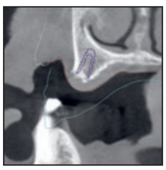
# Guided Implant Placement in Fully Edentulous Patients. The Full Retraction Protocol: Registration Technique to Improve Treatment Outcome



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*Preoperative planning and implant placement can be optimized using implant planning software followed by the creation of an individual surgical guide. Alongside clinical advantages of using guided surgery, a variability in the accuracy of implant position has been reported. This variability is even more substantial in fully edentulous patients and attributed to errors from intrinsic and extrinsic sources. The aim of this paper is to discuss the potential process errors and present two digital data registration protocols to be implemented in fully edentulous patients. The suggested protocols are aimed to improve accuracy of data acquisition, data superimposition on planning software, and therefore treatment outcome as well.*
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As life expectancy increases, so does the number of people with edentulous arches. With higher expectations for quality of life, dentures often no longer meet patient expectations. As a result, many prefer an implant-supported dental prosthesis.[1] Patient demand, compliance, dexterity, skeletal maxillo-mandibular relations, and residual bone anatomy must be considered when determining the appropriate implant position and type of prosthesis. In preoperative planning and implant placement, the use of implant planning software followed by the creation of individual surgical guides has been shown to improve treatment results.[2–8] Nevertheless, variability in the accuracy of guided implant surgery has been reported and attributed to errors from intrinsic and extrinsic sources.[9–11]

The data registration needed to compose a digital file for planning includes impressions and 3D imaging of anatomical structures[12] (computerized tomography [CT]). Transferring registered information from the patient to the software to create an accurate digital file for implant planning (calibration)[12] can be involved with processing errors. This calibration will be even more challenging in edentulous patients due to the absence of reference points, causing inaccuracies in the result (eg, final implant position).[13]

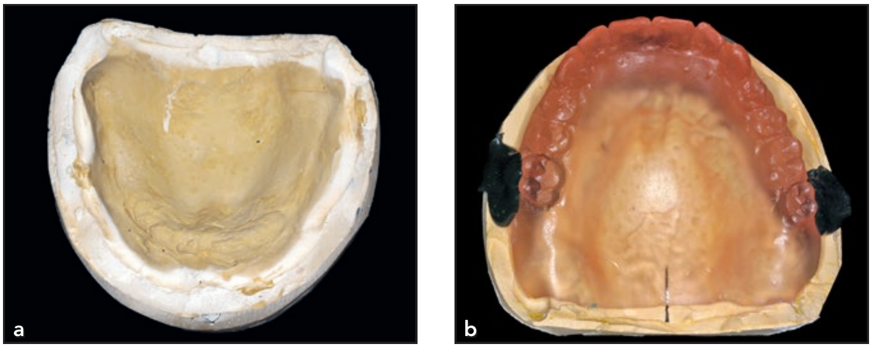

**Fig 1** *To create a proper file for case planning,* (a) *a working model and* (b) *a wax-up are required. The palate in the maxilla and the retromolar pad in the mandible are important anatomical structures to be registered. A validated wax-up is prepared and is compatible to the functional and esthetic needs of the patient.*

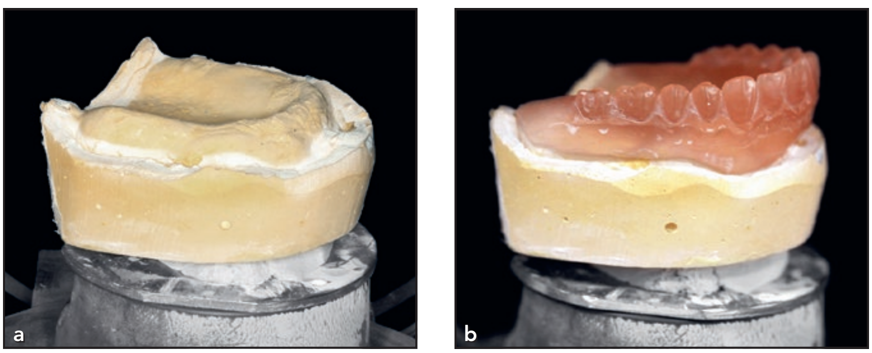

**Fig 2** *The* (a) *working model and* (b) *wax-up are scanned in a laboratory scanner. The working model carrying the wax-up is scanned to create the first STL file. Keeping the model in the same position in the scanner, the wax-up is removed, and the model is scanned alone to create the second STL. The two scans should be done in the same orientation and direction (coordinates).*

