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Original Article

A novel application of dynamic guided navigation system in immediate implant placement

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Abstract *Background/purpose:* Immediate placement in the esthetic zone has been a predictable treatment option. However, it requires the clinician to be experienced and knowledgeable about esthetic diagnosis, accurate 3-dimensional (3D) implant placement, and restoratively driven planning/placement. Therefore, this study aimed to investigate a novel workflow integrating dynamic navigation to immediate single-implant placement in the aesthetic zone.
Materials and methods: We included ten patients who required at least one implant in the esthetic area and were treated with post-extraction socket implant placement. Osteotomy and implant placement followed computer-assisted implant positioning and image-guided dynamic navigation. Treatment outcomes were implant success rates, surgical and prosthetic complications, marginal bone level (MBL), modified pink esthetic score, and white score.
Results: In the consecutive clinical cases, patients were satisfied with implant therapy's function and esthetic outcome in the esthetic zone. No other surgical or biological complications occurred, which accounts for the 100% cumulative success rate. The mean MBL was -0.76 ± 0.15 mm assessed using standardized intraoral digital periapical radiographs.
Conclusion: The novel application of a dynamic guided navigation system is a dependable clinical protocol to obtain optimal implant position/angulation and esthetics on immediate implant placement.

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Introduction

Implant dentistry constitutes a predictable treatment option in the modern dental field that is associated with favorable clinical outcomes, and has the capacity to maintain adequate function for many years.[1] A flapless extraction, immediate implant placement, and immediate provisional restoration (IIPIP) protocol of a single tooth in the esthetic zone can minimize tissue loss, reduce treatment time, and provide an optimal esthetic outcome for an implant-supported restoration.[2,3]

However, the challenge and difficulty of execution of IIPIP therapy persist.[4,5] One of the main issues with this challenging task is the anatomy of the extraction socket, especially the slope on the buccal surface of the palatal socket wall and the palatal bone volume, which challenge the dentist to place an immediate implant in an ideal position and angulation and obtain desire primary stability under the flapless procedure.[6,7] It is very critical and technique-sensitive for placing the implant in the correct angulation to recreate the ideal critical zone of provisional restorations with customized screw retained immediate provisional restorations, which leads to the preservation of the buccal-lingual dimensions of the ridge.[7,8]

The fusion of different sets of 3D imaging files (digital imaging and communications in medicine [DICOM]) and standard tessellation language (STL) files provide superimposition and 3D images of oral-facial skeleton, soft tissue, and dentition that resulted in the creation of a virtual dental patient. An integrated digital workflow provides a systematic method for evaluating all aspects of dentofacial anatomy, function, and esthetics in a more logical and interdisciplinary manner than the conventional approach.[9]

Today, the use of dynamic surgical navigation for the planning and execution of implant surgery has demonstrated improved accuracy outcomes when compared to freehand surgery.[10,11] The dynamic guided navigation system was developed to enable the real-time visualization of anatomic structures such as bone and teeth, as well as drill tips during implant surgical procedures.[12] This type of system has advantages in placing implants in a pre-planned, prosthetic-driven position and avoiding crucial anatomical structures such as the inferior alveolar nerve and the maxillary sinus. Since the system provides real-time feedback, any mal-positioning or false alignment of the drills can be immediately corrected. The related adjustments of position can be made at any time during the surgery.[13]

The purpose of this article was to describe a novel digital technique integrating the dynamic guided navigation system to facilitate IIPIP therapy in the esthetic zone. The treatment outcomes including surgical and prosthetic complications, marginal bone level (MBL), modified pink and white esthetic score (PES/WES), were investigated after 1-year definitive prosthesis delivery.

