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DENTAL TECHNIQUE

Digital dentures: A protocol based on intraoral scans

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ABSTRACT

The use of intraoral scans for complete denture fabrication may improve patient comfort, clinic ergonomics, and laboratory efficiency. Techniques have been reported regarding specific tasks related to the use of intraoral scans for digital dentures, but an integrated workflow is still lacking. This technique article describes a complete workflow for the digital fabrication of complete dentures, starting from intraoral scans and with no physical casts; in addition, the presented workflow integrates partial and complete face scans in the design process to optimize tooth arrangement. (J Prosthet Dent 2021;125:597-602)

The use of computer-aided design and computer-aided manufacturing (CAD-CAM) technology in complete denture fabrication[1] provides improved denture retention[2] and fit,[3] better mechanical[4] and surface[5] properties of materials, reduction in time of both clinical and laboratory procedures,[6] higher patient satisfaction,[7] better clinician acceptance,[7] and reduced procedure time and costs.[8] Manufacturer-dependent systems,[9] as well as a protocol integrating open technologies,[10] have been proposed for digital denture design and fabrication. Although these protocols are evolving, they continue to use conventional clinical procedures that are then digitized in a manner best suited to the specific system.[1,9,11,12] The use of intraoral scans for denture fabrication may provide additional advantages by improving patient comfort (no gag reflex, less time, fewer appointments, no allergies to impression materials) and further reducing chairside time and time for laboratory procedures (no preparation, handling, shipping, or storage of impressions and casts).[13,14]

Intraoral scans have been reported to be sufficiently accurate for complete denture fabrication,[15,16] and the proof of concept for fabricating a functional maxillary complete denture on intraoral scans has been reported.[14] In addition, with the aim of developing a protocol for digital complete dentures based on intraoral scans, different techniques have been published for single tasks related to intraoral scan alignment,[17,18] registration of maxillo-mandibular relationships when using intraoral scans,[18] and merging intraoral scans with face scans.[19] The purpose of this technique article was to demonstrate a workflow for the fabrication of complete dentures, which starts with intraoral scans and uses no physical casts.

TECHNIQUE

1. **Clinical procedure.** Make intraoral scans of the edentulous arches by using an intraoral scanner (TRIOS 3; 3Shape A/S). Process and export the scans (Fig. 1) with either a TRIOS direct connection to export to a desktop or the "3Shape communicate" system.
2. **Laboratory procedure.** Design and 3D print record bases for the fabrication of occlusion rims. Use the workflow for individual impression trays in the 3Shape Dental System software (3Shape A/S) and set the space for the material to zero so that the record bases are completely adapted to the mucosa. Transfer the standard tessellation language files of the designed record bases to the software application of the 3D printer (Prusa i3 MK3S; Prusa Research) and print them with polylactic acid (PLA) (Prusament PLA; Prusa

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Figure 1. Intraoral scans of maxillary and mandibular completely edentulous arches.

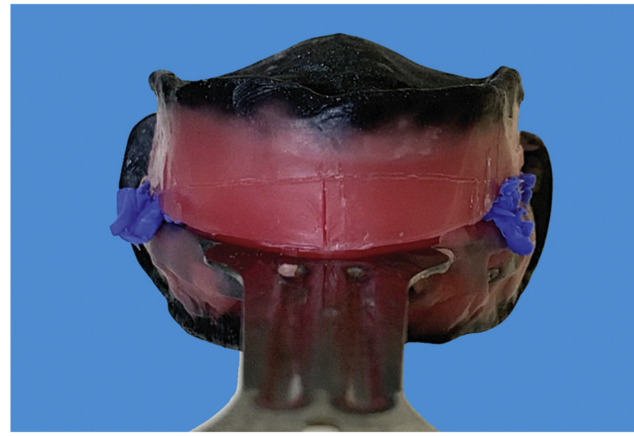

Figure 2. Occlusion rims after adaptation on patient, incorporating maxillo-mandibular relations and information for tooth arrangement.

Research). Add wax (Bite Wax Rims; Henry Schein, Inc) to the printed record bases for the definitive occlusion rims.

