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DENTAL TECHNIQUE

Dynamic and static computer-guided surgery using the double-factor technique for completely edentulous patients: A dental technique

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ABSTRACT

A novel computer-assisted surgery (CAS) technique that merges dynamic and static CAS approaches to treat completely edentulous patients with dental implants is described. Radiographic and surgical stents are designed with specific fiducial markers that are recognized by the static and dynamic CAS software program. During the surgical procedure, implants are placed following the static surgical guide and the indications from the dynamic navigation system. This technique combines the advantages of static and dynamic CAS approaches to allow accurate and predictable minimally invasive implant placement. (J Prosthet Dent 2021;■:■-■)

Dental implants are a predictable option for treating completely edentulous patients with a high survival and success rate.[1] Nevertheless, these rehabilitations are associated with biologic and mechanical complications, and although such problems might not affect dental implant survival, they could result in numerous repair and maintenance appointments.[2]

To reduce the frequency of biologic or mechanical complications, placing dental implants in a prosthetically driven manner is considered the optimal approach.[3-5] It is necessary to ensure accurate preoperative assessment of the available bone and the intended implant position according to the definitive restoration.

Computer-assisted surgery (CAS) aims to reduce the deviations between presurgical planning and definitive implant position. Two CAS approaches have been developed for dental implant placement: static CAS, based on surgical guides that reproduce the virtual implant position, and dynamic CAS (also known as navigation systems), consisting of a tracking system that guides the clinician in real time to the predefined implant position. With static CAS, a rigid stent with sleeves is used to guide drilling and implant insertion to the planned positions, whereas with the dynamic CAS approach, the implant is placed as in a freehand approach but guided to the planned position with real time feedback of the relative position of the drill and the patient's jaw from a computer program.[6,7]

CAS is widely used for dental implant placement, especially static CAS.[8-11] Nonetheless, poorer accuracy has been reported for static CAS when comparing completely versus partially edentulous patients, particularly when using bone-supported surgical guides, which yield the poorest outcomes.[9]

Although the literature on dynamic CAS has increased in recent years, it remains scarce, particularly in reference to completely edentulous patients.[12,13] Limitations arise in the use of dynamic CAS in these patients because of the impossibility of positioning the

Carmen Pomares-Puig owns the intellectual property rights of the double-factor technique.

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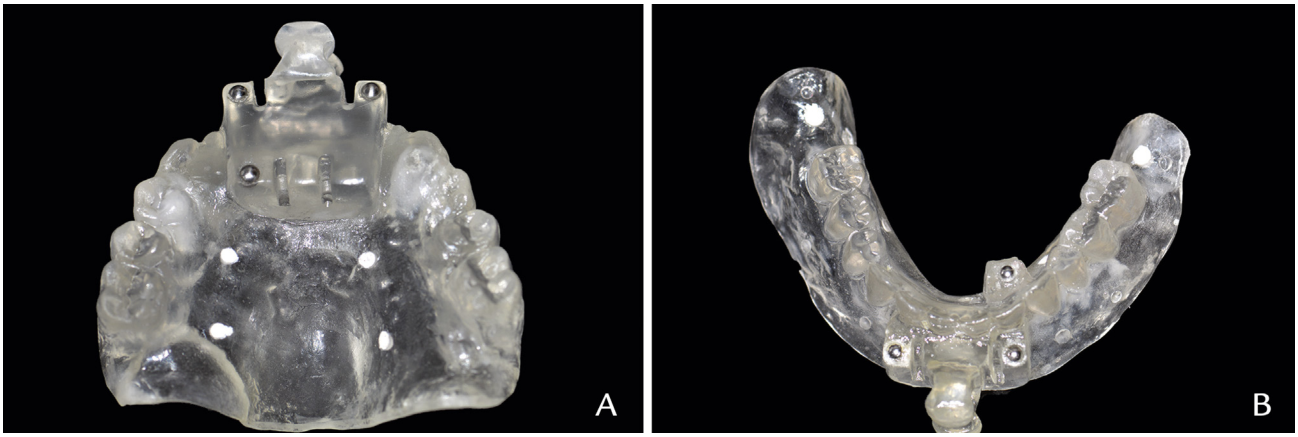

Figure 1. Radiographic stent (CP-Stent-R) with required tooth positions and fiducial radiopaque spheres and markers. A, Maxillary. B, Mandibular.