Materials and methods

Patient recruitment

A total of ten patients (three males and seven females; age range, 29 years—56 years) who required at least one implant in the esthetic area treated with post-extraction socket implant placement participated in this study (Fig. 1). The inclusion criteria for treatment were: good systemic health of the patient, maxillary anterior teeth (first premolar to first premolar), no periodontal disease or gingival recession, and no endodontic lesions with facial plate perforation or dehiscence, the presence of enough teeth in the maxillary arch to register the jaw to the navigation computer system. Patients with any general medical (American Society of Anesthesiologists, ASA, class III or IV) or psychiatric contraindications, pregnancy, local or generalized healing limitations, extraction sockets type II and III,[14] bruxism or other destructive parafunctional habits,[15] compromised soft tissue conditions at the surgical site, poor patient compliance and heavy smoking ($>$10 cigarettes/day) were excluded from the study. The study was approved by the human subject ethics board of Medicine, Tri-service General Hospital, Taipei, Taiwan and was conducted in compliance with the principles of the Declaration of Helsinki for biomedical research involving human subjects, as revised in 2013. Written informed consent was obtained from each patient prior to treatment.

The digital and dynamic navigation protocol

The dynamic navigation protocol has been previously published and consists of three steps: plan, trace and place.[12,16] All patients received a comprehensive examination before the dynamic navigation surgery. A digital intraoral optical scan (IOS) (TRIOS 3, 3Shape, Copenhagen, Denmark) was taken to obtain a virtual cast an STL file. A cone-beam computed tomography (CBCT) scan (ProMax 3D, Planmeca, Helsinki, Finland) was also performed for future planning of implant placement. Facial profiles and intraoral photographs of the patient were taken to provide information for proper esthetic morphology of prosthetic by a dental laboratory technician. Optimal esthetic parameters were applied when digital planning and designing virtual diagnostic wax-up (Fig. 2). Such prosthetic design

Figure 1 Pretreatment situation with fractured maxillary right central incisor. A, frontal view. B, Occlusal view.

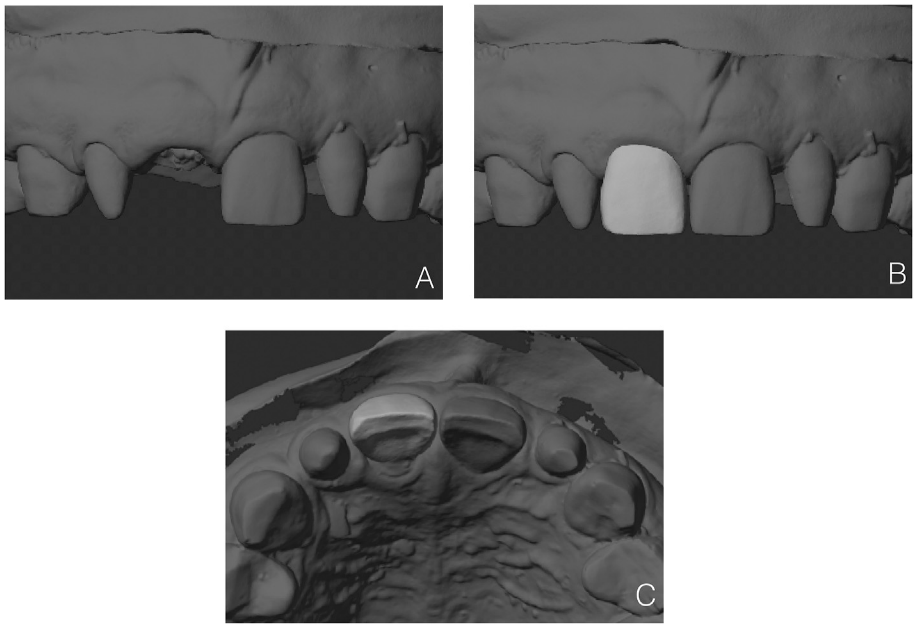

Figure 2 A, Frontal view of initial standard tessellation language (STL) file from intraoral digital scan. B, Frontal view of modified STL file with virtual prosthesis. C, Occlusal view of modified STL file with virtual prosthesis.

allowed the precise positioning of the temporary crown onto the recipient site in the digitally planned position. The STL file of virtual wax-up was generated for further use to implant planning and produce a personalized interim restoration. The DICOM file and the designed STL file were uploaded into the dynamic navigation system (Navident 2.0, ClaroNav Technology Inc., Toronto, Canada) and files were superimposed for carrying out the treatment plan of implant placement.

