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DENTAL TECHNIQUE

# Obtaining more accurate complete arch implant digital scans with the aid of a geometric pattern: A dental technique

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## ABSTRACT

A technique to obtain more accurate complete arch implant digital scans and virtual casts is described. In order to obtain complete arch implant digital scans with greater accuracy, short-span intraoral digital scans are superimposed with the aid of a geometric pattern. Therefore, the technique takes advantage of the accuracy of intraoral scanners to obtain digital scans of reduced spans. Two virtual designs of the geometric pattern have been made available online: one for maxillary arches and one for mandibular arches. From these virtual designs, new virtual designs of geometric patterns of different sizes and shapes can be created to better fit different arch forms and implant positions. (J Prosthet Dent 2025;133:370-375)

In direct digital workflows for implant-supported prostheses, the position of the implants is transferred from the patient's mouth to a virtual cast by means of a digital scan, acquired with an intraoral scanner (IOS).[1–3] To ensure the passive fit of a prosthesis, the position of implants must be accurately transferred to the virtual cast.[4,5] However, intraoral digital scans of implants, particularly complete arch digital scans, often fall short of achieving the required accuracy.[6–12]

IOSs create digital scans by stitching together different images using best-fit alignment algorithms, which obtain the best results when stitching together images of immovable areas with numerous geometric references.[12–14] Therefore, IOSs have difficulty in accurately stitching together images of movable tissues and smooth surfaces in edentulous areas.[12–17] Image-stitching errors may not significantly affect the accuracy of short-span digital scans.[9–12,18] However, the accumulation of errors can significantly affect the accuracy of digital scans of longer spans, which makes it especially difficult to obtain accurate complete arch implant digital scans.[9,12,19]

Photogrammetry devices have been developed to transfer the position of the implants from the patient's mouth to a virtual cast more accurately, but at additional equipment cost.[20–23] Therefore, alternatives have been presented to improve the accuracy of complete arch implant intraoral digital scans,[24–29] most of which consist of adding geometric references between intraoral scan bodies (ISBs) to favor image-stitching algorithms.[26–28] Although adding geometric references can improve the accuracy of complete arch implant intraoral digital scans,[30–38] a large-span digital scan is usually required, the accuracy of which may be significantly affected by the accumulation of image-stitching errors.

This article describes a technique to obtain more accurate complete arch implant intraoral digital scans by superimposing short-span intraoral digital scans with the aid of a geometric pattern. Two virtual designs of the geometric pattern are introduced (Fig. 1): one for maxillary arches (Supplemental File 1, available online) and one for mandibular arches (Supplemental File 2, available online). To implement this technique, each clinic should acquire a set of reusable geometric patterns for maxillary and mandibular arches of different shapes and sizes. The geometric pattern that best suits the patient's

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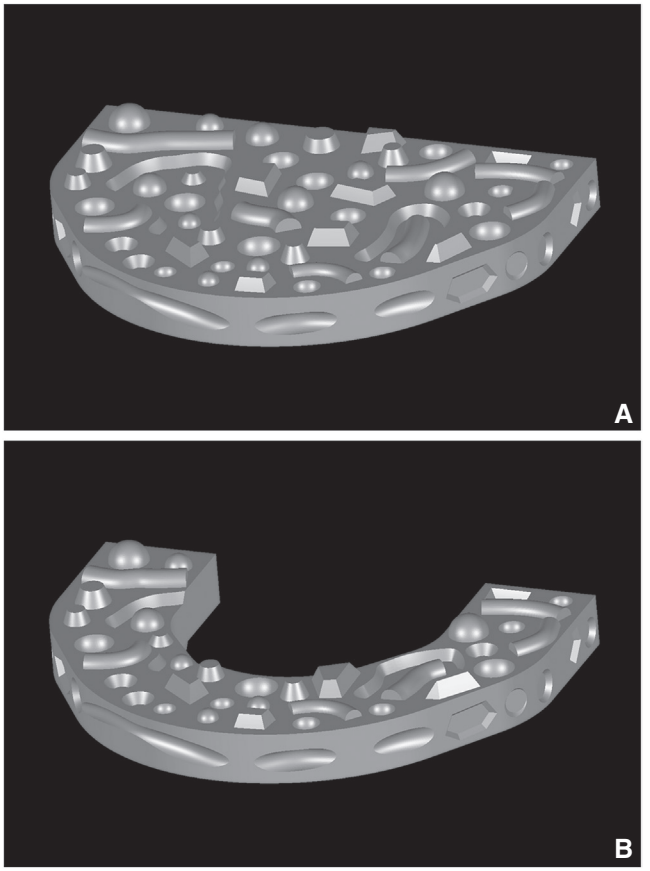


**Figure 1.** Virtual designs of introduced geometric patterns. A, For maxillary arches. B, For mandibular arches.

arch and implant location should be used. As the technique is the same with the geometric patterns for maxillary and mandibular arches, only the use of geometric patterns for maxillary arches is described.

