DENTAL TECHNIQUE

Radiographic markers for merging virtual data sets

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Virtual implant planning, through the combination of intraoral surface scans and cone beam computed tomography (CBCT), has revolutionized dental implant treatment concepts and has led to significant improvement in the workflow for computer-guided implant surgery.[1-4] Implant placement can now be planned virtually, taking into account the proposed restoration and the various vital anatomic structures to maximize the biological and functional outcomes. This plan can be transferred reliably to the surgical field with the aid of computer-generated surgical templates.[1-3]

Creation of a virtual patient by merging various digital data sets has been recognized as a significant breakthrough in digital diagnosis and treatment-planning workflows.[4] Merging and registration of digital intraoral scans with CBCT data can overcome the limitations in the surface reproduction of teeth in a CBCT image.[2,5] In a partially dentate patient, the registration of a digital scan with the CBCT image allows the introduction of the proposed prosthetic plan in the form of a digital waxing, eliminating the need for radiographic templates.[2,5,6] Furthermore, because of the presence of the soft tissues in the digital scan, implant angulation, size, depth, and associated measurements can be more accurately made.[2,5] This combined data set is also required for the fabrication of a computer-aided design and computer-aided manufacturing (CAD-CAM) surgical implant template.

ABSTRACT

A procedure for registering digital intraoral surface scans onto cone beam computed tomography in the presence of significant scatter artifact is described. The technique uses chairside-fabricated composite resin markers placed on well-distributed teeth to serve as common landmarks in each digital data set for accurate registration. This straightforward, noninvasive, and cost-effective technique facilitates registration without the need for a specialized armamentarium or radiographic templates. (J Prosthet Dent 2019;122:5-9)

The accuracy of digital scan registration onto CBCT scans has been reported.[2,7-9] Compared with conventional radiographic templates, digital scan registration can more accurately represent the proposed prosthetic plan and is less affected by variations in the location of the edentulous area.[2] In addition, surgical templates

Figure 1. Initial presentation with posterior metal-ceramic restorations which can be anticipated to cause significant scattering in cone beam computed tomography images.

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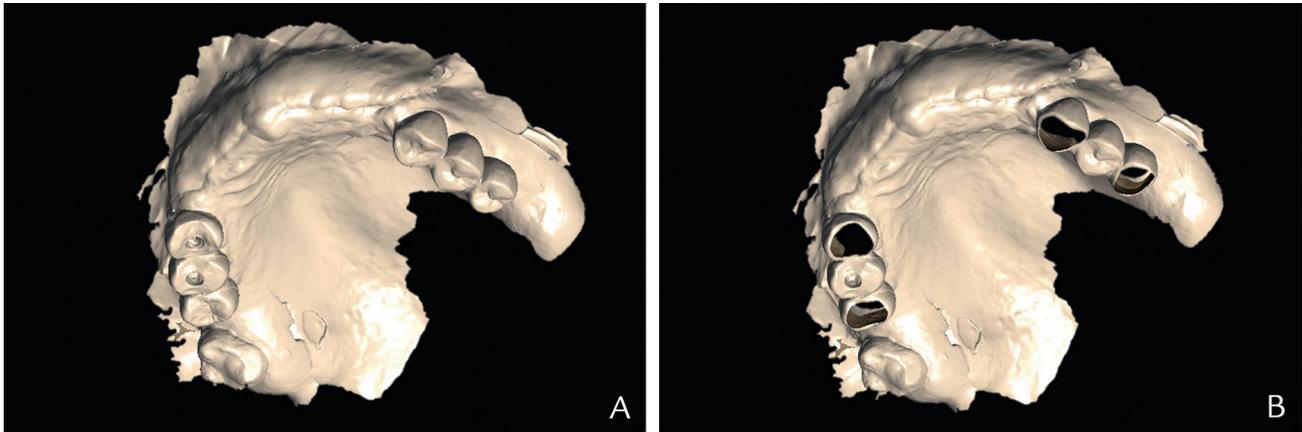
Figure 2. A, Unaltered intraoral digital scan. B, Duplicate digital scan with occlusal tables of selected teeth deleted.