By utilizing the software of the navigation system, an accurate image of the bone teeth, root and soft tissue can be obtained and analyzed. A virtual implant can be simulated positioned based on the ideal biological and prosthetic parameters (Fig. 3). Planning of the position 3 mm apically from the gingival margin for the optimal esthetics of the future prosthesis. To engage the pilot drill to the socket slope in the correct position, a virtual pilot osteotomy, that is 1 mm in diameter, was then planned from the border of the buccal gingiva perpendicular to the buccal surface of the palatal socket wall (Fig. 4). This drill tip is positioned at the center of the further drill. To accurately guide the drilling process the software registered the patient's physical jaw structures with the patient's CBCT image using optical tracking tags. Following registration, the drill tip is calibrated to the software using a calibration tool. With this technology, real-time feedback and guidance are provided to the surgeon on the computer's screen. In addition, the position and direction of the drill, in relation to the virtually planned osteotomy, are integrated into a single crosshair.

Surgical protocol

All patients were premedicated prior to surgery with either amoxicillin (2 g, 1 h before implant surgery) or clindamycin (600 mg, 1 h prior to surgery) if the patient had a penicillin allergy. Each patient rinsed with 0.2% chlorhexidine mouthwash for 1 min prior to the implantation procedure. Profound local anesthesia was achieved by infiltration using articaine with epinephrine (1:100,000). Proceeding with the implant placement surgery, the non-restorable tooth was extracted following an atraumatic approach (Benex Pro extraction kit, Salvin Dental Specialtie, Charlotte, NC, USA) under local infiltration anesthesia to reduce the potential post-extraction fracture of buccal bone (Fig. 5). The extraction socket was debrided thoroughly, and osteotomy was initiated in the palatal bone of the socket following the procedures.

A long, 2-mm diameter diamond round bur was placed on a handpiece and calibrated. The round bur was used to only to sink 2-mm deep into the bone to create a ledge following the first virtual planned osteotomy. Once the round bur reached the planned position, a Lindeman bur was calibrated and used to perform a further osteotomy. The drill angulation was first performed following the first planned osteotomy. Once the bur tip approached the center of the virtual implant, the insertion angle of the drill was gradually adjected to fit the axis of the virtual planned implant. The drills were calibrated through each step of the osteotomy to ensure the accuracy of implant position and the sequences were carried out according to the manufacturer's instructions.

The implant (RSX, BEGO Semados, Cologne, Germany) was also calibrated before placing it into the osteotomy site, and primary stability was achieved (>25 Ncm). After implant placement, the engaged polyetheretherketone (PEEK) temporary abutment (Provisional abutment, BEGO Semados) was connected. Polymethylmethacrylate (PMMA) (Super T, AMCO International, Conshohocken, PA, USA) was utilized to connect the abutment with a pre-fabricated root form the PMMA shell to maintain the soft tissue contour around the extraction socket (Fig. 6). The temporary

