec, Mérignac, France) and diamond coated tips (Perfect Margin, Acteon Satelec) were used to cut through the dentin. Since the ultrasonic instrument was less aggressive than the diamond bur, minimal damage would be inflicted on the proximal bone (Figure 8). Once the buccal and lingual portions were separated, the lingual fragment was carefully removed with extraction elevators and forceps. The apical area of the socket was thoroughly curetted and rinsed to make sure no endodontic obturation material or periapical pathology remained.

Next, a round diamond bur was calibrated and used to reduce the coronal portion of the buccal root fragment to the level of the buccal bone crest. The gingival tissue was protected with a metal instrument to prevent any damage. The positions of the round bur, tooth, and crestal bone were visualized on the software to aid in the root reduction process.

A beveled chamfer was prepared on the inner coronal edge of the buccal root fragment with a chamfer diamond bur to create more space between the root and the implant. The remaining buccal root fragment was modified into a C-shape. The surface of the root fragment was then smoothened with piezo-instruments (Newtron P5 and Perfect Margin, Acteon Satelec). This completed the socket shield preparation (Figure 9).

Another CBCT scan was taken to verify the shape of the socket shield. This DICOM file was imported into the Navident software for the planning and placement of the implant. A 3.6 × 13 mm implant was planned in a lingual position to keep a gap between the implant and the socket shield, to engage in enough apical bone for good primary stability, and to have screw access hole aiming toward occlusal surface for a screw-retained restoration (Figure 10).

To place the implant in the proper 3-dimensional position, the implant drills were calibrated with the Calibrator, and used to create osteotomies in the sequence recommended by the manufacturer. The implant (Astra Tech Implant System EV, 3.6 × 13 mm, Dentsply Implants Manufacturing GmbH, Mannheim, Germany) was also calibrated before placing it into the osteotomy. The implant was placed with its platform at 1 mm apical to the coronal edge of the socket shield (Figure 11).

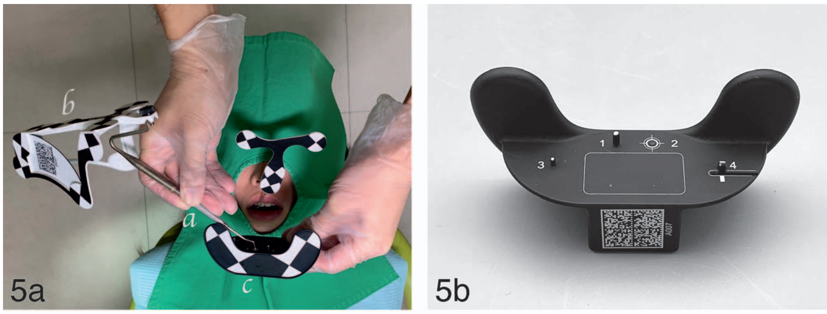
Next step was the fabrication of a custom provisional restoration. A titanium temporary abutment was placed onto the implant, and light-curing flowable composite was used to capture the soft tissue margins around the extraction socket. The temporary abutment was then removed from the mouth, and the subgingival emergence profile was completed extra-orally to ensure the facial tissue and papillae were properly supported. The custom temporary abutment was placed back onto the implant to verify that there was no interference in seating of the abutment. The crown portion of the screw-retained provisional restorations was then fabricated.

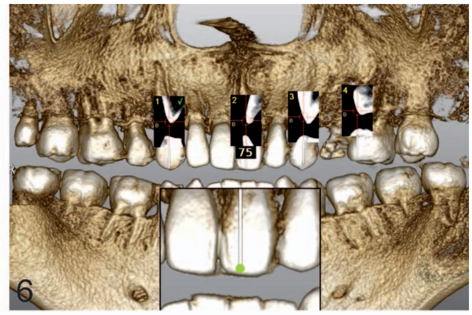
The freeze-dried bone allograft (MinerOss, BioHorizons Inc, Birmingham, Ala) was placed into the space between the socket shield and the implant (Figure 12). A piece of sub-epithelial connective tissue graft was harvested from the palate and sutured inside the facial marginal tissue to cover the socket shield and the bone graft materials (Figure 13). The screw-retained provisional was connected to the implant to complete the procedure (Figure 14). The occlusal surface of the provisional restoration was reduced approximately 1 mm to prevent any occlusal contact during maximum intercuspation and lateral excursive movements. A postoperative CBCT scan was taken to evaluate the implant position (Figure 15).