Data registration using CT withholds integral errors of hundreds of micrometers up to 1 mm,[13,14] depending on the scanning technique, parameters, machine in use,[15,16] and voxel size. When the voxel size is $0.125 \times 0.125 \times 0.125$ mm, a minimal error or resolution of the CT image is at least 0.125 mm.[17] 3D optical scanning techniques are mainly applied for dental impressions during prosthodontic and orthodontic treatment, but are also applied as a method to provide volumetric measurements of soft and hard tissues.[18,19] The scanning technique and the scanner in use will have an impact on the accuracy of intraoral scanning, but in most cases scanning resolution will be 10 to 20 mm and up to 0.1 mm. Being more accurate and minimally invasive, intraoral scanning should replace CT scanning whenever possible.

The aim of this paper is to present two alternative digital data registration protocols, replacing one CT scan (producing a DICOM file) with an intraoral scan (producing an STL [standard tessellation language] file) in fully edentulous patients. This will improve the accuracy of data acquisition, data superimposition on planning software, and therefore treatment outcome as well.

## Digital Registration Protocols

In treatment plans including implant surgery on a fully edentulous patient, the following diagnostic records should be obtained for the two protocols described.

### *Full Retraction Protocol*

#### Impressions/Intraoral Scanning

A dynamic impression of the patient is taken in the same way as for a full denture. Since the template/guide will be supported on the outline of the soft tissues in most fully edentulous cases, it is essential to register the palate in the maxilla and the retromolar pad in the mandible. A working model is created (cast or printed) (Fig 1). The working model will set the base to make a wax-up.

#### Model and Wax-up Scanning

Using a lab scanner (eg, 3Shape E4), the working model carrying the wax-up is scanned (Fig 2a). This creates the first STL file. Keeping the model in the same position in the scanner, the wax-up is removed, and

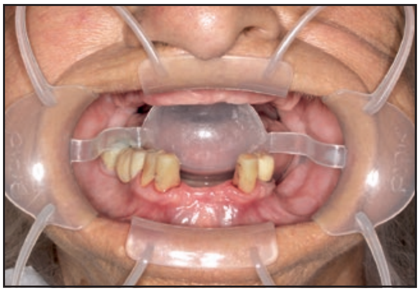

**Fig 3** *During CT scanning, the soft tissues (lips, cheeks, and tongue) are reflected from the gingiva to create an air chamber around the soft tissues. This will enable a clear visualization of the gingival outline.*

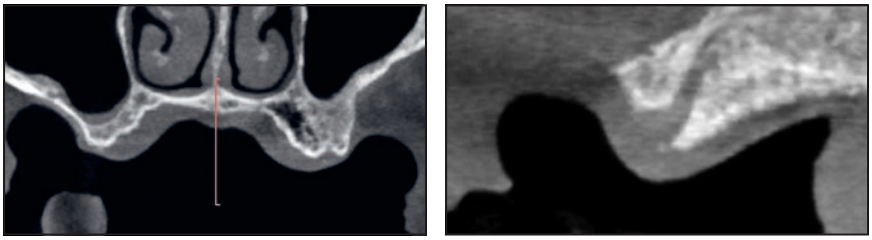

**Fig 4** *The soft tissue outline, revealed due to the contrast created by tissue separation, serves as numerous points of reference for CT and STL overlapping.*