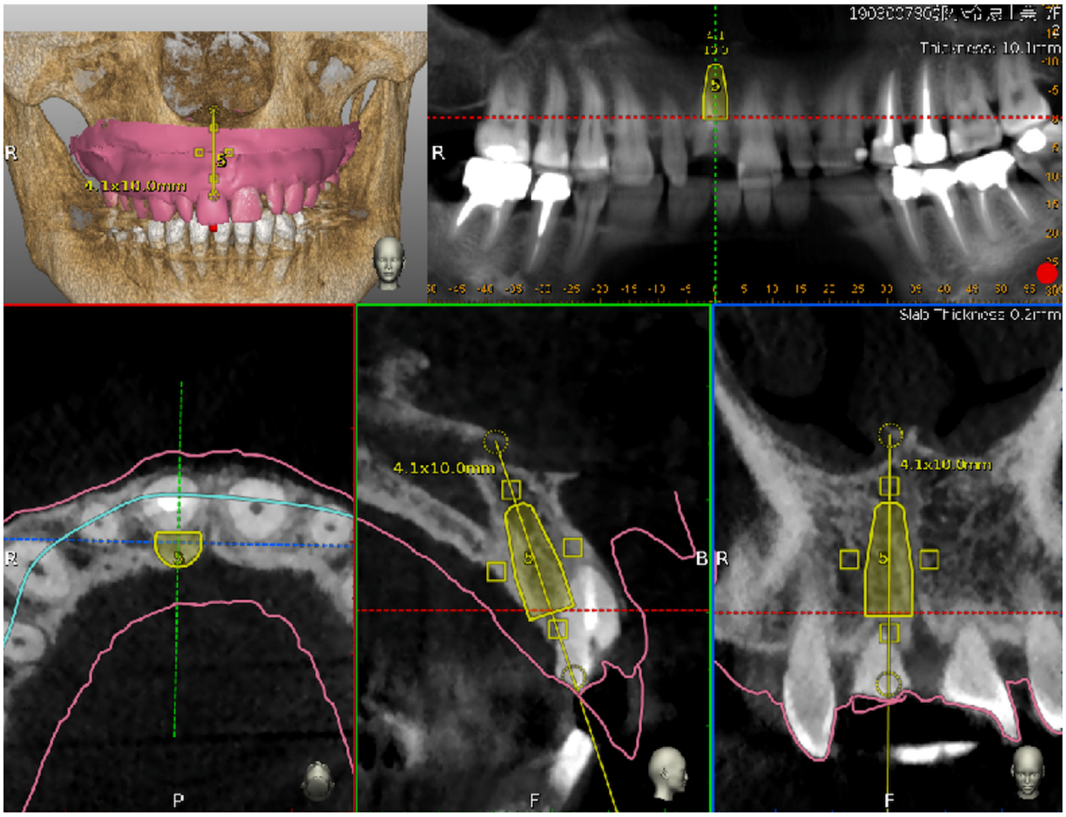

Figure 3 Virtual implant planning (yellow object) based on the biologic and prosthetic parameters.

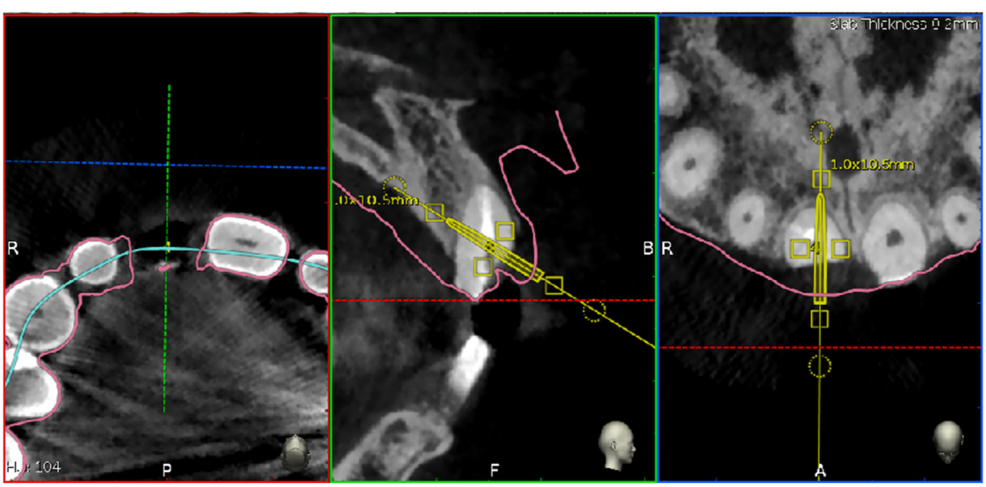

Figure 4 Virtual osteotomy planning (yellow object) for the position and angulation of 1 mm diameter pilot drill.

abutment was then disconnected from the implant, and the emergence profile of the abutments was adjusted and polished to ensure that the facial tissue and the papillae were properly supported.[17] The xenograft bone substitute material (Bio-Oss, Geistlich, Wolhusen, Switzerland) was filled into the gap between the implant and the buccal cortical bone and all the way to the free gingival margin. The screw-retained provisional customized healing abutment was screwed into the implant and helped protect the blood clot as well as any graft particles that were placed. After surgery, each patient rinsed with 0.2% chlorhexidine mouthwash for 1 min twice a day for one week. Patients were instructed to use ibuprofen (600 mg, bid to qid as needed) or paracetamol (1 g) for those who were allergic to nonsteroidal anti-inflammatory drugs (see Fig. 7).