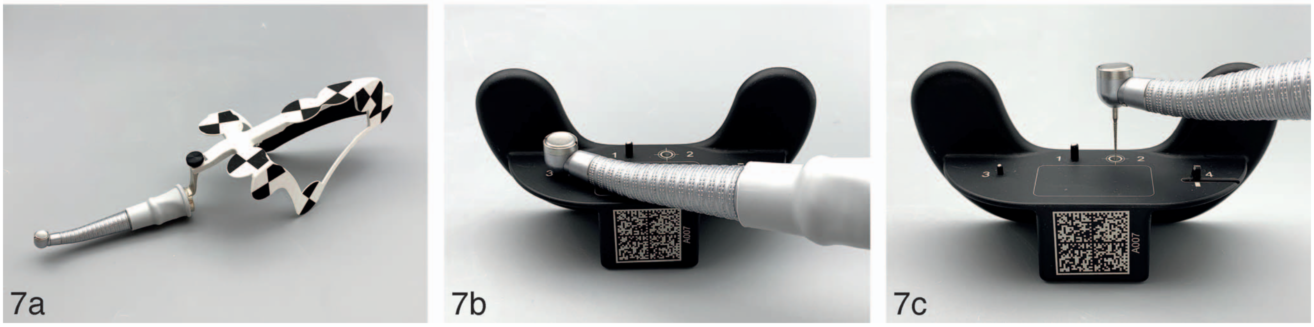
Discussion

Hürzeler et al first published a proof-of-principle study on the socket shield technique in 2010.[5] The rationale of this technique is by keeping a portion of a root, retaining the periodontal ligament and blood supply, thereby preserving the buccal bundle bone and alveolar bone. With the bony structures intact, the surrounding soft tissue contour and volume are well maintained and optimal esthetics can be achieved.

In a subsequent animal histologic study, Bäumer et al demonstrated how the socket shield was attached to the buccal plate by a physiologic periodontal ligament.[6] There was no resorptive activity of the buccal bone or the retained root structure, and the surrounding soft tissue was free of any inflammatory reaction. Furthermore, new bone formation was







Figures 5–7. Figure 5. (a) The Tracer Tool (1) was attached to the TracerTag (2) and calibrated on the Calibrator (3). (b) The Calibrator: #1 is the pin for calibrating the axis of a contra-angle handpiece; #2 is the dimple to calibrate the tip of an instrument, bur, or drill; #3 is the pin for calibrating the axis of a high-speed handpiece. **Figure 6.** Four teeth were selected as landmarks for the trace registration step. Tracing of 4 teeth to map the patient's actual anatomical structures to the CBCT scan images. **Figure 7.** (a) A high-speed hand-piece was attached to the TracerTag. (b) The chuck of the handpiece was placed over pin #3 on the Calibrator to register the axis of the bur. (c) A bur was inserted into the handpiece and calibrated by placing the tip of the bur in the dimple (#2) on the Calibrator.

observed between the socket shield and the implant. This bone formation phenomenon was confirmed in two human histologic reports by Mitsias et al and Schwimer et al.[7,8]

There are limited numbers of medium to long-term follow-up studies on the socket shield technique. In a 5-year follow-up study of 10 cases, Bäumer et al reported 100% implant success rate with minimal facial tissue recession, buccal volume loss, and marginal bone resorption.[9] Gluckman et al reported a retrospective evaluation of 128 cases with up to 4 years follow-up[10] and an implant survival rate of 96.1% with a complication rate of 19.5%. The main complications occurred were internal and external exposures, which would be preventable or correctable with the techniques described in their study.

Two studies reported on the medium to long-term survival rates of the "Root membrane technique" which has a similar treatment concept to the socket shield technique.[11,12] One of the studies reported 100% cumulative implant survival rate with up to 5 years follow-up, while the other reported cumulative implant survival rate of 97.3% with up to 10 years follow-up.