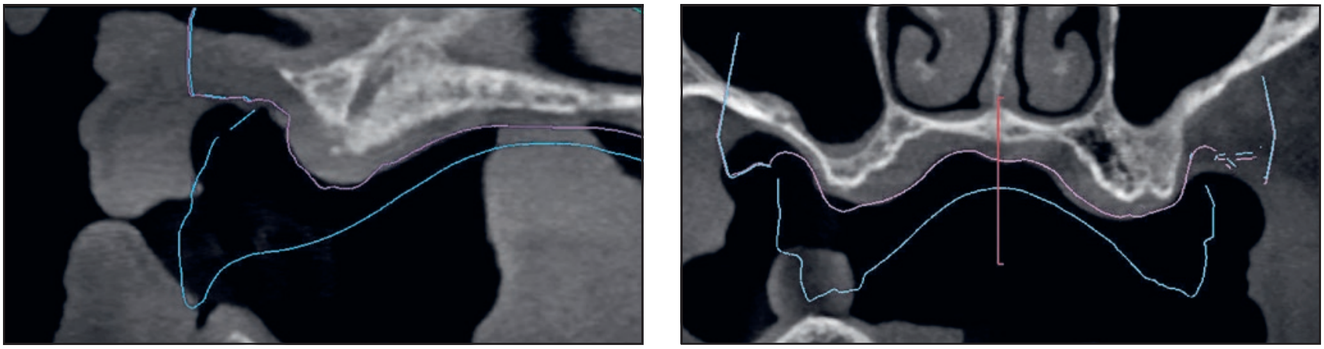

**Fig 5** *Calibration of STL files over the CT image is done by following the soft tissue outline.*

the model is scanned alone (Fig 2b) to create a second STL file. It is important not to change the position of the model in the scanner between the first and the second scans to allow an automatic calibration of the two scans (one on top of the other) when uploaded to the software (MSoft, TechMed 3D).

## CBCT Scan

The patient is then referred to CBCT scan. The CT image is presented in degrees of gray according to its Hounsfield units (HUs). HUs are defined as linear transformations of measured x-ray attenuation coefficients of a material with reference to water (0HU).[20] Air will be represented as black, measured as (–1,000) HU, and metal will be presented as white, measured as (+1,000) HU. These units can provide an accurate absolute density for the type of tissue described. In the full retraction protocol, retractors or cotton rolls are used to reflect the buccal mucosa, tongue, and lips from the gingiva during scanning (Fig 3), creating an air chamber around the soft tissues of the patient. This enables clinicians to discern and outline the borders of the soft tissues overlaying the bone (Fig 4). The soft tissue outline will be used as reference to superimpose the scanned working model and wax-up on the CT image.

## Software Data Superimposition

The DICOM files are uploaded to the software. The STLs of the scanned model and the scanned wax-up are calibrated on the CT image. In edentulous cases, there are no teeth or rigid components to serve as a reference for calibration. The soft tissue outline revealed by the contrast from tissue separation will be used as a reference for overlapping the CT and STL images (Fig 5).

At this stage, the digital file is ready for implant planning (Fig 6), considering tissue volume and the planned restoration ("top-down planning"). A surgical guide will be virtually planned according to the implant position, surgical plan, and

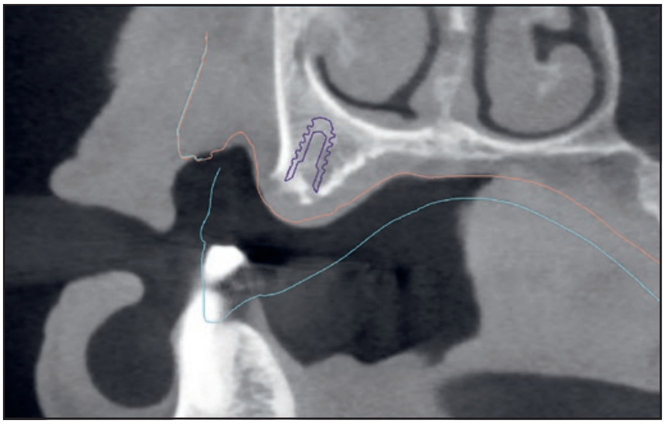

**Fig 6** *After superimposing the STLs of the impression and the wax-up on the DICOM image, the digital file is ready for implant planning, considering tissue volume and the planned restoration ("top-down planning").*

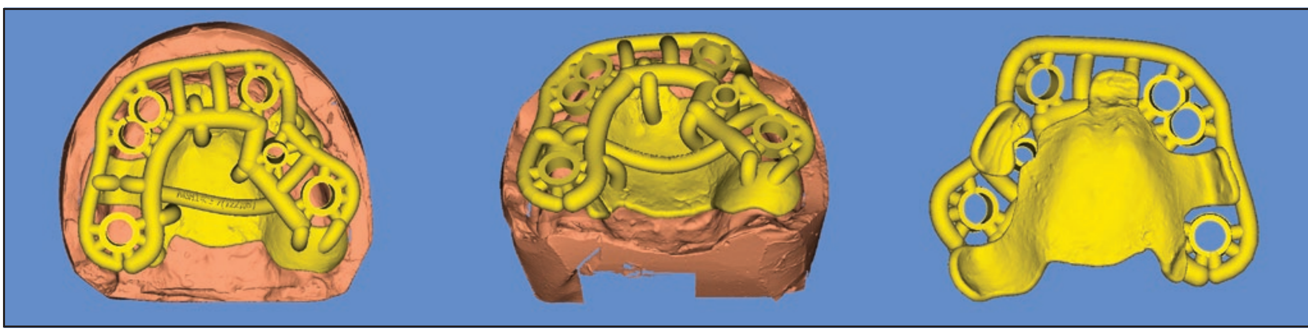

**Fig 7a** *A surgical guide will be virtually planned according to implant position, considering the need for tissue support to stabilize the guide during drilling.*