## TECHNIQUE

1. Create a set of geometric patterns of different sizes and forms in a reverse engineering software program (Geomagic Design X; 3D Systems Inc) based on the virtual designs introduced (Supplemental Files 1, 2, available online).
2. Manufacture the geometric patterns in an opaque material that meets or exceeds established biocompatibility requirements (HP 3D HR PA12; HP Inc).[39,40]
3. Obtain an accurate digital scan of each geometric pattern with a laboratory scanner (E2; 3Shape A/S).
4. Screw an ISB (Tiny Universal Platform Multi-IM ISB; BTI Biotechnology Institute) to each abutment by following the manufacturer's recommendations (Fig. 2). Preferably use ISBs that provide orientation information and, if necessary, confirm that they are completely seated with radiographs.

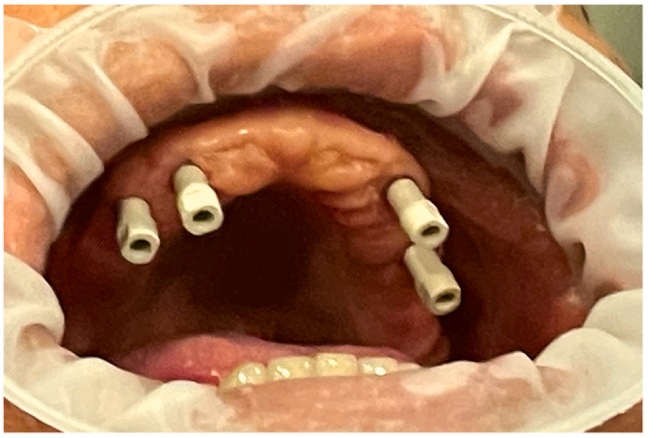

**Figure 2.** Intraoral scan bodies screwed to multi-unit abutments.

5. Obtain a conventional complete arch intraoral digital scan with an IOS (TRIOS 3; 3Shape A/S) as per the manufacturer's recommendations (Fig. 3).
6. Attach a geometric pattern to the patient's mouth with a polyvinyl siloxane impression material (Express 2 Putty Quick; 3M ESPE) (Fig. 4). Select the geometric pattern that best suits the patient's arch form and implant position and place it as

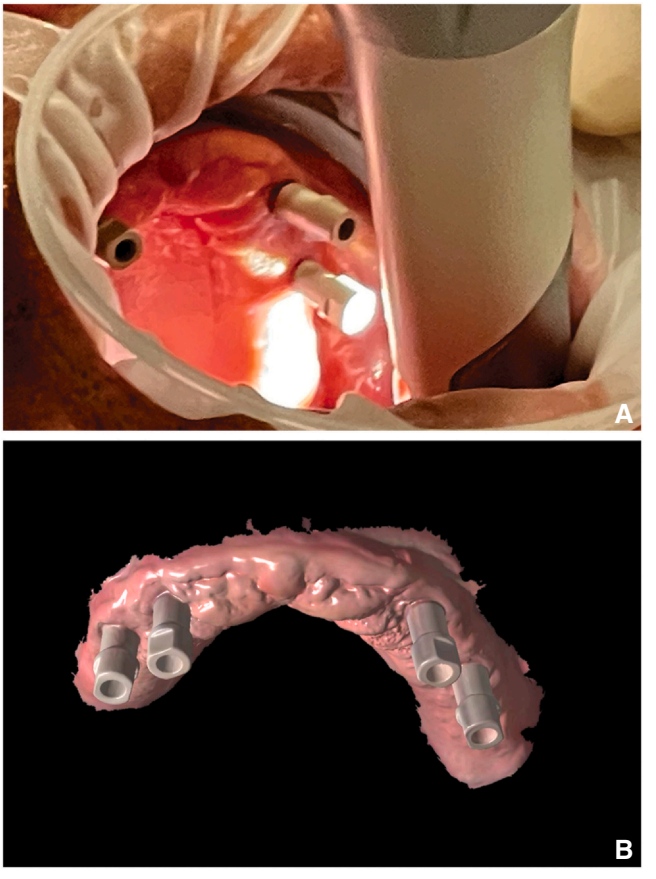


**Figure 3.** Acquisition of complete arch implant intraoral digital scan. A, Intraoral scan. B, Complete arch implant intraoral digital scan.

