Evaluation of Precision of Custom Edentulous Trays Fabricated with 3D Printing Technologies

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Purpose: To evaluate the reserved space quantity and printing accuracy of custom edentulous trays produced by two 3D printing methods (fused deposition modeling [FDM] and stereolithography apparatus [SLA]) and to compare them to traditional handmade (HM) methods. ***Materials and Methods:*** The tissue surface data of maxillary and mandibular edentulous gypsum models were obtained through a 3D scanner to design the digital custom trays in Geomagic software. The custom trays were then printed with FDM and SLA technologies, and handmade custom trays were used as control. The scanned data of printing trays were registered with their digital data, and the printing errors were analyzed using the deviation analysis function. The distances between the tissue surface of gypsum models and the custom trays were measured in ImageWare and represented by 3D deviation. ***Results:*** None of the six groups revealed a significant difference ($P > .05$) compared to the set value of 1.00 mm. In the SLA group, the deviation of the mandibular area was significantly closer to the set value than for the HM group ($P < .05$), while no significant difference was displayed between the other groups. For the printing error between the two 3D groups, the SLA method showed significantly less error and better stability ($P < .001$). ***Conclusion:*** 3D-printed custom trays can meet clinical needs in the adaptability of tissue surfaces, and SLA-printed trays revealed better precision and less error than the other two methods. Accordingly, the use of SLA technology to make a 3D-printed custom tray is expected to be promoted in clinical practice. *Int J Prosthodont 2021;34:109–117. doi: 10.11607/ijp.7101*

With an aging population causing increased life spans, comfortable complete dentures with a convenient and timely fabrication process are ever more in demand. According to the development of the Chinese Oral Health Report,[1] the loss rate of dentition in the 65- to 74-year age group reached 6.8% in 2012, accounting for around 10 million people. With the trend of an aging population, the loss of dentition maintains a certain proportion in the population. In recent years, although implant restorations have achieved great success, complete dentures are still a routine prosthodontic method for edentulous patients.[2] Therefore, the demand and potential for complete dentures will continue to grow, and how to make complete dentures with high efficiency and quality is still a clinical challenge for the restoration of edentulous arches.

As the foundation for manufacturing, the accuracy of the impression and gypsum will affect the retention and stability of the complete denture.[3] Currently, the secondary impression method is still widely applied in the clinic.[4] First, a stock impression tray and alginate impression material are used to obtain the initial impression, into which the primary gypsum is perfused. Second, a custom resin tray is made on the gypsum, and this is used to make the final impression.[5–7] The utilization of custom trays can help the operator obtain an accurate impression according to different anatomical characteristics of the oral cavity, such as the number of residual teeth, frenulum attachment, mucosal condition, and so on. It is conducive to perform a functional border mold and record the extension range of the complete denture under functional conditions.[8,9] In addition, adaptation of custom trays to the patient's oral structure can reduce the patient's discomfort when taking the impression. The thickness of each part of the impression material in the trays is roughly the same so that the deformation of the impression can be minimized. However, some problems