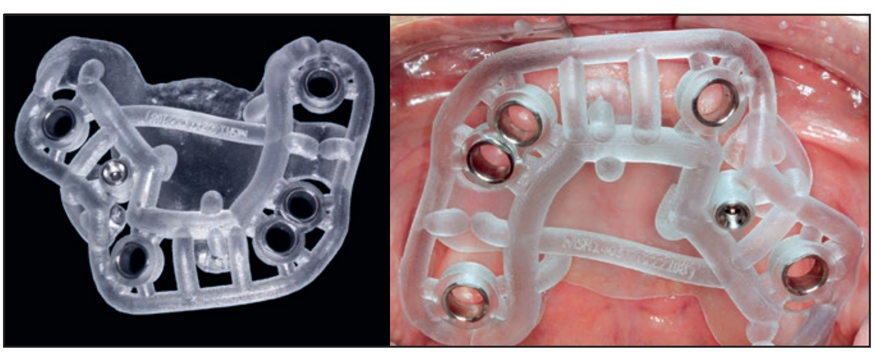

**Fig 7b** *The STL of the designed surgical guide will be 3D printed* (left), *becoming a physical instrument to be used during surgery* (right).

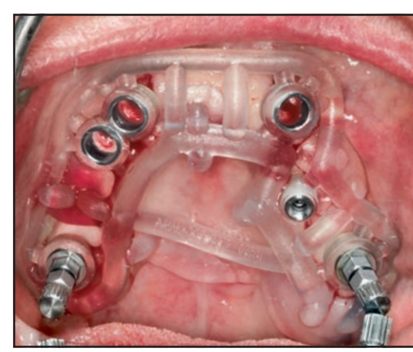

**Fig 7c** *The posterior implants were prepared and placed first. Insertion tools were used for additional guide stabilization during placement of the anterior implants.*

tissue morphology (Fig 7a). The STL of the designed surgical guide will then be 3D-printed and used during surgery (Fig 7b).

During surgery, the guide is supported by the soft tissues with hand fixation to prevent its shift during the drilling stage (Figs 7c and 7d). In the presented case (Fig 7c), after the insertion of the posterior implants using the MGuide drilling system (MIS Implants Technologies), it was used for further fixation by keeping the insertion tools in the guide during drilling of anterior implants. Correct registration of data and passive drilling will enable a predictable final implant position (Figs 7e to 7g, Table 1), compatible with previously reported results in cases of fully edentulous patients.

In cases where the patient cannot hold the retractors or cotton rolls due to physical problems, a

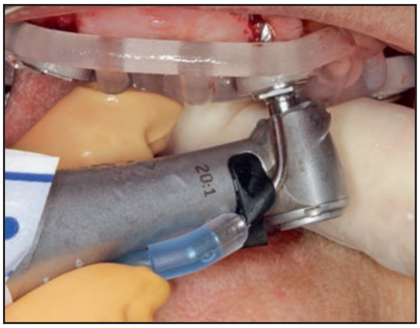


**Fig 7d** *When using tissue-supported guides, gentle hand-stabilization of the guide and passive drilling are important to prevent distortion of guide position during drilling.*

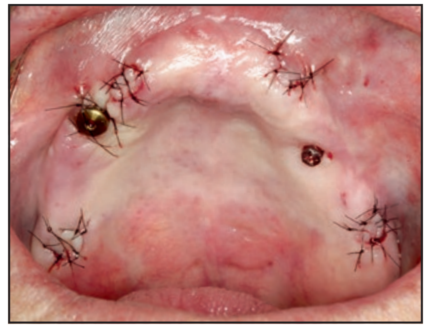

**Fig 7e** *Five implants were placed. One was intended to be immediately loaded together with an orthodontic temporary anchorage device to prevent force implementation from the denture to the submerged implants during the osseointegration period.*