optical and radiographic markers required by the navigation systems on the patient's jaw. To overcome this limitation, dynamic CAS protocols for completely edentulous patients use bone-fixed devices to place these markers. Such protocols are invasive, however, and require the clinician to perform cone beam computed tomography (CBCT) scans and surgery on the same day and location because the bone-supported device cannot be removed until the implants are placed.[13]

Contemporary navigation systems have improved the protocol for completely edentulous patients, offering novel tracing techniques that use miniscrews placed in the jaw as fiducial markers. Before surgery, the miniscrews are traced with a specific device to register the patient's jaw.[14-17] The optical marker needs to be placed with a head-mounted device or intraoral miniscrews. Although this approach remains invasive, it overcomes some limitations of the traditional protocols. However, the evidence on the accuracy of these protocols is scarce.[14-16] Recently, novel protocols have been proposed, directly tracing the bone anatomy from the CBCT scan as a fiducial marker and avoiding the placement of miniscrews; at the present, the supporting scientific evidence is lacking.

In seeking to achieve high accuracy and predictable outcomes when treating completely edentulous patients in a minimally invasive manner and to overcome the limitations of the CAS protocols in completely edentulous patients, a novel technique referred to as the double-factor technique has been developed. This technique combines 2 factors: static CAS, using a surgical guide, and dynamic CAS, affording real-time accuracy feedback during the surgical procedure. The present report describes this novel technique and compares it with traditional dynamic or static CAS.

TECHNIQUE

1. Perform an accurate analysis of the patient with photographic records and diagnostic casts.
2. Make a digital or analog diagnostic waxing and preoperatively evaluate the waxing intraorally to confirm the position of the teeth of the definitive prosthesis and analyze esthetic and functional parameters. Once confirmed, obtain a polyvinyl siloxane (Zhermack Elite HD+; Zhermack) maxillomandibular relationship record. This record must be precise and concise because it will be used to place and stabilize the stents.
3. From the diagnostic denture waxing, design a radiographic stent (CP-Stent-R) with the information of the desired tooth positions (Fig. 1). In addition, provide specific features to make it compatible with the dynamic and static CAS systems. For the dynamic CAS system (X-Guide; X-Nav Technologies), place a clip in the anterior area to attach the optical marker with 3 radiopaque metal spheres to be recognized as fiducial markers by the navigation system. For the static CAS software, display a minimum of 4 radiopaque markers along the stent to enable the software program to overlap and recognize it.
4. Scan the patient with a CBCT scanner (ProMax 3D Mid; Planmeca) by using a dual scan protocol. Scan the patient with the CP-Stent-R in place. Remove the stent from the patient and scan it separately. Use the maxillomandibular relationship record to stabilize the stent when performing the CBCT scan and ensure that it is correctly located.
5. Import the Digital Imaging and Communications in Medicine (DICOM) data of both scans to the virtual planning software program (DTX Studio Implant; Nobel Biocare). Plan the ideal virtual implant position as per the definitive prosthesis (Fig. 2).