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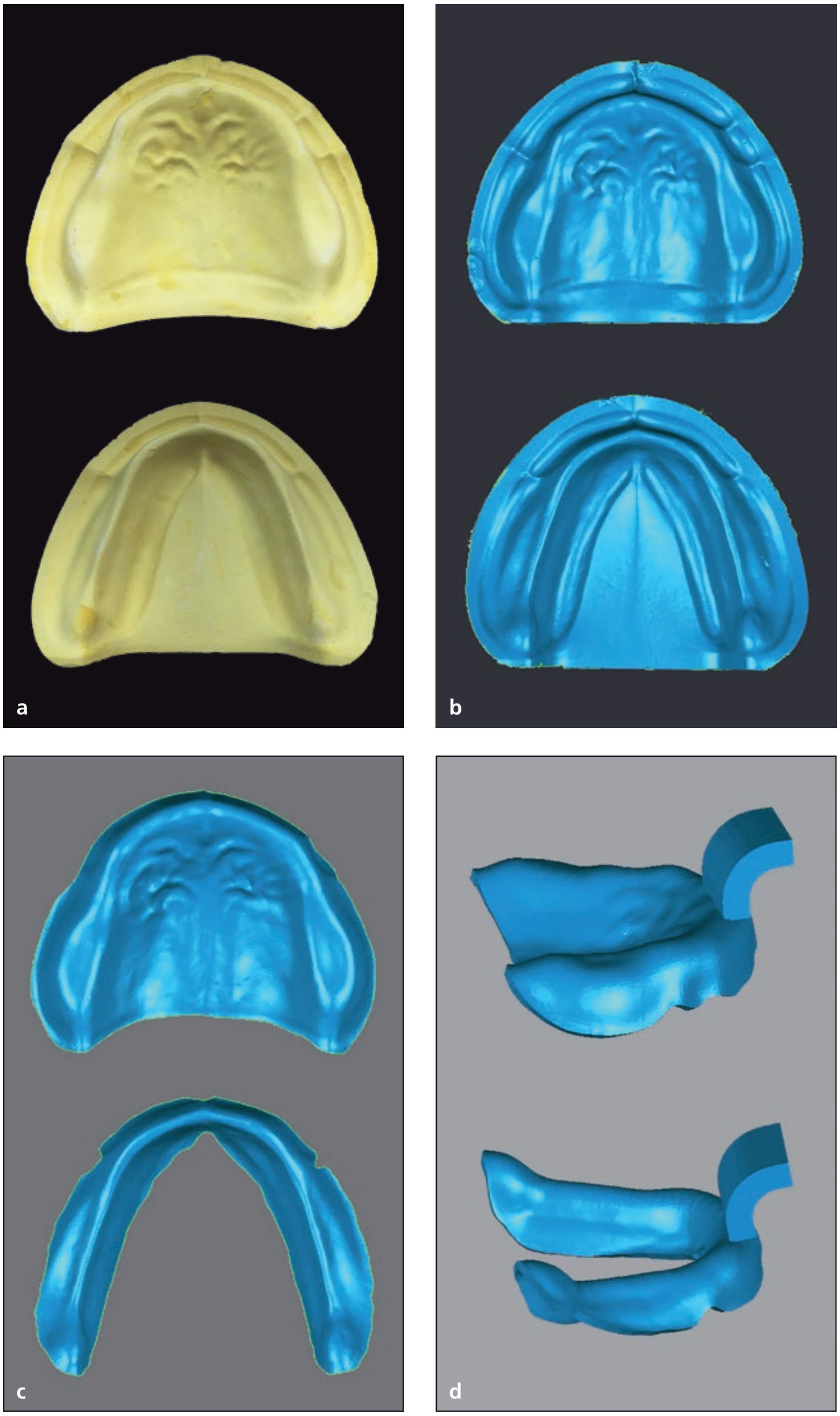

Fig 1 Computer-aided design of custom trays. *(a)* Standard edentulous gypsum model. *(b)* Scanned data of tissue surface. *(c)* Digital data after border molding. *(d)* Finished design of custom trays.

appear in the application of the method: the operation of manual custom trays is tedious, and the primary gypsum is difficult to preserve for a long time and use repeatedly.[10]

Recently, along with the wide application of 3D printing for prosthesis fabrication, more manual operations can be replaced to gain production with higher efficiency and accuracy.[10] 3D printing is technology based on computer-aided design (CAD) digital data that allows fabrication of a physical model via an additive manufacturing method.[11–13] The manufacturing processes mainly include fused deposition modeling (FDM) and use of a stereolithography apparatus (SLA).[14,15] Some researchers have used FDM to complete the manufacturing of custom trays with polylactic acid (PLA) and have discussed the properties of their final impressions. Their results showed that custom trays made by FDM can achieve higher accuracy and reproducibility than handmade (HM) trays.[16,17] However, few studies have used SLA to evaluate the reserved space of 3D-printed custom trays quantitatively, and no study has compared it to traditional manual methods and FDM printing techniques. The maxillary impression emphasizes the closure of the edge and postdam area, while the mandibular impression emphasizes the extension of custom trays in the retromolar pad and the lingual floor of the mouth and closure of the edge. In addition, when compared to maxillary impressions, the edge line of the mandibular impression is much longer and requires higher sealing of the edge. Because of these different key points that must be considered when making maxillary and mandibular edentulous impressions, the present authors believe that these may affect the clinical application of 3D-printed individual trays, and it is necessary to study the manufacturing methods of customized maxillary and mandibular trays.

In this study, three methods (SLA, FDM, and HM) were used to make edentulous custom trays, which were scanned and imported into the computer to analyze the quantity of the reserved space and to evaluate the applicability of these two new techniques. The scanned data were compared to the designed data to analyze errors and stability produced by these different 3D printers in Geomagic Studio and ImageWare software. This study will provide a basis for the clinical application of digital technology for the production of custom trays. The null hypothesis is that custom edentulous trays produced by 3D printing cannot satisfy clinical needs and achieve clinical standards.