3. **Clinical procedure.** Make a maxillo-mandibular relation record. Record the vertical dimension of occlusion, occlusal plane, lip support, maxillary incisor length, and midline. Obtain a centric relation record, evaluate that it is a repeatable position, and record it in the occlusion rims by using a recording material (Registrado X-tra; VOCO GmbH) placed on notches created on their occlusal aspect (Fig. 2).
4. **Clinical or laboratory procedure.** Scan the occlusion rims. Perform this task either intraorally[17,18] or extraorally.[10,14,20] Occlusion rims can be scanned either intraorally or extraorally with an intraoral scanner (TRIOS 3; 3Shape A/S); alternatively, they can be scanned in the dental laboratory by using a laboratory scanner (E4; 3Shape A/S).
5. **Clinical procedure.** Scan the lower third and middle third of the face (Fig. 3A), as well as the complete face (Fig. 3B), with the occlusion rims in place and while the patient is smiling.[19] Use an intraoral scanner (TRIOS 3; 3Shape A/S) for the lower and middle third of the face scans. Make the complete face scan with a mobile phone (iPhone X; Apple Inc) with a dedicated application (Bellus Dental Pro; Bellus3D Inc).[19]
6. **Laboratory procedure.** Align these scans and design dentures.
   A. Create an order ("order" is how the designing process is referred to in 3Shape Dental System software) for complete denture design and import the intraoral scans of the edentulous arches and the scan of the occlusion rims. If the occlusion rims were scanned extraorally,[10,14] align the intraoral scans to the scan of the occlusion rims by using the "align to bite" function (considering the scan of the occlusion rims as the "bite"); if the occlusion rims were scanned intraorally and the automatic alignment procedure carried out,[17,18] omit this step. Once the scans are aligned (Fig. 4A), start the design process (Fig. 4B).

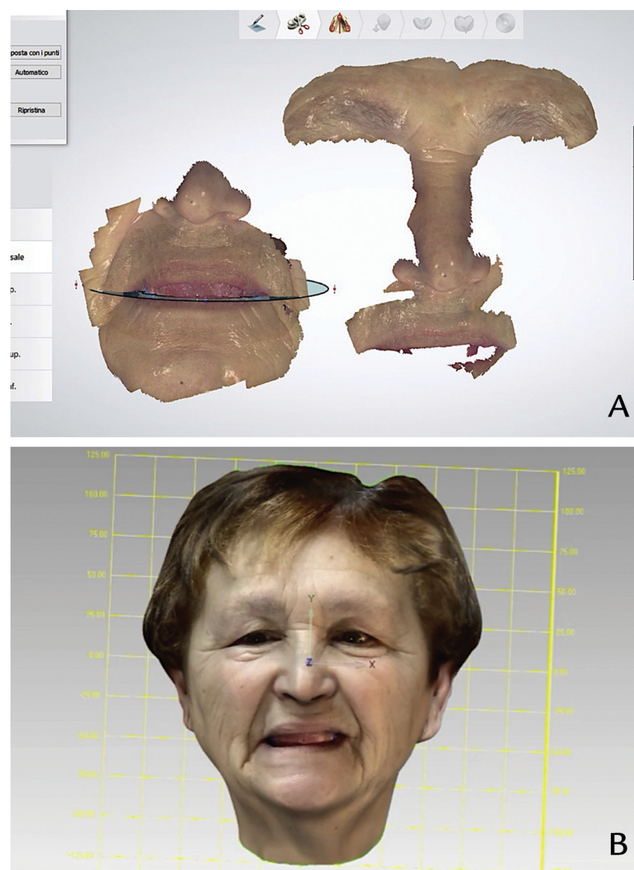

Figure 3. Face scans. A, Lower and middle third of face scans. B, Complete face scan made with mobile phone application.