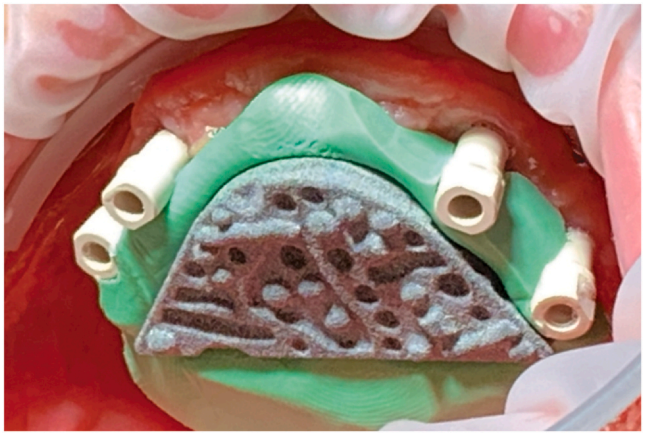

**Figure 4.** Geometric pattern attached intraorally.

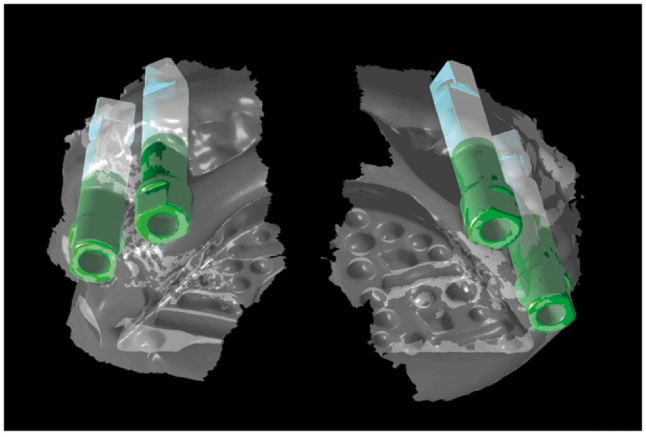

**Figure 7.** Superimposition of virtual designs of scan bodies with scan bodies of reconstructed complete arch implant digital scan.

closely as possible to the ISBs at a similar height to them. If necessary, cover the gaps between the geometric pattern and the ISBs with impression material, ensuring that most of the scan region of the ISBs remains clear.

7. Obtain a partial intraoral digital scan for each ISB with the IOS, capturing in each partial digital scan the scan region of the ISB and a nearby region of the geometric pattern (Fig. 5).
8. Reconstruct a complete arch implant digital scan in a dental computer-aided design (CAD) software program (exocad; exocad GmbH) by superimposing the partial intraoral digital scans obtained in step 7 with the digital scan of the geometric pattern obtained in step 3 (Fig. 6). For this step, superimpose common regions of the geometric pattern by using a best-fit algorithm, avoiding the use of poorly scanned regions with apparent defects. Verify each alignment by analyzing the deviations by means of a color map (Fig. 6A).
9. In the dental CAD software program, superimpose a virtual design of the ISBs used with each ISB of the reconstructed digital scan to obtain the position of the implants (Fig. 7). For that, superimpose common regions of the ISBs by using a best-fit algorithm.

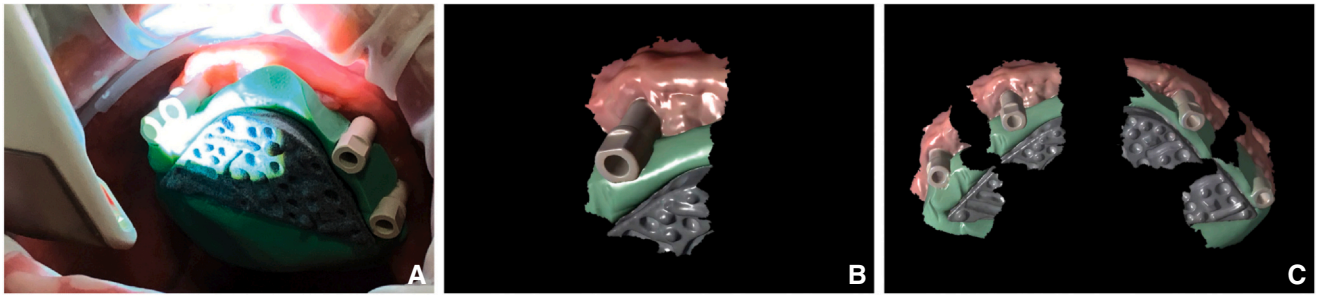


**Figure 5.** Acquisition of partial intraoral digital scans. A, Intraoral scan. B, Partial short-span intraoral digital scan. C, All partial intraoral digital scans.