MATERIALS AND METHODS

Equipment and Materials

The equipment used in the study was: a 3D scanner (AutoScan-DS100+, Shining 3D); reverse engineering software (Geomagic Studio 12, Raindrop; ImageWare 13, Siemens); an SLA 3D printer (SLA600, ProtoFab; printing accuracy = 0.1 mm, positioning parameters: x-axis and y-axis = 0.01 mm, z-axis = 0.002 mm); and an FDM 3D printer (Replicator 2X, MakerBot; printing accuracy = 0.1 mm, positioning accuracy: x-axis and y-axis = 0.011 mm, z-axis = 0.0025 mm). The materials used were photosensitive resin (Somos EvoLVE 128, DSM), PLA (NatureWorks), and light-cured resin sheet (MEGADENTA).

Edentulous Gypsum Model Preparation and 3D Data Acquisition

Five maxillary and five mandibular anhydrite models were perfused with the same standard edentulous gypsum models, which were numbered 1 to 5 (Fig 1a). Their tissue surface data were obtained through a 3D scanner and preserved in stereolithographic (STL) format (Fig 1b).

CAD of Custom Trays

The digital data of these 10 models were imported into the reverse engineering software Geomagic Studio 12 and designed through the following steps: *(1)* border modeling (Fig 1c); *(2)* use of the function "Deviation Command" to offset 1 mm along the model surface to form the inner surface of the custom trays; *(3)* use of the function "Extraction Command" to offset the inner surface 2 mm along the model surface to form the outer surface and to obtain a 2-mm–thick entity; and *(4)* addition of the designed handle to the custom tray (Fig 1d).