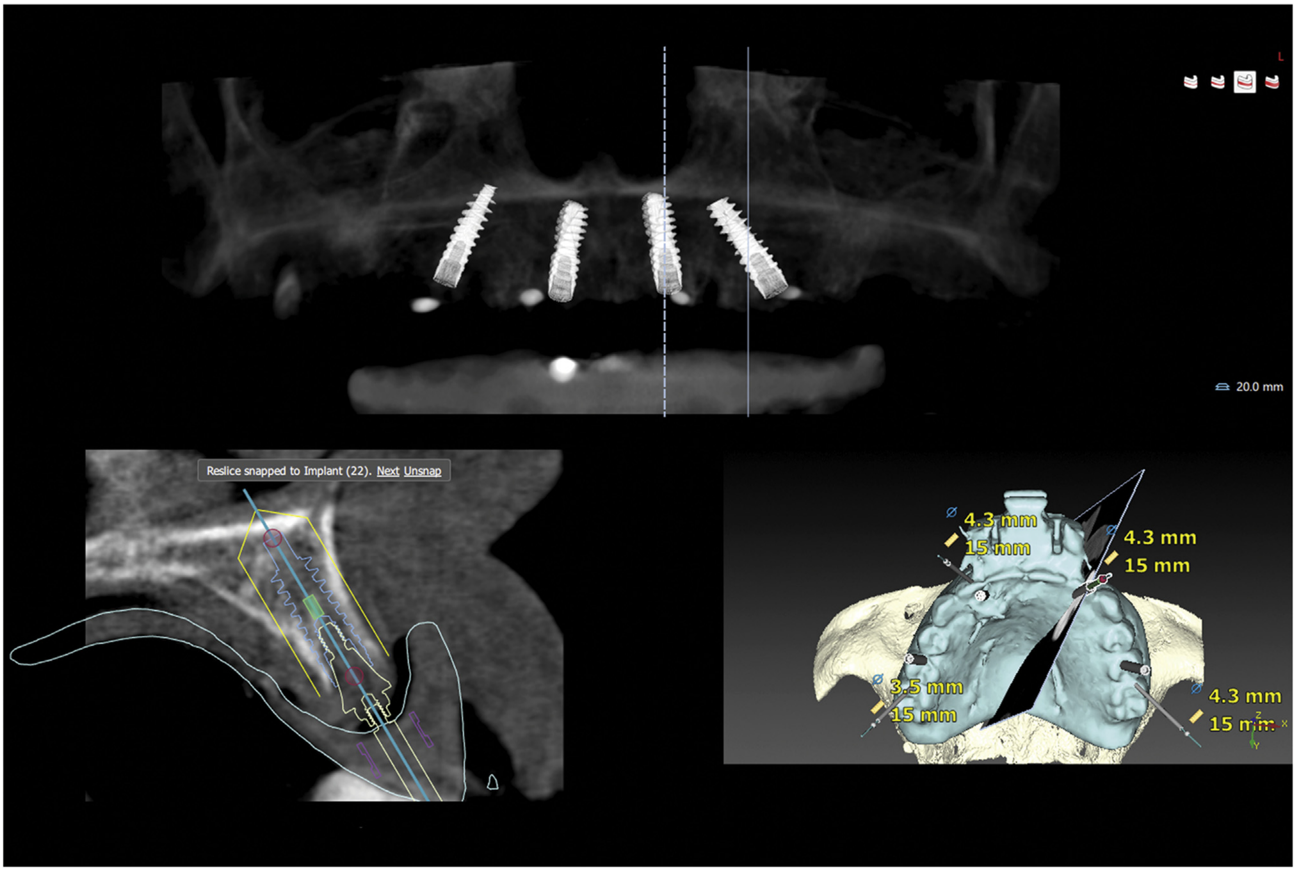

Figure 2. Virtual planning software program. Interface showing bone anatomy with required tooth positions and virtually planned dental implants.

6. Design the surgical stent (CP-Stent-S) as per the virtual positioning of the dental implants. It is essential to design the clip and the 3 radiopaque fiducial spheres in exactly the same position as in CP-Stent-R to allow the navigation system to register the fiducial markers.
7. Evaluate whether the position of the sleeves for the static CAS factor interferes with the radiopaque spheres placed in the clip for the dynamic CAS factor. If the clip does not hinder the position of the sleeves, design a 1-piece CP-Stent-S with the clip and radiopaque spheres integrated in the surgical stent (Fig. 3).
8. If 1 or more implants are planned in the same area where the clip is located, design a 2-piece CP-Stent-S (Fig. 4). Radiographic markers cannot be built in the stent because this would hinder placement of the sleeves. Design a surgical stent with the desired sleeves and the clip to attach dynamic CAS optical markers but without the radiographic fiducial spheres. Then, design a removable piece with the radiopaque fiducial spheres to be attached to the clip. This piece is referred to as "Top" and will allow the dynamic CAS to register the fiducial markers at the start of surgery. Once it is registered, it can be removed, allowing both the static and dynamic CAS to function simultaneously.
9. Obtain the standard tessellation language (STL) file of the CP-Stent-S and print it.
10. During the surgical procedure, place the CP-Stent-S in the jaw with the maxillomandibular relationship record, fixing it with pins. Evaluate the position, fit, and stability of the surgical stent and attach the navigation system optical markers to the clip (Fig. 5A). At this stage, firmly attach the top if a 2-piece CP-Stent-S is used to allow the dynamic CAS software program to register the fiducial markers and make the calibration. Check the accuracy of the navigation system after calibration.
11. Place dental implants through the surgical stent adopting a fully guided approach with real-time feedback of the drilling and implant position from the navigation system, allowing correction of the position or angulation of the implants during surgery (Fig. 5B-D).
12. If primary stability is achieved, place an immediate loaded prosthesis if indicated.