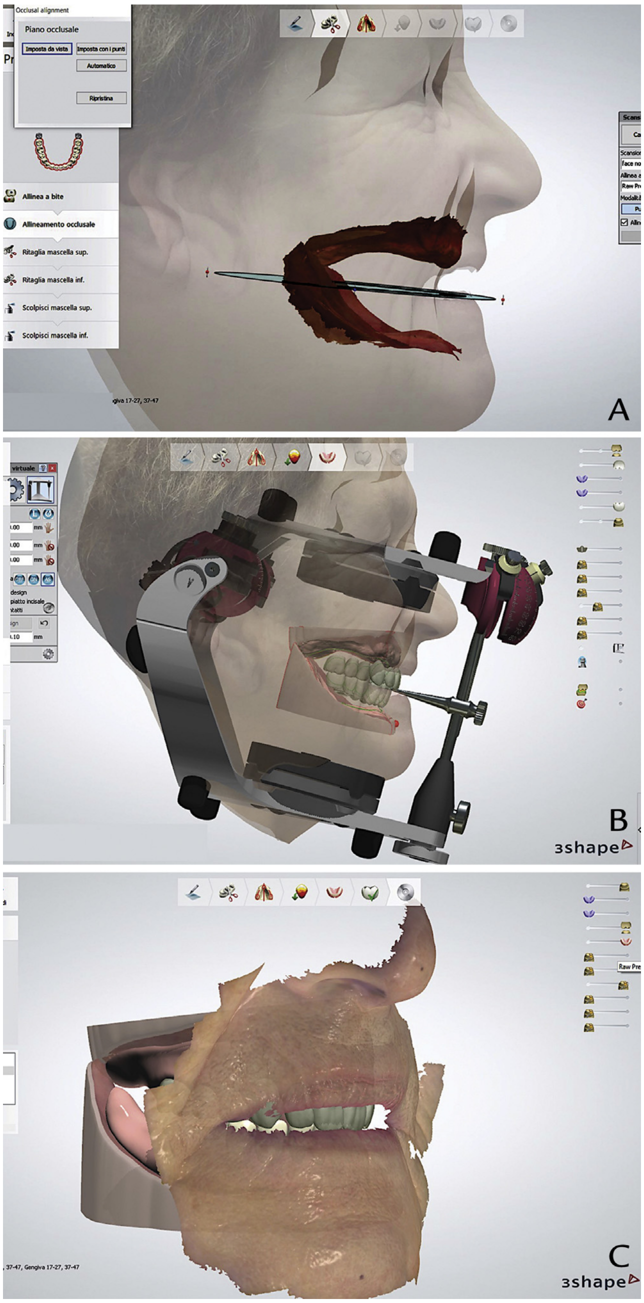

Figure 4. Design workflow. A, Intraoral and extraoral scans are aligned: "digital patient" ready to guide design process. B, Tooth arrangement and occlusion designed and assessed virtually. C, Partial or complete face scans used for esthetic preview.

B. At any time during the design process, import into the workflow the scans of the lower and middle third of the face, as well as of the complete face by using the "additional scans" function. This function loads and aligns all these scans,[19] which are used to optimize individual tooth arrangement in the context of the patient's profile and the 3D preview offered by such scans (Fig. 4C).