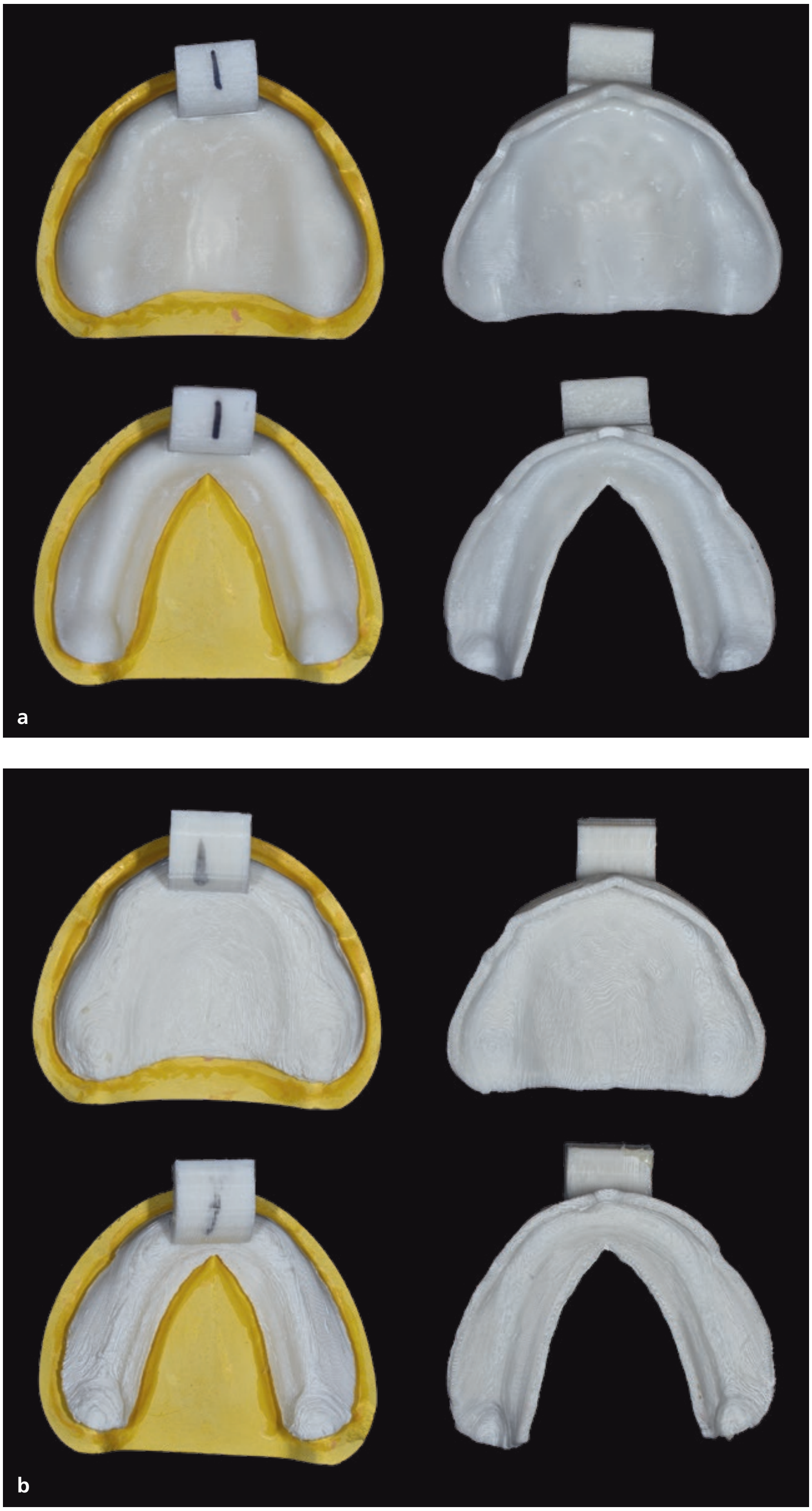

Fig 2 3D-printed custom trays. *(a)* SLA-printed custom trays (polished surface and tissue surface). *(b)* FDM-printed custom trays (polished surface and tissue surface).

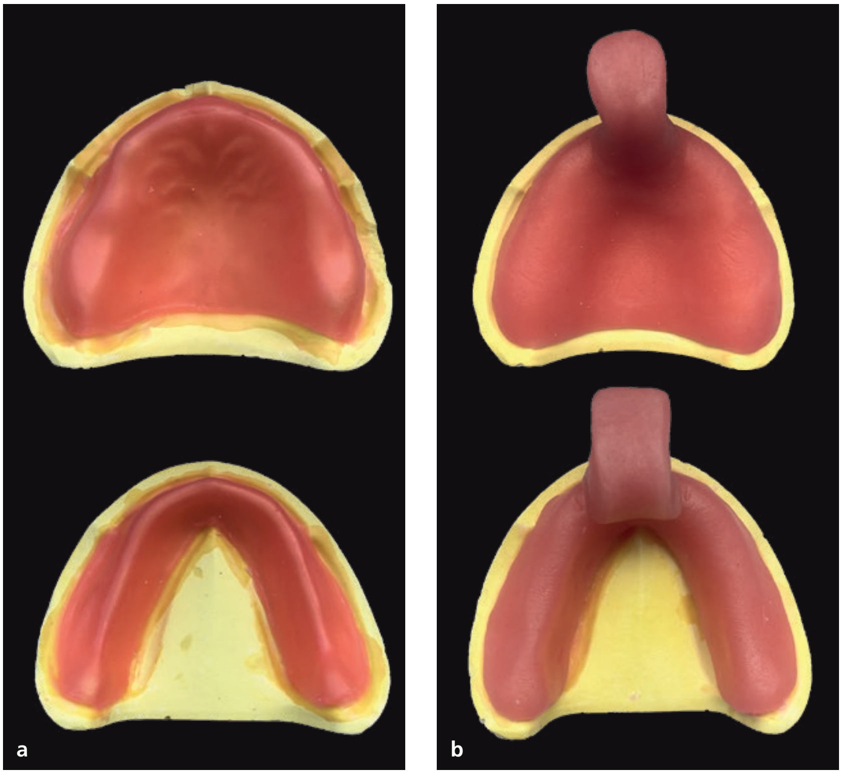

Fig 3 Manufacturing of custom trays. *(a)* Edentulous models with 1-mm baked wax laying on the tissue surfaces. *(b)* Finished handmade custom trays.