Follow-up visits were scheduled at one week, two weeks, and four months after implant insertion and up to 1 year after definitive prosthesis placement (Fig. 8). Custom abutment and all-ceramic crowns were fabricated and delivered approximately five months after implant placement.

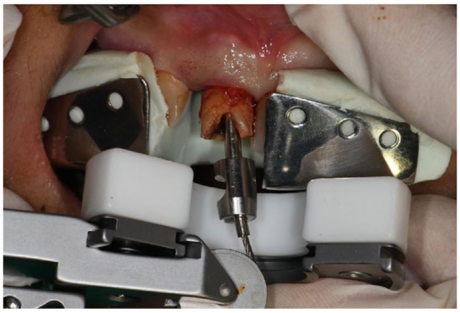

Figure 5 Residual tooth was extracted by an atraumatic approach.

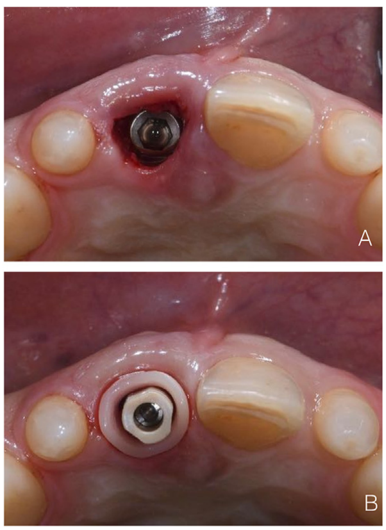

Figure 6 A, Occlusal view after implant placement. B, Prefabricated root form shell was seated over the polyetheretherketone (PEEK) temporary cylinder.

Outcomes

MBL were assessed using standardized intraoral digital periapical radiographs with the parallel technique by means of a periapical radiograph with a dedicated holder, at implant placement (baseline) and after one year from the definitive prosthesis delivery. The distance between the outer edge of the implant platform and the first bone-to-implant contact points were measured on both mesial and distal surfaces of the implant. Either positive or negative measurement depends on whether the bone level was above/coronal or below/apical to the implant platform, respectively. The esthetic evaluation was assessed using the modified pink esthetic score and white esthetic score (PES/WES) as described previously.[18] Evaluation was carried out one year after definitive prosthesis placement. To reduce bias and ensure optimum reproducibility, the evaluation was carried out twice on different days. In the few cases of diverging scores (total score PES/WES score difference >2), consensus was reached through discussions. In the case of a disagreement, the lower of the two scores was used.

Figure 7 Healing was uneventful one-week post-treatment. A, Frontal view. B, Occlusal view.

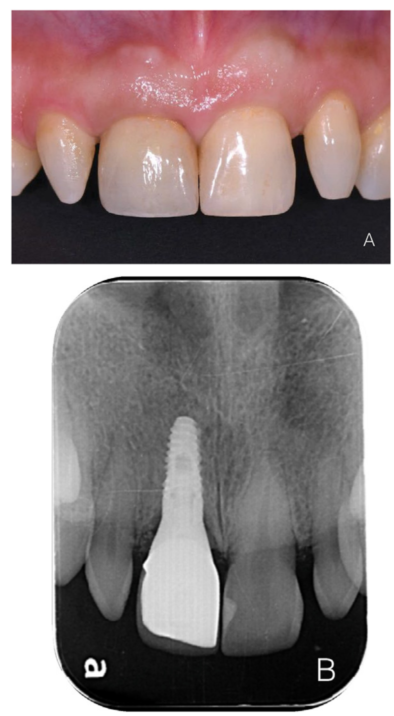

Figure 8 Definitive restoration delivery at 12 months after implant surgery. A, Frontal view. B, Periapical film.