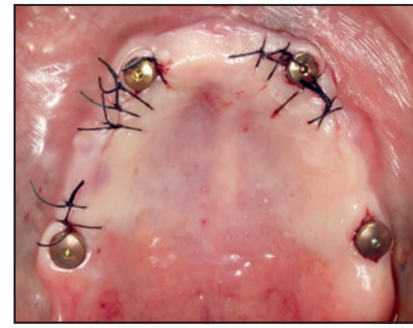

**Fig 7f** *Following 6 months of healing, the guide was used for minimally invasive access to implant heads, and healing caps were connected.*

**Fig 7g** *The patient received a mini-dose postoperative CT scan (scanning resolution of 0.4 mm, effective scanning radiation of 13 μSv). Postoperative analysis was performed, overlapping preoperative planning to postoperative implant position.*

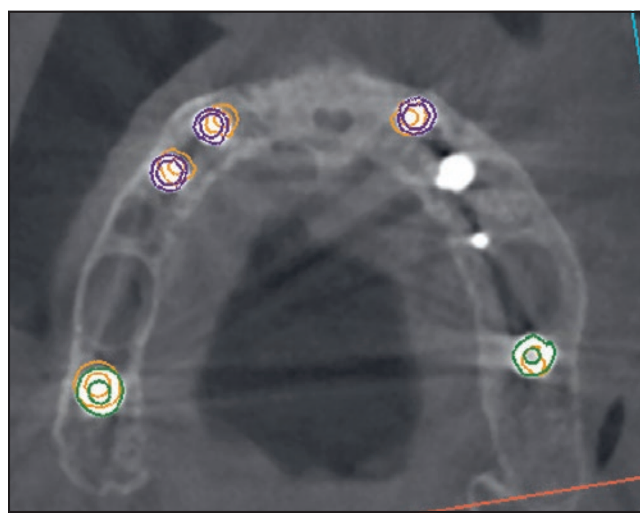

**Table 1 Deviations Between Preoperative Planned and Postoperative Implant Positions**

| Implant no. | Mesial | Distal | Buccal | Lingual | Height | Angle |
|---|---|---|---|---|---|---|
| 17 | 0.73 | | 0.45 | | 0.24 | 2.2 |
| 15 | 0.69 | | 0.05 | | 1.31 | 4.1 |
| 12 | 0.91 | | | 0.03 | 0.92 | 4.6 |
| 22 | | 0.05 | 0.19 | | 2.26 | 1.7 |
| 27 | | 0.36 | | 0.26 | 1.12 | 1.4 |

Mesial, distal, buccal, lingual, and height measurements are presented in millimeters. Angle measurements are presented in degrees. The calculations were performed using Microsoft software. Implant numbers are listed according to the FDI tooth numbering system. Despite having only partial tissue support for guide stabilization, the deviation is minimal between the planned and final implant positions.

**Fig 8** *Four or five radiopaque beads are glued to the plaster base. The base with the beads carrying the wax-up is scanned in a table scanner.*

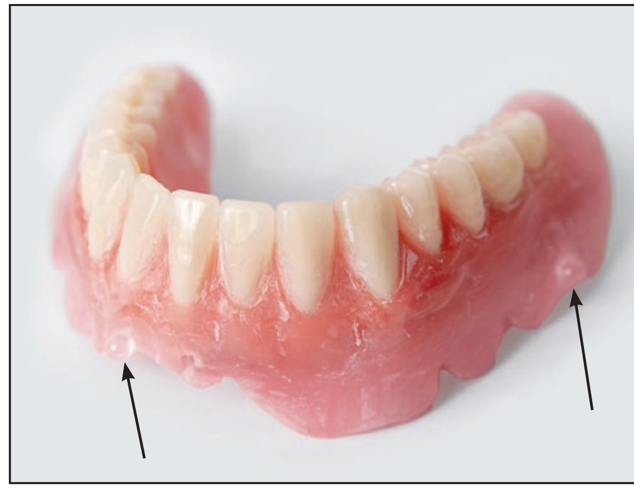

**Fig 9** *After the first scan (described in Fig 6), the radiopaque beads are integrated into the denture* (arrows). *This denture will be inserted in the patient's mouth to be used and therefore scanned during the CBCT.*