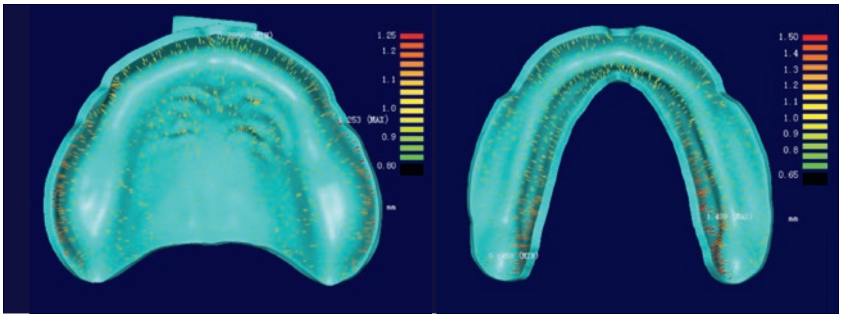

Fig 4 Evaluation of reserved space between the scanned data of finished products made through SLA, FDM, or HM fabrication and the edentulous model tissue surface digital data in Imageware 13.

3D Printing of Custom Trays

The designed custom tray data were imported into the SLA and FDM 3D printers separately. Photosensitive resin was used as the raw material to make the SLA trays (Fig 2a), while PLA was used to make FDM trays (Fig 2b). In the SLA group, postprocessing included cleaning, support removing, sandpaper grinding, and postpolymerization for 15 minutes, while the FDM group included support-removing and grinding-polishing processes.

Manufacturing of Custom Trays

Ten custom trays in the control group were handmade on the same corresponding standard edentulous gypsum models using the traditional method. First, a 1-mm–thick wax was baked to be soft enough to lay on the tissue surface of the gypsum model (Fig 3a). After cooling, the 2-mm–thick photosensitive resin was spread on the surface of the wax and trimmed to the appropriate form. Finally, the handle made of excess resin was bonded to the body of the custom tray and irradiated with a light-emitting diode curing light for 10 minutes to make sure it solidified enough (Fig 3b).

Evaluation of the Reserved Space

For each tray in each group, the deviation between the tissue surface of the custom trays and models was measured using the following procedure: the scanned and designed data of the custom trays were imported into Geomagic Studio 12 to perform a best-fit alignment with the "Best Fitting Alignment Command," with the designed STL files as references and the scanned files as test objects. The sample size was set to 25,000, and the tolerance was set to 0.10 mm. The aligned data were then imported into ImageWare 13, and about 1,000 corresponding sample points on the tissue surfaces of the trays were selected to calculate the distance distribution of the corresponding sample points on the tissue surface of the gypsum model; that is, the size distribution of the reserved space (Fig 4).

Error Analysis of 3D Printing

The scanned data of SLA and FDM custom trays were obtained through the 3D scanner. After importing the scanned and designed data into Geomagic 12, the printing error was compared using the "Deviation Command" function after alignment with the "Best Fitting Command" function (Figs 5a and 5b). Then, about 1,000 sample points of each tray were collected for statistical analysis of the deviation in Imageware 13 (Fig 5c).

Statistical Analyses

All statistical tests were performed in SPSS 22.0 (IBM). The outlier test was used to test the exception and extreme values, and Shapiro-Wilk test and Levene test were performed to test the normality and equality of variance, respectively. In the two handmade groups and the mandibular FDM group, the medians were compared with a set value of 1.00 mm using Wilcoxon signed-rank test, and the means of the other groups were tested using one-sample *t* test. Kruskal-Wallis H test was performed to test the differences among the medians of distance in both the maxilla and mandible between each group. Independent sample *t* test was used to compare the printing error data. *P* values ≤ .05 were considered to be statistically significant.

RESULTS

This study compared the accuracy of custom trays produced by different fabrication processes through evaluating the distribution of the reserved space. The expected reserved space distribution was that the distance between the tissue surface of the gypsum model and the sample points on the custom tray would be 1.00 mm.

Figure 6 indicates that for both the maxilla and mandible, the SLA groups were closest to the set value of 1.00 mm and had the lowest deviation. Shapiro-Wilk test showed that all groups satisfied the assumption of normality; however, both HM groups had an exception value, and the mandibular FDM group had an extreme value. Hence, Wilcoxon signed-rank test was chosen to test whether the deviation was significantly different from the set value in these three groups, while other groups were tested with one-sample *t* test. All these tests indicated no significant differences for the means or medians of deviation from the set value ($P > .05$), which suggests that