produced using digital scan registration were able to achieve high levels of accuracy and required shorter operating times.[3] Despite the advantages and good results reported with digital scan registration onto CBCT scans, this process is not free of limitations.[2,5-7]

Metal structures such as crowns, restorations, posts, dental implants, and orthodontic brackets induce streak and beam-hardening artifacts in the CBCT image.[6,7,10,11] Streak artifacts appear as radiopaque lines in the image reconstruction, whereas beam-hardening artifacts appear as dark streaks or bands often simulating disease conditions.[10] These artifacts appear predominantly in the direction in which the X-rays travel and are therefore more pronounced in the horizontal than the vertical plane.[12]

Digital scan registration onto CBCT scans is a method of reducing the problems of scatter artifacts as the dentition is more clearly visible on the digital scan than with the CBCT alone.[7-9,11,13] Although digital scan registration has been proposed as a method of correcting the scatter artifacts produced by metal restorations, a high amount of scatter on CBCT scans can adversely affect the accuracy of the registration and ultimately the implant placement.[6,7,11]

The following technique accurately registers a digital scan onto a CBCT scan in the presence of significant scatter artifacts using chairside-fabricated composite resin markers. It is illustrated with a patient presenting for digital evaluation before implant therapy with metal-ceramic restorations on posterior teeth from which significant metallic scatter can be anticipated on the CBCT image (Fig. 1).

TECHNIQUE

1. Make a digital intraoral surface scan of the patient's dentition (TRIOS 3 Pod; 3Shape) (Fig. 2A).
2. Duplicate the digital scan by making a copy of the work order, which permits the modification of the

Figure 3. Radiographic markers fabricated and polymerized chairside from composite resin.

scan while still maintaining the original unaltered digital scan.

3. On the duplicate digital scan, delete and remove the occlusal tables of 3 to 5 (minimum of 3) well-distributed teeth that are selected to receive the composite resin markers (Fig. 2B). This allows the clinician to modify and rescan only these specific areas without the need to rescan the entire arch.
4. Fabricate composite resin markers (Vit-I-escence; Ultradent Products, Inc) approximately 3 to 5 mm in length and 1 mm in diameter and light polymerize them extraorally chairside (Fig. 3).
5. Using flowable composite resin (PermaFlo; Ultradent Products, Inc), lute a composite resin marker vertically onto the occlusal surface of each of the selected teeth spread as far around the arch as possible. The markers should protrude 2 to 3 mm above the occlusal plane (Fig. 4). At this point, the patient should refrain from occluding to avoid dislodging the markers.
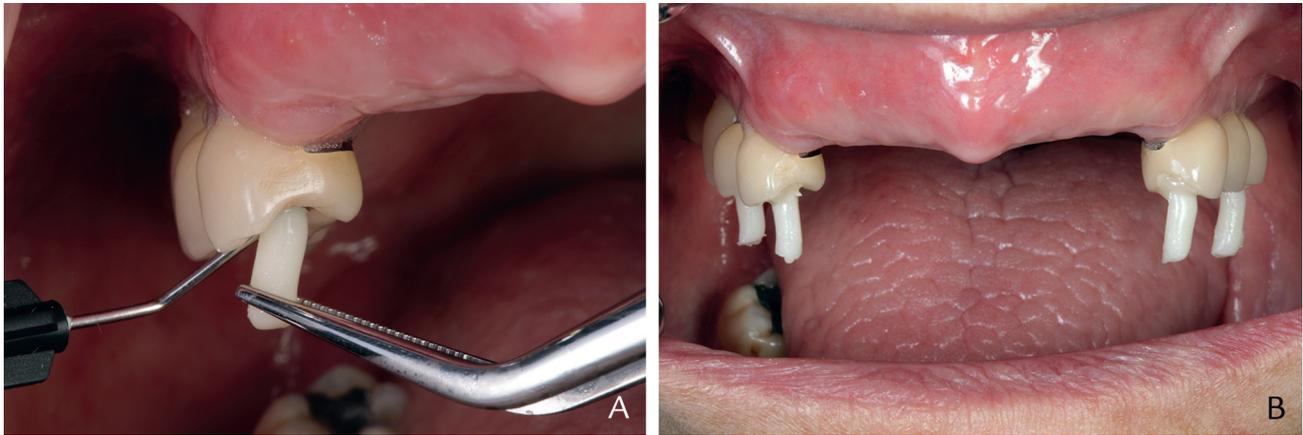
Figure 4. A, Luting composite resin marker to occlusal surface of metal-ceramic crown with flowable composite resin. B, Markers placed in strategic locations around arch to create anterior-posterior and lateral distribution possible.

