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Accuracy of computer-aided design/computer-aided manufacturing–generated dental casts based on intraoral scanner data

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ABSTRACT

Background. Little is known about the accuracy of physical dental casts that are based on three-dimensional (3D) data from an intraoral scanner (IOS). Thus, the authors conducted a study to evaluate the accuracy of full-arch stereolithographic (SLA) and milled casts obtained from scans of three IOSs.

Methods. The authors digitized a polyurethane model using a laboratory reference scanner and three IOSs. They sent the scans (n = five scans per IOS) to the manufacturers to produce five physical dental casts and scanned the casts with the reference scanner. Using 3D evaluation software, the authors superimposed the data sets and compared them.

Results. The mean trueness values of Lava Chairside Oral Scanner C.O.S. (3M ESPE, St. Paul, Minn.), CEREC AC with Bluecam (Sirona, Bensheim, Germany) and iTero (Align Technology, San Jose, Calif.) casts were 67.50 micrometers (95 percent confidence interval [CI], 63.43-71.56), 75.80 µm (95 percent CI, 71.74-79.87) and 98.23 µm (95 percent CI, 94.17-102.30), respectively, with a statistically significant difference among all of the scanners ($P < .05$). The mean precision values were 13.77 µm (95 percent CI, 2.76-24.79), 21.62 µm (95 percent CI, 10.60-32.63) and 48.83 µm (95 percent CI, 37.82-59.85), respectively, with statistically significant differences between CEREC AC with Bluecam and iTero casts, as well as between Lava Chairside Oral Scanner C.O.S. and iTero casts ($P < .05$).

Conclusion. All of the casts showed an acceptable level of accuracy; however, the SLA-based casts (CEREC AC with Bluecam and Lava Chairside Oral Scanner C.O.S.) seemed to be more accurate than milled casts (iTero).

Practical Implications. On the basis of the results of this investigation, the authors suggested that SLA technology was superior for the fabrication of dental casts. Nevertheless, all of the investigated casts showed clinically acceptable accuracy. Clinicians should keep in mind that the highest deviations might occur in the distal areas of the casts.

Key Words. Intraoral scanner; digital impression; milling; stereolithography; dental casts; accuracy; precision; trueness.

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Plaster casts have been used as a standard of care for many years in diagnosis, treatment planning and fabrication of restorations. These casts, however, are subject to loss, fracture and degradation and require storage space.[1,2] To overcome these disadvantages, three-dimensional (3D) digital models obtained from intraoral scanners (IOS) can be used as an alternative to conventional casts. They can be stored easily, require little storage space and can be transmitted digitally,[3] and their use may increase productivity.[4,5] However, some cases, such as those involving complex prosthodontic treatment or removable restorations, still require physical dental casts. Several manufacturers provide physical dental casts based on IOS data sets using either stereolithography (SLA) (Sirona, Bensheim, Germany, and 3M ESPE, St. Paul, Minn.) or milling (Align Technology, San Jose, Calif.).

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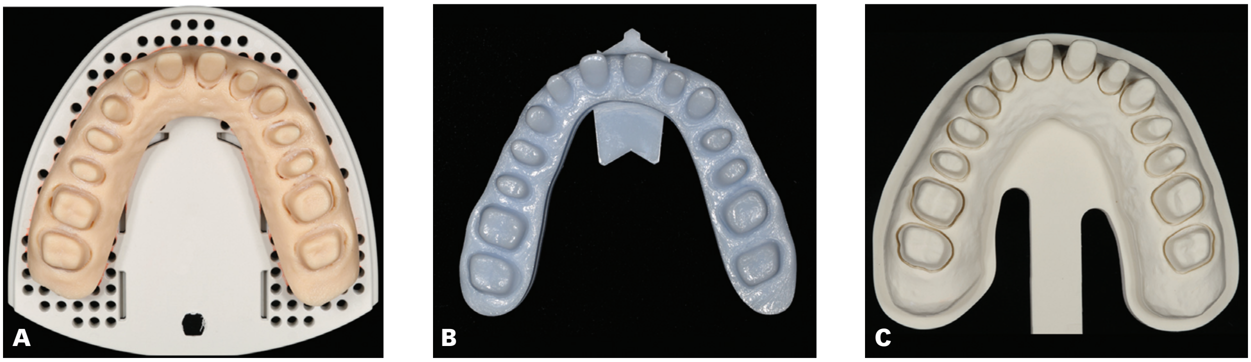

Figure 1. Computer-aided design/computer-aided manufacturing–generated casts. **A.** Stereolithographic cast based on data from CEREC AC with Bluecam (Sirona, Bensheim, Germany). **B.** Stereolithographic cast based on data from Lava Chairside Oral Scanner C.O.S. (3M ESPE, St. Paul, Minn.). **C.** Milled cast based on data from iTero (Align Technology, San Jose, Calif.).