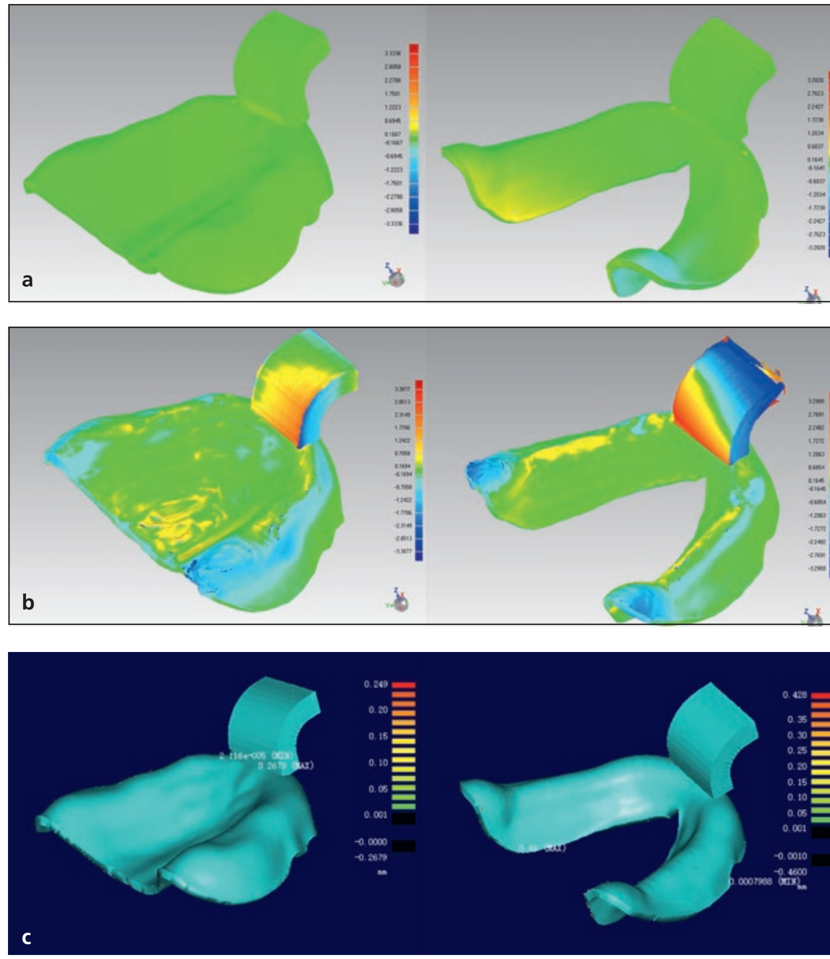

Fig 5 Error analysis of *(a)* SLA-printed custom trays and *(b)* FDM-printed custom trays in Geomagic 12. *(c)* Point cloud deviation between designed trays and scanned trays in ImageWare 13.

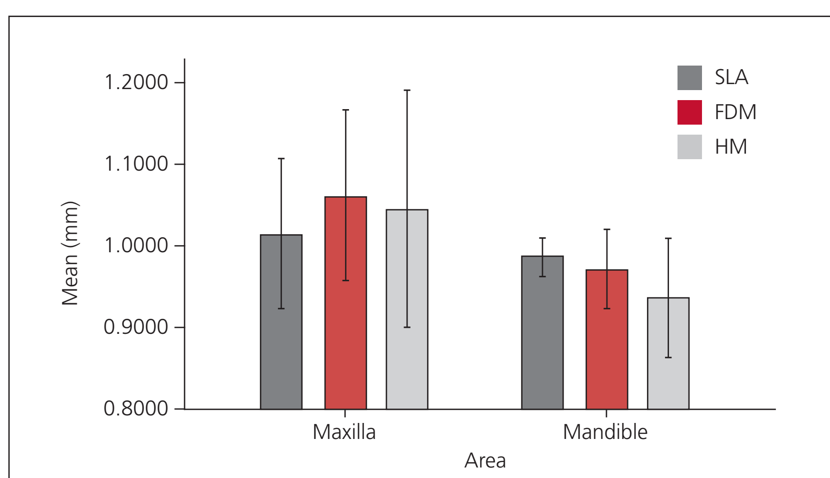

Fig 6 Means of distance distribution in maxilla and mandible in all groups.

Table 1 Differences Between Mean or Median Deviation and Set Value (mm)

Area/group	Mean	SD	Median	Set value	*P* value
Maxillary model					
SLA	1.0141	0.0747	0.9957	1.0000	.6950
FDM	1.0603	0.0850	1.0494	1.0000	.1880
HM[a]	1.0428	0.0772	1.0368	1.0000	.2250[a]
Mandibular model					
SLA	0.9860	0.0188	0.9833	1.0000	.1710
FDM[a]	0.9709	0.0403	0.9738	1.0000	.0800[a]
HM[a]	0.9420	0.0585	0.9526	1.0000	.0800[a]

SLA = stereolithography apparatus; FDM = fused deposition modeling; HM = handmade.
[a]Median value was tested with Wilcoxon signed-rank test.