6. Rescan the previously deleted areas of the selected teeth with the composite resin markers in place using the intraoral scanner. The scanner can recognize the neighboring landmarks and will incorporate the markers into the digital scan (Fig. 5).

7. Make a CBCT scan (i-CAT; Imaging Sciences Intl, LLC) of the patient with the composite resin markers in place and slightly out of occlusion with the opposing arch. Artifacts from high-density objects such as metal in crowns appear predominantly in the horizontal plane; as a result, the composite resin markers will be clearly identified above the occlusal plane even in the presence of an excessive artifact (Fig. 6A, B).

8. Remove the composite resin markers from the patient's mouth and discard them.

9. Using an implant planning software program (CoDiagnostiX; Dental Wings Inc), identify and isolate the markers from the CBCT data by a process of segmentation.

10. Register the intraoral digital scan with the composite resin markers onto the CBCT scan by selecting the markers as common points between the 2 data sets (Fig. 6C).

11. Register the original intraoral digital scan without markers onto the intraoral scan with the composite resin markers by using the remaining dentition as common points (Fig. 6D).

12. With all the images aligned, remove the scatter in the CBCT data set using the segmentation tool to leave a clean image of the bone, soft tissues, and dentition (Fig. 6E).

13. Using the dentition of the registered unaltered cast, introduce a digital diagnostic waxing that meets the patient's esthetic and functional requirements onto the original scan for the purpose of virtual implant planning (Fig. 6F).
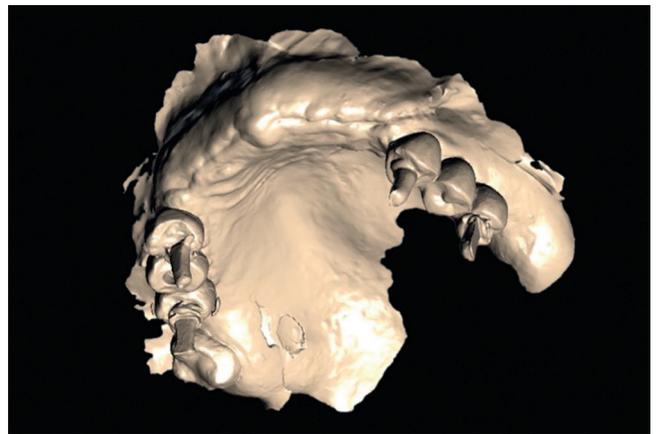

Figure 5. Intraoral digital scan with composite resin markers.

14. Once the implants have been ideally positioned, fabricate a surgical guide on the original unaltered digital scan for transfer of the plan to the patient's mouth (Fig. 7).