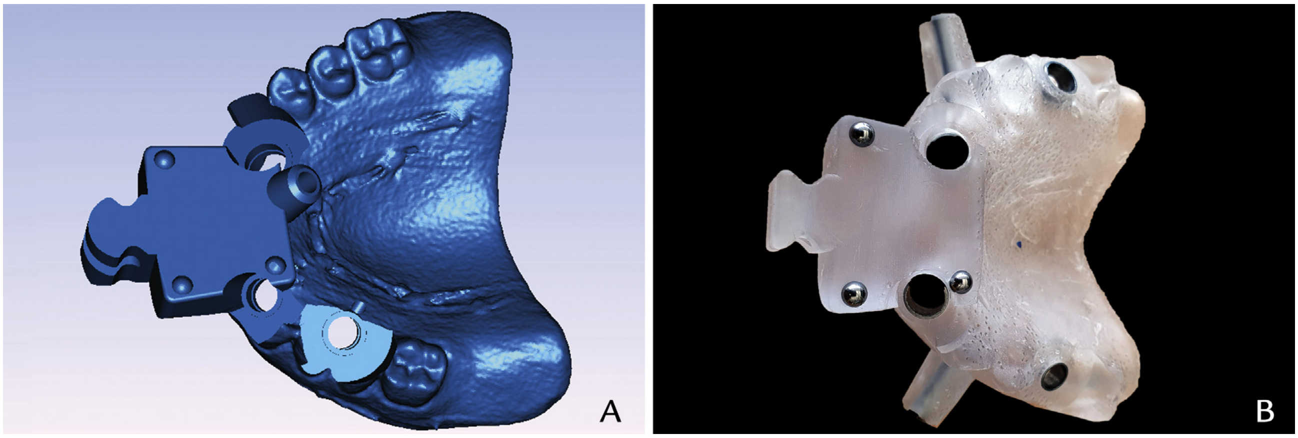

Figure 3. One-piece surgical stent (CP-Stent-S). A, Definitive laboratory design of the CP-stent-S. B, 3D-printed CP-stent-S. 3D, three-dimensional.