Table 2 Differences Between Mean and Median Deviation (mm) Among Groups

Area/group	Mean	SD	Median
Maxillary model			
SLA	0.0585	0.0392	0.0595
FDM	0.0763	0.0671	0.0494
HM	0.0934	0.0703	0.1050
Mandibular model[a]			
SLA	0.0169	0.0155	0.0167
FDM	0.0370	0.0311	0.0262
HM	0.0659	0.0469	0.0474

According to Kruskal-Wallis test, the null hypothesis was accepted for the maxillary model data and was rejected for the mandibular model data.
[a]The comparison between the SLM and HM groups showed a statistically significant difference in the mandible area (adjusted $P = .033$). For SLA vs FDM: $P = .269$. For FDM vs HM: $P = 1.000$.

Table 3 Mean and SD 3D Printing Error (mm) and Differences Between Groups

Group	Mean	SD
SLA	0.0907	0.0358
FDM	0.2241	0.0394

Levene test for equality of variances: $F = 0.001$, $P = .981$.
Independent sample *t* test: $t = –7.930$, degrees of freedom = 18, *P* (2-tailed) = .000.

all three methods could meet clinical needs in producing the custom trays (Table 1).

Before the post hoc comparison of differences between the deviation data and set value among the three groups in the maxilla and mandible, an outlier test showed an exception value and Shapiro-Wilk test found that the FDM group did not satisfy the assumption of normality, so Kruskal-Wallis test was performed to test the differences between each group. The significance level was adjusted, and the results indicated that the SLA and HM groups showed a statistically significant difference in the mandible area ($P < .05$). No significant differences were found for other comparisons (Table 2).

The printing error between the two 3D printing methods was tested with independent *t* test after confirming the data of the two groups had no exceptions and satisfied the assumption of normality and equality. The results indicated that the SLA printing method had less error and better stability, with statistically significant differences for both comparisons ($P < .01$; Table 3).

DISCUSSION

In the clinical setting, the edentulous gypsum model is usually made with a stock impression tray and alginate impression material to obtain the first impression, and then a resin tray is paved on the gypsum model to be used to make the final impression with alginate or silicone impression material.[7] This process requires the pouring of two gypsum models, which is a more complex operation, and the initial gypsum model is difficult to preserve long term and reuse. Besides, the accuracy of custom trays manufactured by traditional methods may be related to the experience of the operators, the change of uneven wax thickness, and the deformation of custom trays in the whole process.[18] In this study, digital design and two kinds of 3D printing technology were used to make custom trays, and these methods could set the size of the reserved space according to the needs of different impression materials and eliminate the wax-related factors on the size of the space reserved. A steady quantity of reserved space is conducive to the uniform flow and distribution of impression materials in the gap between the tissue surface of the tray and mucosa, reducing the patient's tenderness in the process of preparation of the final impression. Besides, a good impression is propitious for denture base production in the future, reducing tenderness after the final denture production. In addition, the research process and method of this experiment lay a foundation for the study of 3D printing complete denture bases in the future and could be the key to the study of complete denture manufacturing accuracy.

3D printing is a rapid prototyping technology that is based on digital model files and uses powdery metal or plastic and other adhesive materials to construct objects by printing in layers.[19] FDM has the advantages of high product strength and low equipment or material cost, but its lack of molding accuracy or printing precision are apparent. The technical principle is that the designed 3D CAD solid model is first discretized and divided into thin layers of a certain thickness according to the geometric shape change (called "stratification"), and the profile of the section and the filling trajectory are obtained. The control system melts filamentous thermoplastic materials.[20] At the same time, under the control of the computer, the 3D sprinkler is selectively applied to the worktable according to the profile and filling track information. A layer of cross-section is formed after rapid cooling, and the nozzle rises to a certain height and continues to print on the next floor, repeating the above process and continuing to melt spray until the whole solid shape is formed.[21–23] Because of its layer-by-layer printing process, it is difficult for the FDM group to avoid the "step effect," and generally the surface roughness of an FDM printing product is relatively large. In addition, support structure needs to be added in the printing process. Therefore, support removing, grinding, and polishing are usually required after the FDM printing process. The purpose of such postprocessing is to remove the burr and processing lines on the surface of the printing products so as to make the surface of the parts brighter and smoother. Considering that these processes might have a certain impact on the results of this experiment, more attention should be paid to guarantee that printing trays are kept the intact shape—for example, using sandpaper with smaller particles to grind carefully and slowly during the polishing process. Sun et al used FDM to manufacture custom trays for complete dentures with PLA and discussed the properties of their final impressions. Their results showed that the tissue surfaces of FDM custom trays were well adapted, which further confirms the feasibility of applying 3D printing to custom trays.[16] The present study almost confirmed their conclusion, but found that the surfaces and edges of FDM products were rough, as shown in Fig 2b. The reason for this may be that the FDM process uses the nozzle spinning method to extrude materials. Due to the limitation of nozzle size, the product surface will inevitably produce a filamentous irregular surface. Hence, lack of molding accuracy and rough product surface of FDM products are also obvious.