DISCUSSION

Metal restorations, crowns, and orthodontic brackets introduce scatter artifacts in the CBCT image which often interfere with the ability to visualize and assess the proposed implant site and may adversely affect the planning process.[2,6] Because the CAD-CAM surgical template fabrication process requires a clear and accurate representation of the teeth, which cannot be produced using scatter-affected CBCT scans, the presence of a digital scan is essential.[7] Scatter artifacts can also obscure the anatomy of the dentition, reducing the accuracy of digital scan registration onto CBCT scans and the overall accuracy of the planning.[6,7,11] Flügge et al[7] reported that the accuracy of registration is reduced with an increased number of metal restoration, whereas Nkenke et al[11] reported that the mean distance between the data sets
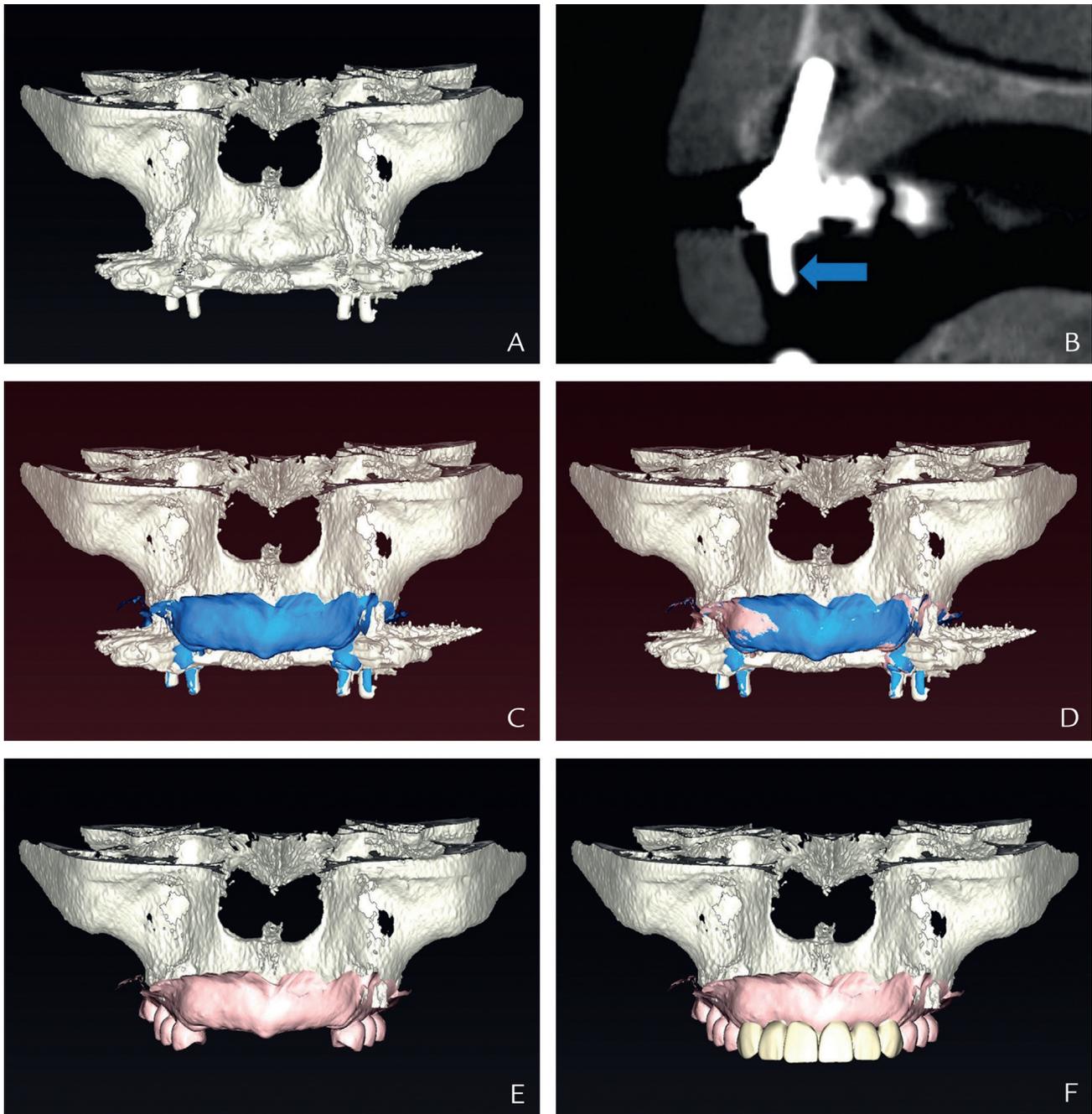
Figure 6. A, Composite resin markers visible despite presence of scatter. B, Cross-sectional CBCT image showing composite marker (arrow). C, Registration of intraoral scan (*blue*) onto CBCT scan using composite resin markers as reference points. D, Marker-free intraoral scan (*pink*) registered onto scan with composite resin markers (*blue*). E, Marker-free intraoral scan (*pink*) registered onto CBCT scan with scatter removed. F, Digital waxing introduced onto marker-free intraoral scan (*pink*). CBCT, Cone beam computed tomography.