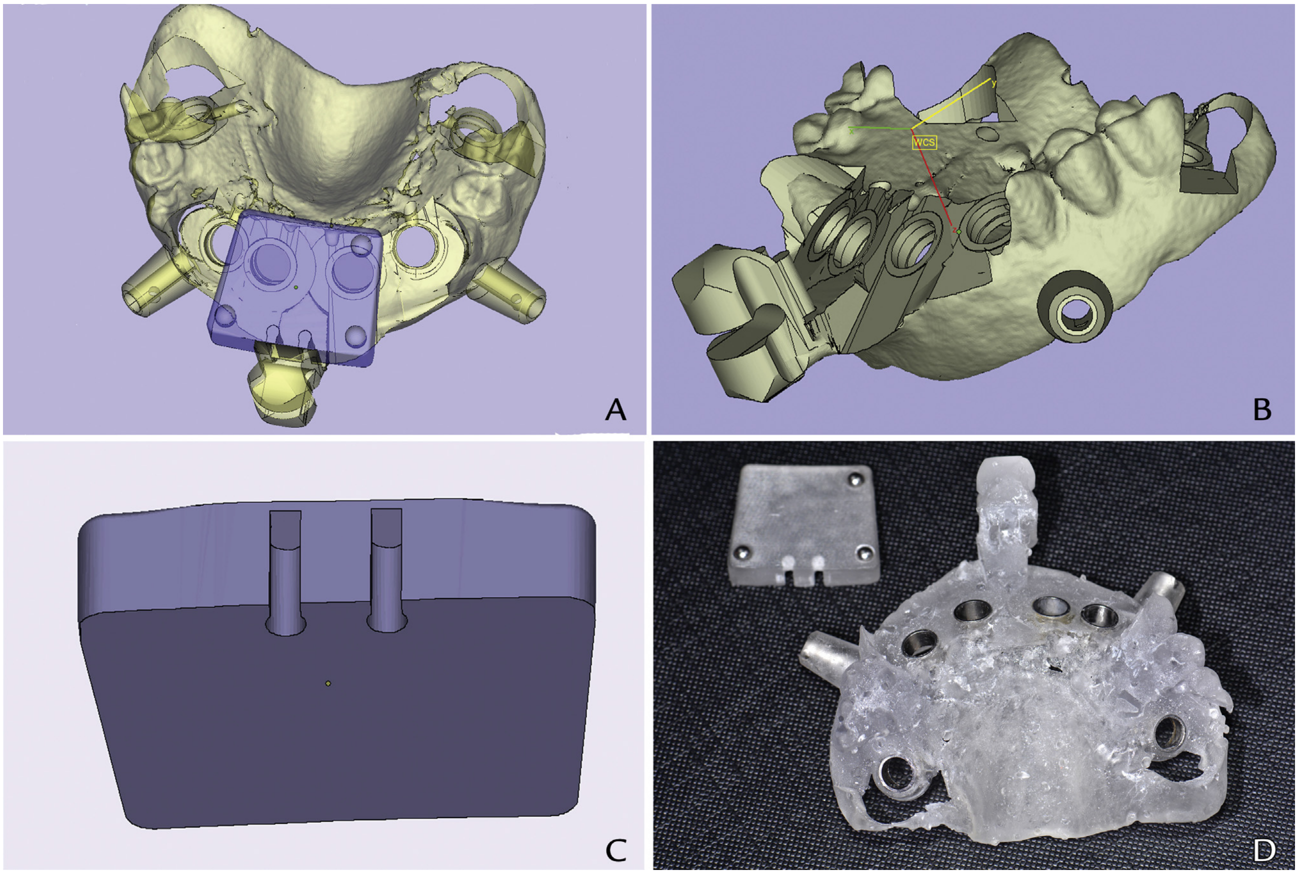

Figure 4. Two-piece surgical stent (CP-Stent-S) with top. A, Design. B, CP-Stent-S without top design. C, Top removable piece design. D, 3D printed CP-Stent-S with top. 3D, three-dimensional.

DISCUSSION

The accuracy, success, and survival rate of dental implants placed with CAS and their usefulness in clinical practice have been assessed.[13] High survival rates between 97.8% and 100% after 1 year have been reported.[10,11] Both the static and dynamic CAS approaches afford highly accurate results in replacing single teeth.[18] Nevertheless, dynamic CAS requires longer surgical times than static CAS, with an average of 3 to 8 minutes more for single implant surgery.[18] This limitation, which is not clinically relevant in partially edentulous patients, could be an important drawback in completely edentulous patients if the surgical time increases substantially.