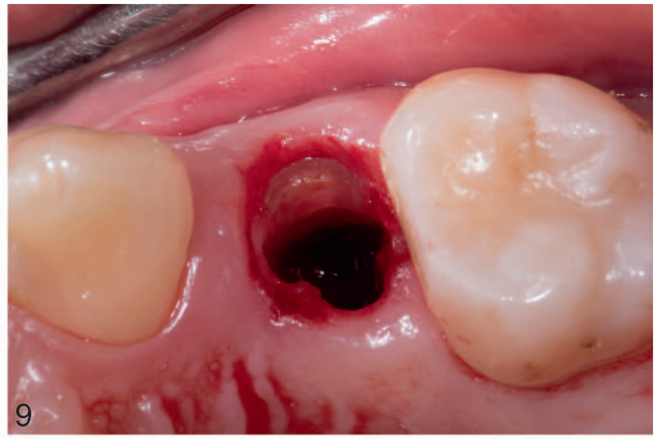
The preparation of the socket shield is one of the keys to treatment success. However, it is technically challenging. During preparation of the socket shield, the root apex should be completely removed to minimize the possibility of endodontic infection. Determining which direction or plane to cut the root and how deep to cut is a difficult and time-consuming process due to limited access and visibility in the root's apical region. To the best of the author's knowledge, this is the first case report using a dynamic navigation system to aid in preparation of a socket shield. The application of such a system enables the visualization of the root structure, the surrounding bone, and the cutting instruments in real-time. Therefore, preparation of the socket shield can be performed in a precise and timely manner.

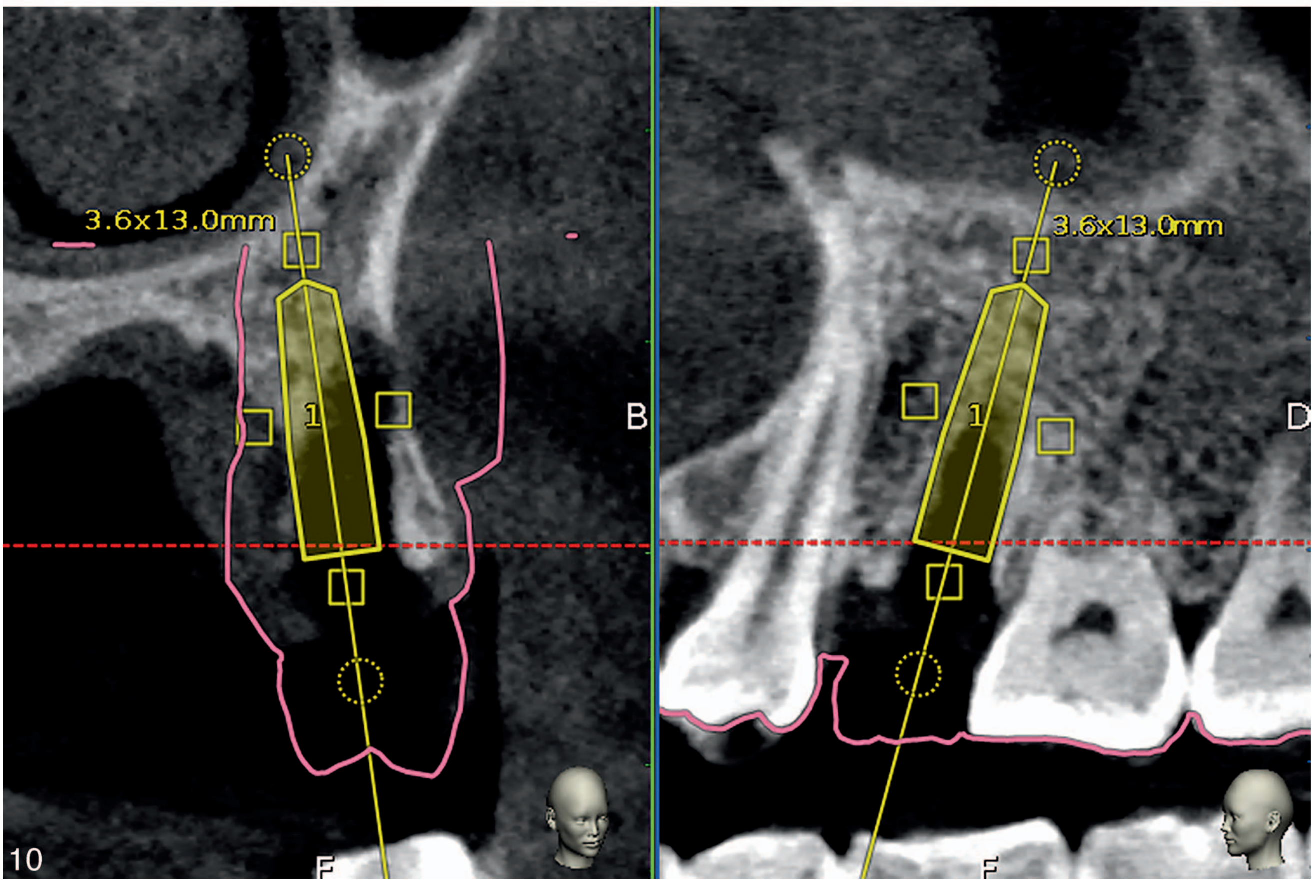
The emergence profile of the provisional restoration was shaped according to Su's critical zone and subcritical zone concept (Figure 15).[13] The critical zone contour of the provisional restoration should properly support the free gingival margin, while the subcritical zone was prepared in a concaved shape to allow enough space for soft tissue ingrowth and complete coverage of the socket shield. There is currently no consensus on how much space is needed, but in the author's experience, at least 1.5 ~ 2 mm of distance between the socket shield and the restoration is needed to avoid internal exposures.[10]