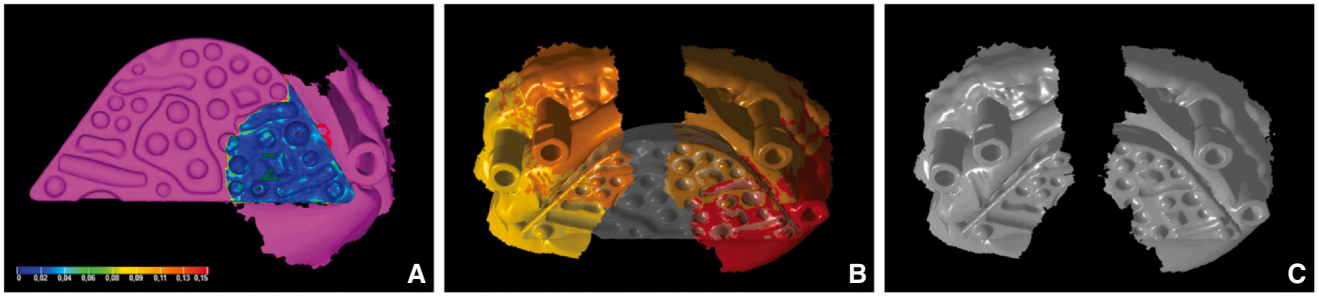


**Figure 6.** Reconstruction of complete arch implant digital scan. A, Superimposition of partial intraoral digital scans with digital scan of geometric pattern. B, Partial intraoral digital scans superimposed with digital scan of geometric pattern. C, Reconstructed complete arch implant digital scan.

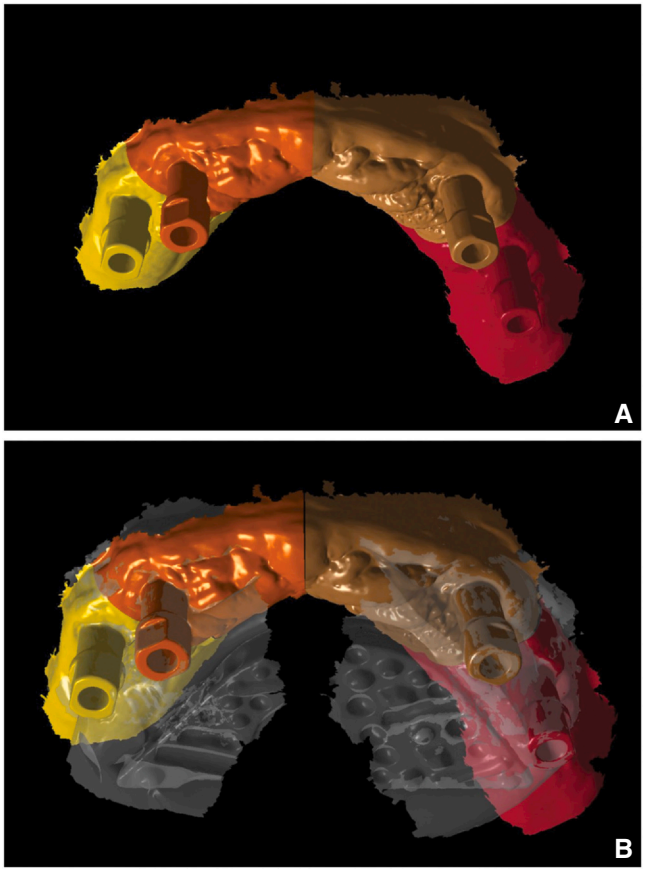


**Figure 8.** Splitting of complete arch implant intraoral digital scan and superimposition of each part with reconstructed complete arch implant digital scan. A, Splitting of complete arch implant intraoral digital scan. B, Superimposition of each part of complete arch implant intraoral digital scan with reconstructed complete arch implant digital scan.

10. In the dental CAD software program, split the conventional complete arch intraoral digital scan obtained in step 5 into as many parts as implants (Fig. 8A) and superimpose each with the reconstructed digital scan (Fig. 8B). For that, if the ISBs used provide orientation information, common regions of the ISBs should only be superimposed by using a best-fit algorithm. If not, common regions corresponding to soft tissues should also be superimposed.
11. Remove or hide the reconstructed digital scan and retain the virtual cast composed of the split complete arch digital scan and the virtual designs of the ISBs (Fig. 9).