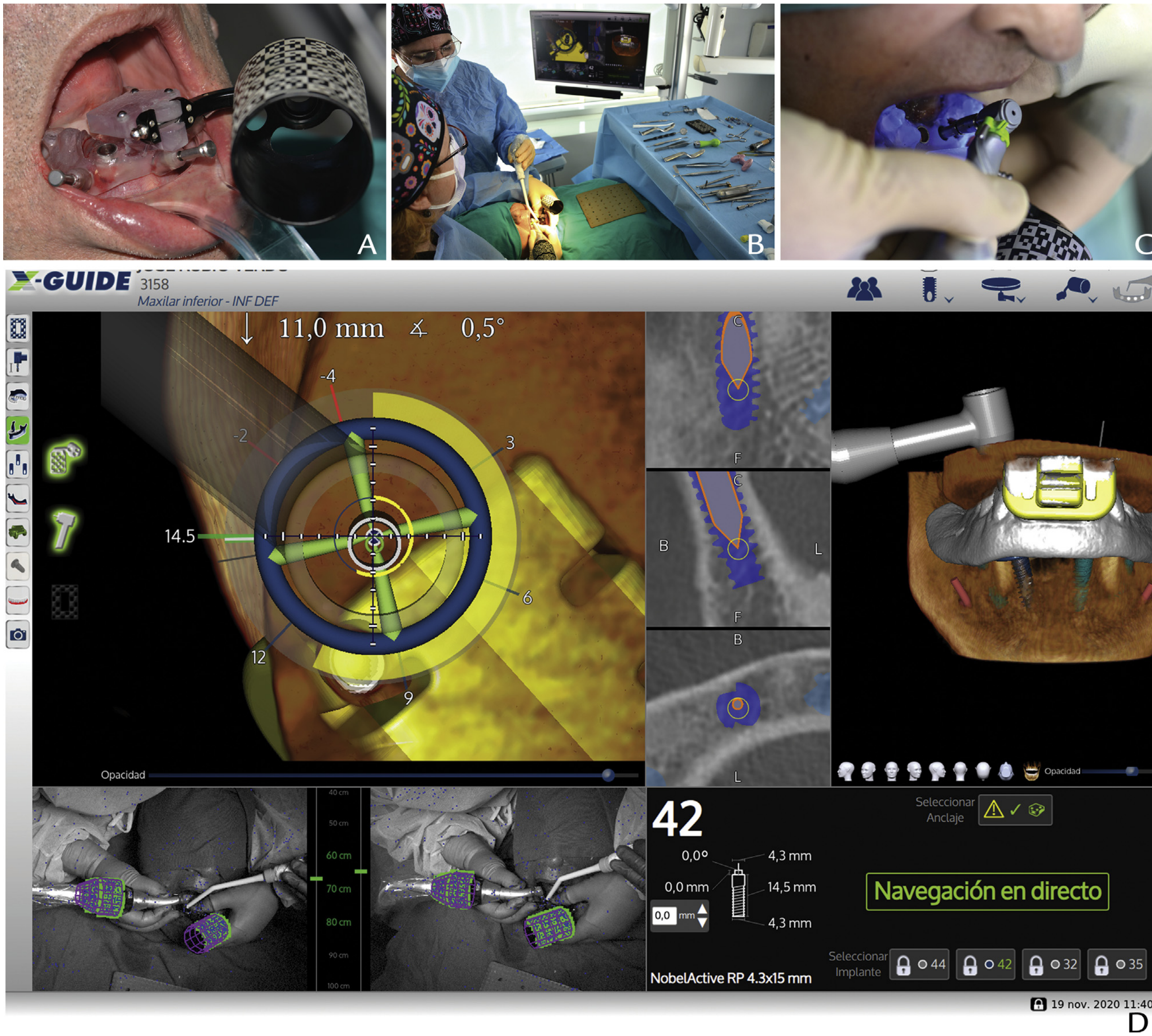

Figure 5. Surgical procedure using double-factor technique. A, Fixation of surgical stent (CP-Stent-S) and dynamic CAS system optical marker. B, C, Surgical procedures. D, Dynamic CAS software program interface during surgical procedure. CAS, computer-assisted surgery.

Sun et al[19] compared 3 guided approaches: a dynamic CAS system, a static CAS system, and the combined use of both guidance systems in the same surgery. They reported that in spite of a longer surgical time, the combination of static and dynamic CAS afforded the most accurate results: 0.98 ±0.19 mm for apex total deviation and 2.20 ±0.38 degrees for angular deviation, while static CAS yielded 1.49 ±0.08 mm and 4.54 ±0.29 degrees and dynamic CAS 1.25 ±0.09 mm and 3.24 ±0.36 degrees.

Although accurate results have been reported in completely edentulous patients, the existing studies failed to assess other variables such as patient-reported outcome measures (PROMs), surgical time, or technical complications during surgery.[13] In the authors' experience, the treatment of completely edentulous patients with the protocol proposed by the manufacturer for dynamic CAS systems is time-consuming, technically difficult, and uncomfortable for the patient, and it jeopardizes the possibility of performing minimally invasive surgery − the latter being one of the main advantages of CAS use in implantology.

The strength of the present technique is the combination of both CAS approaches, offering restrictive surgical guidance with rigid sleeves through static CAS, and real-time feedback for verification and the possibility of performing any intraoperative modifications through dynamic CAS. Hence, this approach allows shorter surgical time, highly accurate results with double guidance, easier and minimally invasive surgical procedures, a better ergonomic position for clinicians, and the possibility of placing a premade immediate loading prosthesis.

Although chair time can be reduced with this technique, clinicians will have to spend more time planning and designing the stents. Furthermore, this technique might increase costs because 2 stents must be printed, a navigation system license must be used, and specific burs for guided surgery must be acquired.

The most sensitive procedure in this technique is the placement and stabilization of the stents during all the steps. It is essential to place all the stents in the same exact position; hence, an accurate maxillomandibular relationship record must be obtained at the start and rigorously maintained. To ensure that the surgical stent is placed in the correct position, an accuracy check after fiducial marker registration and calibration is essential. Moreover, performing accuracy checks before advancing to the next steps of the surgical procedure is recommended.

This report sheds light on the combination of static and dynamic CAS to treat completely edentulous patients. However, only a few patients have been treated by using this approach. Research is required, ideally in the form of prospective clinical studies reporting accuracy and PROMs and with long-term follow-up to confirm the applicability and usefulness of this novel technique.

SUMMARY

In spite of the limited evidence, the novel double-factor technique could provide an accurate and predictable minimally invasive approach for implant placement in completely edentulous patients. This technique combines the advantages of both static and dynamic CAS to enhance the benefits of CAS in treating completely edentulous patients with implant-supported rehabilitations.

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