Results

A total ten patients participated in the study by undergoing surgery and being followed up for at least one year after the definitive prosthesis placement. A total of 10 implants were placed and evaluated using dynamic navigation with a flapless approach. The osteotomy procedure was in progress smoothly under dynamic navigation. It had a significant advantage in accuracy drilling and reduced the time for the surgery following this protocol. All patients showed satisfaction toward the esthetics and function of the therapeutic implants. No implant failed, and biological or mechanical complications occurred during the follow-up, accounting for a cumulative success rate of 100%. The cumulative mean MBL between implant placement and the 1-year follow-up was -0.76 ± 0.15 mm (-1.23 to -0.04 mm). Using PES and WHE for esthetic evaluation, the median values of total PES/WES, PES, and WES at 1-year recall were 17 (range: 15—19), 8 (range: 7—9), and 8 (range: 7—10), respectively. The median total PES/WES had an overall score $\geq$12, where a score of 12 was set as the threshold for clinical acceptability.

Discussion

This digital-dynamic navigation technique ensures an IIPIP in the proper angulation, which is determined according to the future prosthesis with the consideration of bucco-lingual, apico-coronal, and mesio-distal positions. The definitive restoration was well integrated and in harmony with the surrounding tissue at one year after which it showed satisfactory PES/WES.

Computer-assisted guidance for implant positioning included static and dynamic systems. Several clinical trials showed that fully guided surgery offers the highest accuracy in the transmission of the implant positioning from the pre-surgical planning to the patient.[11,19] Static guided surgery was synonymous with a predetermined implant position without real-time visualization of the implant site preparation. Guidance was achieved by means of a computer-aided design/computer-aided manufacturing template, with metal sleeves and coordinated surgical instrumentation.[20] The dynamic guided navigation system has several advantages over the static surgical stents or the freehand drilling methods.[10,21,22] The dynamic navigation system can be used in sites with limited vertical spaces and allows for the direct visualization of the surgical field, whereas the static surgical guides block the direct view to the surgical sites. The drills and implant movements, which can be monitored in real-time, provide better tactile sensation during osteotomy preparations with the dynamic guided navigation system, allowing the adjustment of the drill axis angle from the first drill to the virtual implant. Furthermore, optimal implant positioning through prosthetically driven decision-making was mandatory to achieve function and satisfactory esthetics in IIPIP.[23]

The mean MBL between implant placement and the last follow-up was -0.76 ± 0.15 mm. This favorable bone resorption was in accordance with previously published studies assessing the radiological outcome of IIPIP in the esthetic zone and followed up to one year in post-extractive sites.[24,25] Pozzi et al. reported a mean MBL of -0.57 ± 0.25 mm in immediately loaded post-extractive implants after one year of function.[25] With proper case selection and the digital-dynamic protocol, the IIPIP insertion did not affect the peri-implant bone remodeling of the fresh extraction sockets within the investigated follow-up.

When placing an implant in an esthetic zone, the criteria for successful immediate implant placement are not only to ensure a high implant survival rate, but also to provide long-lasting and stable esthetic outcomes. Recently, it is recommended to place a bone graft and provisional restoration at the time of flapless post-extraction socket implant placement, which results in the smallest amount of ridge contour change.[2]

In the present study, the overall digital navigation-guided protocol with bone graft and provisional restoration for immediate implant placement may be directly connected to the favorable soft tissue and esthetic outcomes (median value of PES/WES = 17). These finding are in line with previously published evidence on the positive influence of IIPIP restoration on the aesthetic outcome.[25,26] In addition, the digital technique also allows experts to set the optimal provisional restoration form combining the DICOM data from the emergence profile and the mouth impression for the coronal part the copies the shape of the natural tooth before surgery.[27] The customized provisional restoration following the critical contour zone concepts maintained the existing soft tissue architecture that influenced the esthetic appearance of the peri-implant soft tissue.[28,29] Based on the reported outcomes, this novel approach integrating dynamic navigation surgery and digital technology can be used to optimize the efficacy and safety of IIPIP implant placement, and minimize the negative impact of the prosthesis in the esthetic zone.

Declaration of competing interest

The authors have no conflicts of interest relevant to this study.

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