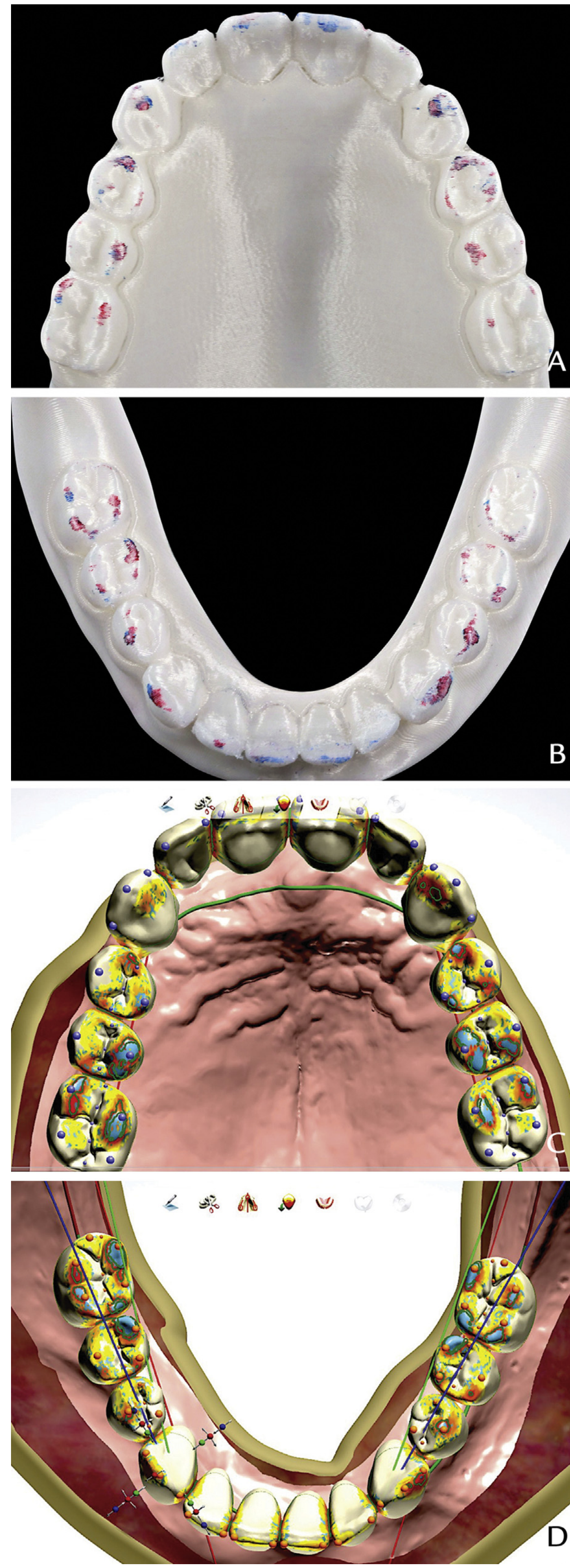

Figure 5. A, B, 3D printed trial maxillary and mandibular complete dentures with marked static and dynamic occlusal contacts assessed intraorally. C, D, Digitally calculated occlusion.

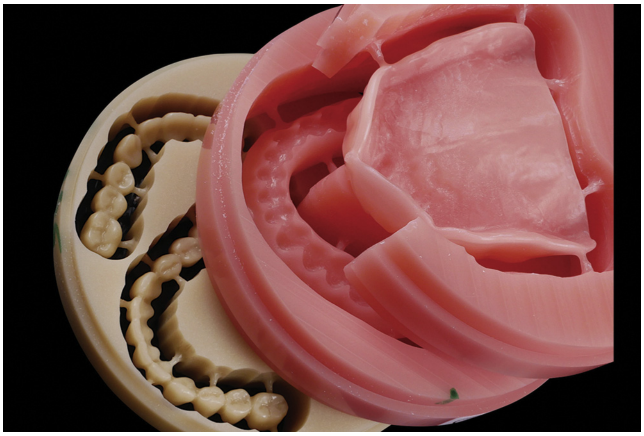

Figure 6. Milled bases and teeth.

7. **Laboratory procedure.** Make a rapid prototype of the trial denture (Fig. 5A, B). Use procedures as described in step 2 and the same material with a whitish shade. To mimic the shade of the natural dentition, PLA may not be ideal; nonetheless, it is inexpensive and can be used with straightforward and affordable 3D printing technologies with acceptable dimensional accuracy.[21] Thus, it is an appropriate option for a trial denture to assess tooth arrangement and overall function.
8. **Clinical procedure.** Evaluate the trial dentures (Fig. 5C, D) (Video 1). At this stage, changes, if required, can be incorporated into the definitive denture. A correct adaptation of the occlusion rims and the use of face scans reduce the need for corrections. Nonetheless, if the tooth arrangement is not accepted by the clinician or the patient, it can be adjusted chairside by modifying the tooth shape by grinding or adding composite resin or wax. The tooth position can be modified quite easily because PLA is a thermoplastic polymer, and a heated instrument is sufficient to separate and detach teeth from the trial base; once detached, teeth can be repositioned and reattached in the corrected position with wax.
9. **Laboratory procedure.** If required, amend the design in accordance with the new data acquired during the clinical evaluation. The design can be adjusted either by simply reopening the "order" and making the desired amendments or by using the scan of the adapted trial denture, imported in the "order," as a guide for more precision. If maxillo-mandibular relations were updated, use the "try-in workflow" available in 3Shape Dental System software to automatically modify the position of the scans, maintaining the design and simplifying its definitive adjustment.
10. **Laboratory procedure.** Mill the denture base and the teeth (Fig. 6). Use standard tessellation language files of both the denture base and teeth with open CAM software (hyperDENT; FOLLOW-ME! Technology Group) to create the corresponding projects in a 25-mm-high polymethyl methacrylate (Smile Cam Total Prosthesis; Pressing Dental Srl) blank and in a multilayer polymethyl methacrylate copolymer blank (Smile Cam; Pressing Dental Srl). Then, generate the corresponding output for the specific milling machine (Roland DWX-51D; Roland DGA Corp).