## DISCUSSION

A technique to obtain complete arch implant digital scans and virtual casts with high accuracy is described. For that, complete arch implant digital scans are reconstructed by superimposing short-span intraoral digital scans with the aid of a digital scan of a geometric pattern. Two virtual designs of the geometric pattern are introduced (Fig. 1): one for maxillary arches and one for mandibular arches. To implement the technique, a set of reusable geometric patterns for maxillary and mandibular arches of different sizes and shapes should be fabricated, and the one that fits best should be selected, avoiding the need for custom-made geometric patterns, which would involve an additional patient visit.[38]

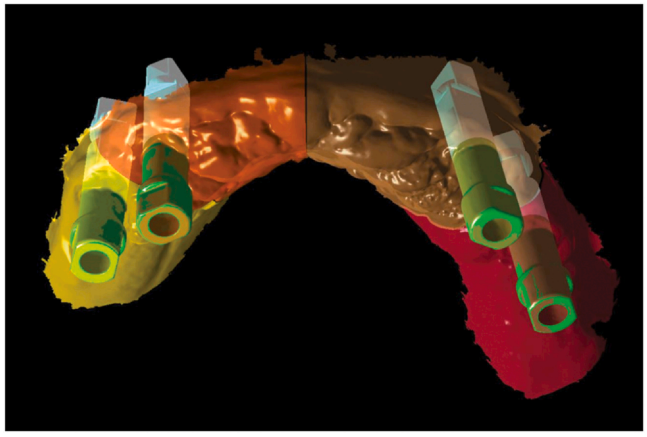

**Figure 9.** Definitive virtual cast.

IOSs create digital scans by stitching together different images using best-fit alignment algorithms which tend to have difficulties in accurately stitching together images of smooth and movable tissues in edentulous regions.[12–17] The accumulation of image-stitching errors can significantly affect the accuracy of digital scans, which makes it particularly challenging to obtain accurate complete arch implant intraoral digital scans.[9,12,19] Most techniques that have been developed to improve the accuracy of such digital scans consist of adding geometric references between ISBs to reduce image-stitching errors.[26–28] However, a complete arch digital scan with the geometric references in place is still required, which can also be affected by the accumulation of image-stitching errors.[26,27] Therefore, the present technique reconstructs complete arch implant digital scans by positioning short-span intraoral digital scans with the aid of the geometric pattern's digital scan. In this regard, the shapes of the geometric patterns were designed not only to facilitate the correct superimposition of their digital scans and the short-span intraoral digital scans (Fig. 6) but also to improve the accuracy of intraoral digital scans.[12–17]

Limitations of the technique include the need for a reverse engineering software program to create the virtual designs of the geometric patterns (step 1 of the technique) and a laboratory scanner to obtain an accurate digital scan of the geometric patterns (step 3 of the technique). Therefore, to avoid the need for a reverse engineering software program and a laboratory scanner

in the clinic, reusable geometric patterns could be designed, manufactured, and scanned in a facility. When manufacturing the geometric patterns, they must meet or exceed the established biocompatibility requirements.[39,40] In addition, geometric patterns should exhibit negligible dimensional changes during use and sterilization. If the geometric patterns might eventually undergo dimensional changes, their digital scans should be updated periodically.

Virtual designs of geometric patterns can be downloaded and used by the dental community. However, studies are needed to assess the accuracy of complete arch implant digital scans reconstructed with this technique and to determine the optimal geometry for the patterns by evaluating different parametric and tooth shapes.

## SUMMARY

A technique to obtain more accurate complete arch implant digital scans and virtual casts is presented. In order to obtain more accurate complete arch implant digital scans, short-span intraoral digital scans are acquired and superimposed with the aid of a geometric pattern, benefiting from the accuracy of IOSs to obtain digital scans of reduced extent. Two virtual designs of the geometric pattern are available online: one for maxillary arches and one for mandibular arches. From the proposed virtual designs, virtual designs of geometric patterns of various sizes and shapes can be created to better fit different arch forms and implant positions.

## PATIENT CONSENT

The patient illustrated signed an informed consent form. The procedure was approved by the university ethics committee (M10_2019_254) according to local and international ethical rules.

## APPENDIX A. SUPPORTING INFORMATION

Supplemental data associated with this article can be found in the online version at doi:10.1016/j.prosdent.2024.01.041.

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