The current case report used a new registration method named "Trace registration" (commercially known as "Trace and Place") (Navident, ClaroNav Inc, Toronto, Canada). Conventionally, to register a patient's physical jaw structures to its on-screen representation, that is, the CBCT scan, the patient would need to take a special CBCT scan with a custom-made stent attached to a radiographic marker known as a fiducial marker. The Trace and Place method, on the other hand, uses a patient's existing structures (such as tooth crowns or abutments) as landmarks to register the Jaw Tracker and the patient's anatomical structures to the CBCT scan images in the software.

This new registration method has several advantages over the conventional fiducial method:

- Eliminating the fabrication of a custom stent reduces treatment time and cost.

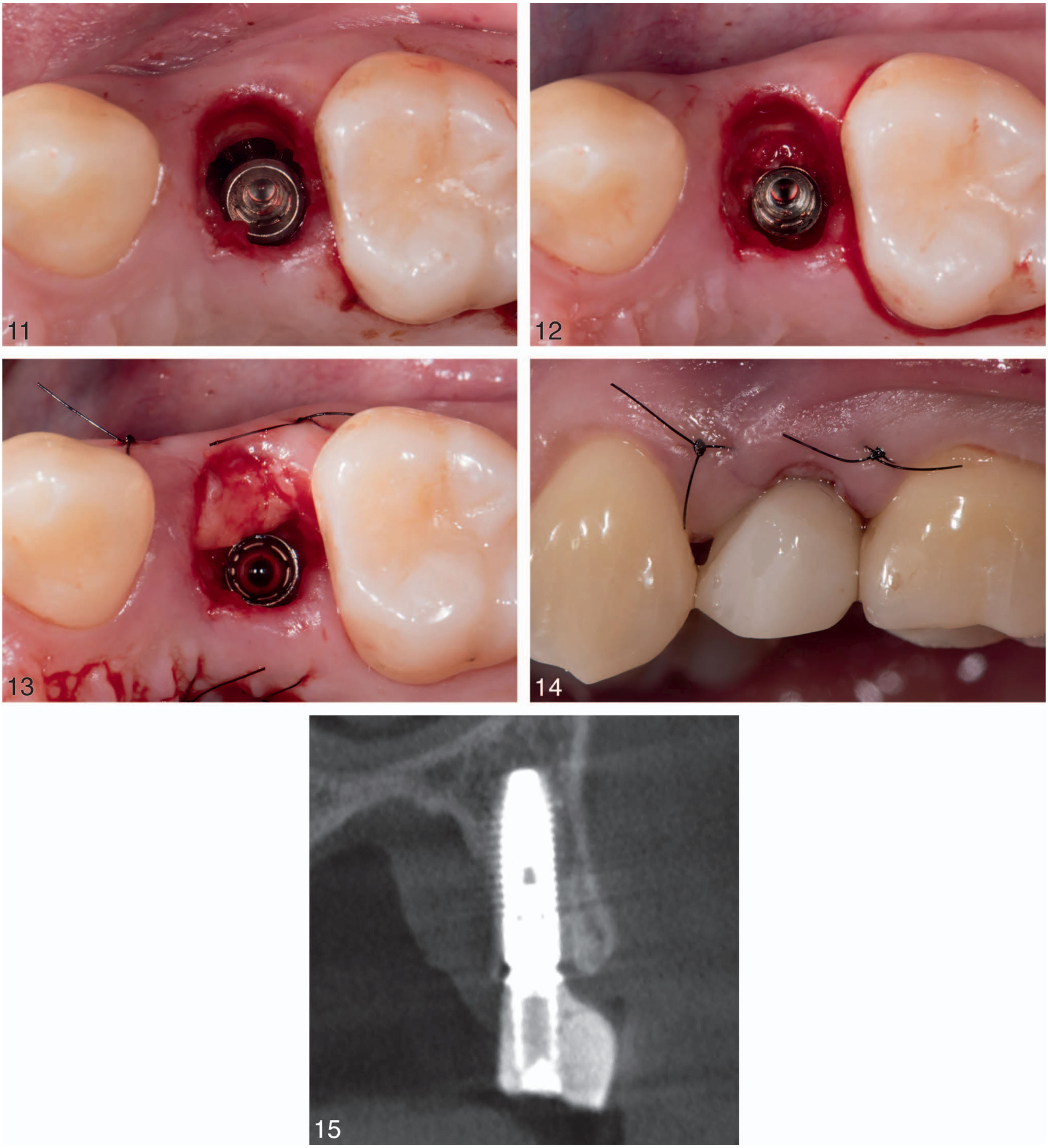




Figures 8–10. Figure 8. The initial osteotomy was prepared according to the planned position, and a mesiodistal cut was performed to separate the buccal and lingual portions of the root. **Figure 9.** A C-shaped socket shield was prepared, and the coronal portion of the shield was reduced to the level of the buccal bone crest. **Figure 10.** A 3.6313 mm implant was planned on the Navident software for a screw-retained restoration.

- Avoidance of potential inaccuracy caused by removing and seating the stent during CBCT scanning and surgical procedures.
- An additional CBCT scan with fiducial markers is not needed, so patient's exposure to radiation is reduced.
- A small field-of-view CBCT scan can be used.

Stefanelli et al studied the positional and angulation accuracy using the same dynamic navigation system (Navident, ClaroNav Inc, Toronto, Canada) as that of the present study.[14] The discrepancies between the actual and planned implant positions were 0.71 (0.40) mm at the entry point and 1.00 (0.49) mm at the apex. The mean angular discrepancy was 2.26 degrees (1.62). Studies using different navigation systems also showed similar positional and angular accuracies.[15–18] These studies indicated that the dynamic navigation system had comparable accuracy to the static computer-generated surgical



Figures 11–15. Figure 11. A 3.6 × 13 mm was placed in a proper 3-dimensional position. Note the gap between the implant and the socket shield. **Figure 12.** Freeze-dried bone allograft (MinerOss) was placed into the space between the implant and the socket shield. **Figure 13.** A piece of sub-epithelial connective tissue graft was harvested from the palatal area and sutured inside the facial marginal tissue to cover the socket shield. **Figure 14.** A screw-retained provisional restoration with proper emergence profile was delivered. **Figure 15.** Postoperative cone-beam computerized tomography scan image of #12. Notice the relative positions of the implant and the socket shield. The buccal emergence profile should be concaved to allow space for soft tissue ingrowth.