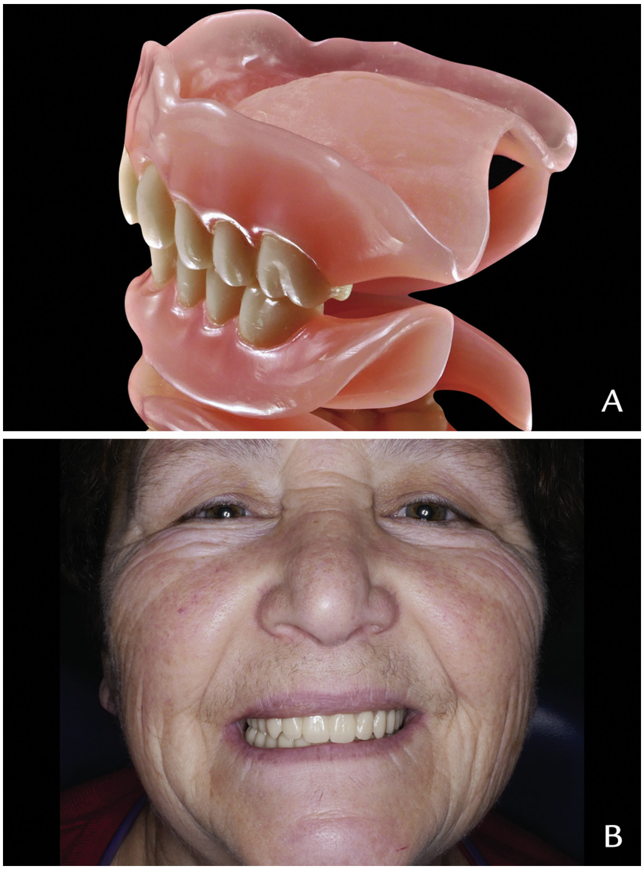

Figure 7. Definitive complete dentures. A, Teeth bonded to bases: complete dentures ready for delivery. B, Patient with definitive dentures; asymmetry of lips discussed with patient, who elected to keep occlusal plane parallel to interpupillary line.

11. **Laboratory procedure.** Bond teeth to the milled base with a fast polymerizing acrylic resin (Jet Repair; Lang Dental Mfg Co, Inc) following the manufacturer's instructions (Fig. 7A).
12. **Clinical procedure.** Deliver the definitive complete dentures (Fig. 7B) (Video 2).

DISCUSSION

The presented workflow was developed to exploit the benefits of digital technologies in all steps of complete

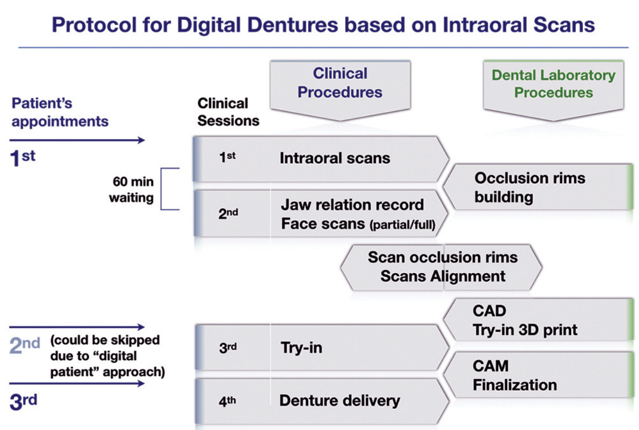

Figure 8. Protocol based on intraoral scans.

denture prosthodontics, providing the definitive denture without physical impressions or casts. Intraoral scans of the edentulous arches enable fully digitalized complete dentures; however, the registration of the maxillo-mandibular relationships cannot be accomplished in a completely digital or virtual environment and still requires the use of a physical object. In the presented workflow, occlusion rims were used and were scanned either intraorally[17,18]or extraorally,[10,14,20] thus making it possible to transfer such data in the digital workflow and align the intraoral scans. By using occlusion rims may make for an easier transition to the digital concept because both clinicians and technicians are familiar with them and their use avoids the need for system-specific trays or instruments or system-inherent techniques.