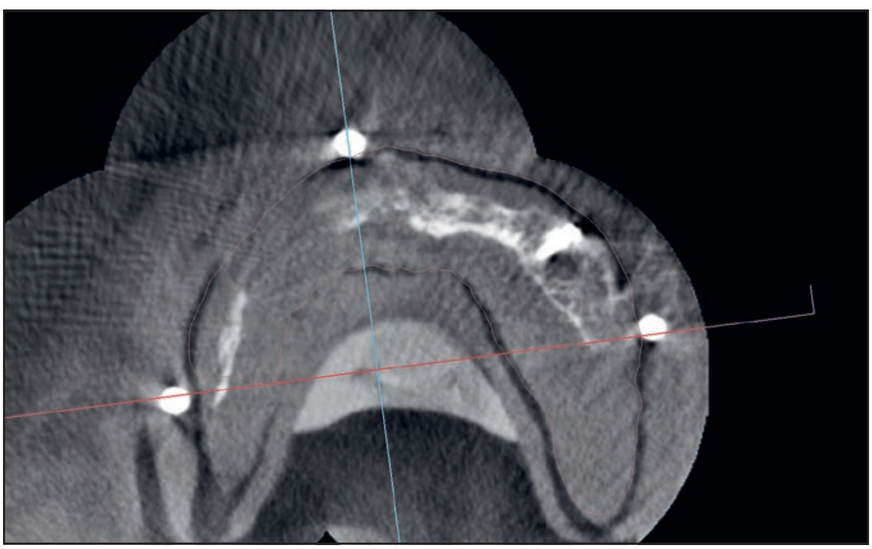

**Fig 10** *The radiopaque beads will be visible in the CT image. This will enable calibration of the wax-up and cast model STL files on the CT image.*

marked gag reflex, or a very resorbed mandible (in which the floor of the mouth is overlaying the ridge), there is a risk for inaccurate soft tissue registration in the CBCT scan. For these cases, the authors suggest the beads protocol. This protocol uses only one CBCT scan, keeping accuracy in data registration. The process is described as follows.

### *Beads Protocol (Revised Dual Scan Protocol)*

#### Impressions/Intraoral Scanning

This process is similar to the one described for the previous protocol. A working model is created (cast or printed) with three indices on the base. A wax-up is created and verified in the mouth of the patient (Fig 8).

#### Model and Wax-up Scanning

Prior to scanning, the model will be prepared by gluing four or five radiopaque markers (Fig 8), such as commercial beads with a standard size and homogenous radiopacity (Visionmark V-25 [Suremark] or custom-made gutta percha balls). Using a laboratory scanner (3Shape E4), the working model carrying the wax-up is scanned producing an STL file. Keeping the model position in the scanner, the wax-up is removed, and the model is scanned separately to create a second STL file. The flanges of the wax-up are then elongated to cover and integrate the beads out of the model and into the denture (Fig 9). This version of the wax-up is then given to the patient to wear during the CBCT scan.

### CBCT Scan

The patient wears the wax-up with the radiopaque markers during the scan. The base of the wax-up should be very well adapted to the soft tissues of the patient, creating equal pressure on the soft tissues. The acrylic material used for the radiographic stent may not be totally radiolucent, causing scatter that affects the soft tissue visualization. To improve visualization of possible calibration errors, the scan is performed the same as in the full retraction protocol (with retraction of soft tissues and the tongue, as described earlier).

### Software Data Superimposition

The DICOM files are uploaded on the software. The STLs of the scanned working model and the scanned wax-up are calibrated with the CT image. In this protocol, the calibration of the model on the CT is possible by superimposing the radiopaque markers from the CT and STL images (Fig 10).

## Discussion

Computer-guided implant surgery offers the ability to plan "top-down" implant position, maximize accuracy, take into consideration hard tissue anatomy and soft tissue volume, and identify the location of future prostheses. Guided surgery is well established to be more predictable in implant positioning than free-hand implant placement,[21] but deviations and errors can still be expected.[22] The process of data registration and superimposition of the registered information in layers in the software is essential to create a digital platform for treatment planning. Superimposing data comprises potential errors that might influence final implant position.[13]

Remaining teeth are used as compatible areas for matching images produced by the scanners (CBCT and table scanner) to create a digital file for planning.[13,23]