The fabrication technology involved in making these casts uses rapid prototyping. The term "rapid prototyping" describes a variety of processes for manufacturing 3D physical objects using 3D computational data and automated machines.[6-8] In general, it can be distinguished from subtractive and additive technologies. Subtractive technologies—such as computer numerical control machining, laser cutting, water jet cutting, electron beam cutting or electrical discharge machining—use computer-driven machines to cut away material when fabricating the predetermined computer-aided–designed (CAD) object.[9,10] In contrast, additive technologies—such as SLA, selective laser sintering, fused deposition modeling or 3D printing—are used to fabricate the objects by gradually adding materials.[11]

Although most IOS manufacturers offer fabrication of dental casts based on intraoral scan data, there is a lack of studies in which investigators evaluated the dimensional accuracy of these casts. Therefore, we conducted a study to investigate the accuracy, in terms of trueness and precision, of computer-aided design/computer-aided manufacturing (CAD/CAM) –generated casts based on the data of three IOSs.

METHODS

We used three IOSs (CEREC AC with Bluecam, CEREC 3D Service Pack V3.85, Sirona; Lava Chairside Oral Scanner C.O.S., Lava Software 3.0, 3M ESPE; iTero, Software Version 4.0, Align Technology), as well as a laboratory reference scanner (IScan D101, Imetric 3D, Courgenay, Switzerland; manufacturer's specifications: point spacing of 70 micrometers, noise level of 5 µm, repeatability level of ≤ 10 µm, accuracy of ≤ 20 µm) to digitize a full-arch polyurethane cast (Alpa-Pur, Shore A 70, CHT BEZEMA R. Beitlich, Tübingen, Germany) with 14 prepared abutments. First, we digitized the reference model by using the laboratory scanner. Then, one dentist who had received one week of training scanned the reference model with the IOSs (five scans per IOS). Subsequently, we sent the data sets obtained from the IOSs to the manufacturers to have them produce one physical cast per data set by means of SLA or milling (Figure 1). We obtained five physical casts per scanner to use in our evaluation.

Digitization of the reference models and the CAD/CAM-generated casts. To verify the reliability of the reference scanner, we scanned the reference model five times (R_1-R_5) before scanning the same model with the IOSs five times each and again with the reference scanner once after all of the IOS scans (R_6). To avoid contaminating and distorting the data sets due to the essential surface coating of CEREC AC with Bluecam and Lava Chairside Oral Scanner C.O.S., we performed all of the scans under the same conditions (temperature [standard deviation {SD}], 20.5 [1] °C; relative humidity [SD], 51 [2] percent) and followed a specific scanning order:

1. reference scanner (n = 5) (data sets R_1-R_5);
2. iTero (n = 5);
3. Lava Chairside Oral Scanner C.O.S. (n = 5), light coating (Lava Powder, 3M ESPE) and cleaning with a soft brush and air;
4. CEREC AC Bluecam (n = 5), coating (CEREC Optispray, Sirona Dental Systems) and cleaning with a soft brush and air;
5. reference scanner (n = 1) (data set R_6).

For Lava Chairside Oral Scanner C.O.S., the scanning process included a prescan calibration (Lava calibration tool, 3M ESPE), followed by using a zigzagwise scanning process and final recalibration.[12] We performed all other scans according to the manufacturers' instructions. Then we sent the data sets obtained from the three IOSs to the manufacturers to have them produce one physical cast per scan, thereby yielding five physical casts per IOS. After receiving the CAD/CAM-generated casts from the manufacturers, we scanned each cast three times with the reference scanner, resulting in 15 data sets per IOS:

ABBREVIATION KEY. CAD: Computer-aided design. **CAM:** Computer-aided manufacturing. **IOS:** Intraoral scanner. **SLA:** Stereolithographic. **UV:** Ultraviolet. **3D:** Three-dimensional.