was increased from 0.126 mm to 0.267 mm when metal restorations were introduced.

The described technique provides a straightforward and cost-effective way of accurately registering a digital scan onto a CBCT scan in situations where excessive amounts of scatter artifacts obscure common landmarks and prevent registration. Because of the horizontal scatter, radiopaque markers placed on the buccal or lingual aspects of restored teeth will not be visible on a CBCT scan. To overcome this limitation, the relative absence of artifacts in the vertical plane can be used, and markers are placed in the space between the maxillary and mandibular teeth. The composite resin markers are designed and placed in a specific manner so that they
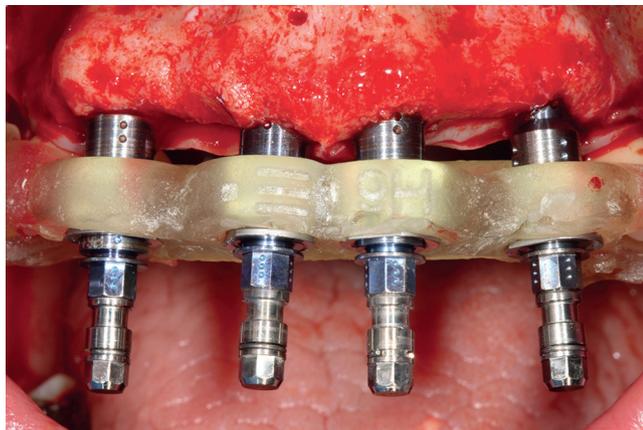
Figure 7. Implants placed using computer-generated surgical template.

extend beyond the scatter-affected areas and are clearly visible on the CBCT scan as well as the digital scan, facilitating precise registration. Because of the horizontal scatter, radiopaque markers placed on the buccal or lingual/palatal aspects of restored teeth will not be visible on a CBCT scan. To overcome this limitation, we make use of the fact that there is a relative absence of artifacts in the vertical plane and place markers in the space between the maxillary and mandibular teeth. Additional advantages to this technique include the absence of the need for a specialized armamentarium or radiographic templates which can be costly and time-consuming.[2,7] A similar technique described by Rangel et al[13] used titanium markers attached to the patient's gingiva with tissue adhesive. However, these markers can easily come loose with tongue movement.

Although the composite resin markers allow the accurate registration of the digital scan onto the CBCT, the presence of the markers does not permit the fabrication of properly seating surgical templates. Therefore, the registration of a markerless digital scan onto the previously registered composite marker scan, as described in this technique, is necessary. This described technique can be somewhat technique sensitive and may require some operator experience and familiarity with the capabilities of the digital scanning system. It also requires patient compliance as the mouth must be open throughout the procedure to avoid dislodging the markers.

SUMMARY

This straightforward and cost-effective procedure uses chairside-fabricated composite resin markers temporarily luted to the patient's dentition. This allows for the accurate registration of digital surface scans onto CBCT data in the presence of excessive amounts of scatter artifacts.

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