When the remaining teeth are insufficient or absent (as in fully edentulous cases), the accuracy of image superimposition decreases dramatically. In patients with extensive tooth loss, the use of additional markers attempts to increase the accuracy in matching CBCT and digital surface scan images.[24,25] The most frequent protocol for data registration and calibration in fully edentulous patients is the dual scan protocol suggested by Verstreken et al[26] followed by van Steenberghe et al.[27] This protocol is based on superimpositioning two DICOM files: one of the patient wearing a denture with integrated radiopaque markers and the second of the denture only. Radiopaque markers used for calibration may create a scattered image on the CT, casting doubt on the ability to perform a precise match. Over the years, other protocols were introduced. Oh et al[28] suggested inserting additional resin markers on the palatal gingiva prior to CBCT scanning, increasing the matching points and thereby enhancing the registration accuracy of CBCT and digital surface scan data. Widmann et al[25] demonstrated the use of implants with ball attachments to increase the number of reference points for image superimposition in edentulous arches and concluded that a fixed reference improves registration accuracy.

The full retraction protocol presented is a nonsurgical, inexpensive, and easily applicable protocol to improve accuracy in data registration. Data superimposition is based on the visualization of the soft tissues, creating numerous reference points for image matching. This protocol reduces the use of CT scans and DICOM data. Additional information of the prosthetic wax-up is registered using an STL file that is more accurate. Intraoral digital scanning has allowed clinicians to directly acquire data from the mouth without needing to make a conventional impression and pour a cast.[29,30] Several reports have focused on the feasibility and accuracy of intraoral digital scans for complete arches. However, few published studies have evaluated direct digital scans of edentulous arches using intraoral scanners due to the difficulty in scanning edentulous sites that are smooth and devoid of features.[31,32] The stitching process can be faulty, especially in the palatal area.[31] Several techniques were suggested to overcome these difficulties and enable a complete, accurate scan.[33,34]

The beads protocol is a revision of the dual scan protocol, providing another possible option for data registration with only one CT

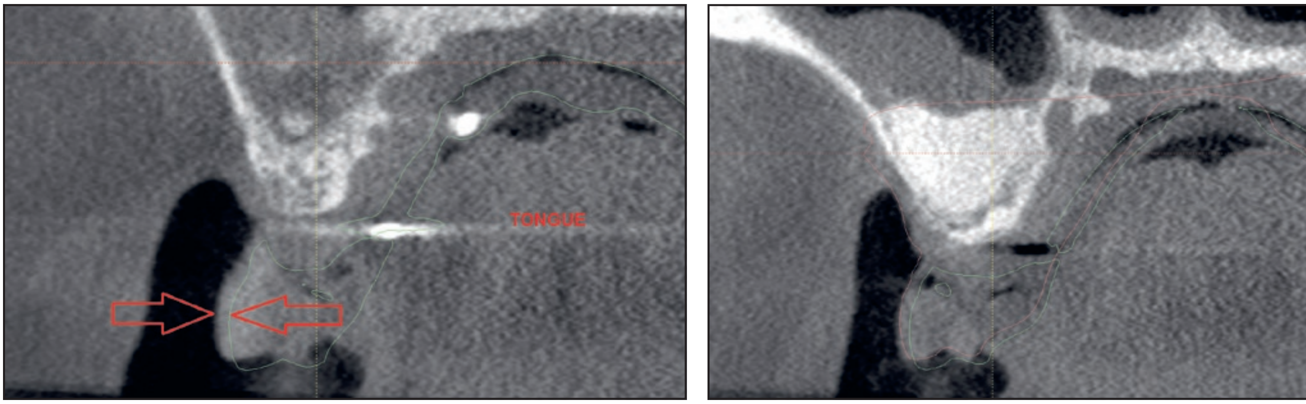


**Fig 11** *The addition of the full retraction protocol will improve the ability to diagnose possible mismatches of STL files on the DICOM files, including cases in which radiopaque markers are in use. The arrows point to the deviation in position between the gray CT image and the green outline of the STL scan.*

scan. This protocol still holds the disadvantage of limited points of reference for calibration of the CT image and the STL files, since primary calibration is done according to radiopaque markers. The addition of the full retraction protocol will improve the ability to diagnose possible mismatches (Fig 11).

## Conclusions

Computer-supported implant planning and guided surgery will become a standard of care to maximize treatment results. To achieve an accurate and safe treatment result, care should be taken in all stages of the workflow, especially during data acquisition, to create a proper digital file for implant planning. In fully edentulous cases, there are limited points of reference for superimposing layers of information on the software. Therefore, data acquisition should be performed according to specific protocols, aiming to maximizing the points of reference.


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