The described protocol is also applicable to removable partial dentures. It can also be tailored to individual needs without affecting its functionality. For example, the maxillo-mandibular relation record can be made either with a straightforward wax recording technique or by adding gothic arch tracing equipment to the occlusion rim. The denture can be fabricated with additive manufacturing technologies instead of milling, although with current technology, milled dentures are better in terms of trueness of the intaglio surfaces.[22] Commercially available artificial teeth can also be used instead of milled teeth.

All steps of this protocol use and integrate open technological systems,[10] thus facilitating the combined and efficient use of any open scanner, CAD-CAM software, milling machine, or 3D printer. Scanning the lower and middle third of the face, as well as the complete face,[19] which is useful to build the "digital patient," is not mandatory; nonetheless, it helps optimize the virtual tooth arrangement, communicate with the patient,[23] and complement or even replace the traditional clinical evaluation of a conventional tooth arrangement.[24,25] This approach has the potential to avoid the appointment for the trial denture evaluation; thus, in such an instance, just 2 appointments are required to progress from the initial intraoral scans to the definitive denture delivery (Fig. 8). In comparison with the conventional technique, it is possible to save at least 1 appointment. Seventy minutes of chairside time are required for the provision of maxillary and mandibular dentures. Laboratory time (110 minutes, excluding the processing time) is considerably reduced, enhancing efficiency and making a fully digital approach more affordable, notwithstanding the increased costs of the materials used in the digital denture workflow.[8]

The omission of border molding is a concern related to the use of intraoral scans for complete removable dentures. However, intraoral scans are similar to a mucostatic impression; thus, complete denture retention is mainly related to surface tension between the mucosa and the intimate contacting intaglio denture surface and does not rely on a peripheral seal. Therefore, the recording of vestibular depth and width from border molding is not essential. At present, border molding and postpalatal seal lack scientific support as regards their functional efficacy.[26]

SUMMARY

The presented technique describes how complete denture fabrication can be fully digitized. The corresponding workflow, based on intraoral scans, results in complete dentures ready to be delivered with no need for physical impression or definitive casts. In addition, partial and/or complete face scans, together with intraoral scans, can be effectively merged into a digital patient to optimize individual tooth arrangement during the denture design process, potentially allowing the trial denture evaluation and the delivery of the definitive denture in just 2 appointments.

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Noteworthy Abstracts of the Current Literature

Accuracy of implant analogs in 3D printed resin models

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Purpose. To study the effect of implant analog system, print orientation, and analog holder radial offset on 3D linear and absolute angular distortions of implant analogs in 3D printed resin models.

Material and methods. A sectional master model simulating a 2-implant, 3-unit fixed prosthesis in a partially edentulous jaw was fabricated. Three implant analog systems for 3D printed resin models-Straumann (ST), Core3DCentres (CD) and Medentika (MD)-were tested. The corresponding scan bodies were secured onto the implants and scanned using an intraoral scanner. Models were obtained with a Digital Light Processing printer. Each implant analog system had 2 print orientations (transverse [X] and perpendicular [Y] to the printer door) and 2 analog holder radial offsets (0.04 mm and 0.06 mm), for a total of 60 models. The physical positions of the implants in the master model and the analogs in the printed resin models were directly measured with a Coordinate Measuring Machine (CMM). 3D linear distortion (ΔR) and absolute angular distortion (Absdθ) defined the 3D accuracy of the analogs in the printed models. Univariate ANOVA was used to analyse data followed by post hoc tests (Tukey HSD, α=0.05).

Results. Mean ΔR for ST (-155.7 ±60.6 μm), CD (124.9 ±65.0 μm) and MD (-92.9 ±48.0 μm) were significantly different (P<0.01). Mean Absdθ was not significantly different between ST (0.57 ±0.48°) and CD (0.41 ±0.27°), but both were significantly different from MD (2.11 ±1.14°) (P< 0.01). Print orientation had a significant effect on ΔR only but no discernible trend could be found. Analog holder radial offset had no significant effect on ΔR and Absdθ.

Conclusions. Implant analog system had a significant effect on ΔR and Absdθ. Compared to the master model, CD produced greater mean interanalog distances, while ST and MD produced smaller mean interanalog distances. MD exhibited the greatest mean angular distortion which was significantly greater than ST and CD.