guides, and both these methods were more accurate than the freehand drilling method.

The dynamic navigation system has several advantages over the static surgical stents.[14–16]

- The dynamic navigation system can be used in sites with limited vertical spaces, such as the second molar sites or in patients with limited mouth-openings. Computer-generated surgical guides are more difficult to use in such scenarios

because they are bulky and the system requires longer implant drills and special instrumentations.
- The dynamic system allows for direct visualization of the surgical field, whereas the static surgical guides block direct view to the surgical sites.
- The drills and implant movements can be monitored in real-time, and accuracy can be verified throughout the procedure.
- The guide cylinders of static surgical guides have certain dimensions and may be too wide for tight mesiodistal space sites.
- It is difficult to judge bone density during the drilling process because friction between implant drills, and guide cylinders of static surgical guides interfere with tactile sensation. The dynamic navigation system provides better tactile sensation during osteotomy preparations.
- The dynamic navigation system allows for modifications of surgical plans during operations.

The dynamic navigation system allows surgery to be done on the same day as CBCT scanning. There is no need to wait for the fabrication of surgical guides. However, the dynamic navigation system has a learning curve. In the study by Stefanelli et al, one surgeon placed 231 implants, and the results showed that the last 50 implants placed were significantly more accurate than were the first 50 implants.[14] In another study by Block et al, significant improvements in placement accuracy were achieved when surgeons performed over 20 cases.[16] The system requires the operator to look at a computer screen while drilling osteotomies. This can be challenging for inexperienced users. Practices are needed to develop the necessary hand-eye coordination to operate the dynamic navigation system.

Conclusion

Within the limits of this case report, the image-guided dynamic navigation system demonstrated useful applications in the socket shield preparation and the implant placement procedures.

Abbreviations

3D: three-dimensional
CBCT: cone-beam computerized tomography
CT: computerized tomography
DICOM: digital imaging and communications in medicine
STL: standard tessellation language

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Note

The author has no conflicts of interest to declare.

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