Compared to FDM, SLA has the advantages of a high utilization rate of raw materials, fast-forming speed, high dimensional precision, excellent surface quality, complex structure model, low cost, and easy maintenance of equipment.[24] SLA is based on the photocuring principle of liquid photosensitive resin, which enables the material to be cured by a rapid cross-linking reaction under a certain intensity and wavelength of ultraviolet radiation. The liquid photosensitive resin is placed in the slot of the SLA printer. After the light curing begins, the ultraviolet laser beam is controlled by the computer control mirror system in accordance with the layered scanning path of the object to be printed. On the surface of the liquid resin, the first curing layer is completed. Then the lifting platform drops a certain distance and continues to scan and solidify the next layer until the 3D solid model is completed.[12,25,26] Due to the principle of light curing, it is unavoidable to add support and have a step effect in the SLA printing process. Therefore, cleaning, support removing, grinding, and postpolymerization were necessary postprocessing steps. First, when using alcohol or other organic solvents to completely wash away the residual photosensitive resin on the surface of printing trays, attention should be paid to avoid direct contact with the skin. Then, a slow-grinding bur should be used to remove the redundant structure that used to offer support, and the surface (especially the parts with an obvious step effect and support) should be ground with sandpaper to achieve better roughness and dimensional accuracy. Finally, the formed trays should be put into the UV curing box for 15 minutes further curing to improve the strength of the formed part. Postpolymerization was very important to obtain stability of size and strength. For years, SLA has been used for surgical planning and guiding for dental implants, which can reduce operating time, surgical trauma, and recovery period.[27] Furthermore, SLA is also used in manufacturing custom implants, temporary crowns, and partial dentures, as well as resin models for lost wax gypsum, which can achieve precise, stable, and biomechanical properties.[28] In the present study, the surfaces of the product using photosensitive resin were smooth, as shown in Fig 2a. The deviation analysis indicated that the spatial distribution of the SLA process was more stable and closer to the set value than FDM, which suggests that SLA printing trays could provide more stable space for alginate impression material when making the final impression. This was of great significance for the buffer zone and mucosal area, where tenderness should be avoided. If the uniform impression space cannot be reserved, there will not be a continuous complete impression, and obvious tenderness may occur during the wearing process of the base. Moreover, a photosensitive resin tray has great convenience in the edge dressing, polishing, and other aspects of the rough surface compared to the PLA custom tray, but can also reduce the mold removal of patients with oral tissue stimulation and help the patient feel more relaxed in this uncomfortable process. Recently, SLA has increased the use of the photocrosslinkable polymer library and biodegradable resin with encapsulation of cells, which may make it possible to solve the disadvantage of the cytotoxicity of unreactive monomers, residual photoinitiators, and the scarcity of biocompatible resins with good processability.[12] Some scholars have added titanium dioxide nanoparticles to photosensitive resins and applied them to the manufacture of complete dentures with SLA technology so that the finished products have certain antibacterial properties.[29] In the future, material research in SLA technology will be of great concern.

The impact of the matching process in the present study is also worthy of attention. The SLA group finished the process of software alignment in almost 20 seconds, the FDM group needed more than 3 minutes, and the HM group took almost 1 minute. Further analysis indicated that, because of the smoothness of the SLA group, the matching process was easier for the software's automatic program than the FDM group. Due to the rough surface in the FDM group, there were more points on the trays per unit area, proving a great challenge for the automatic alignment function of the software. This may also be a reason why the FDM group did not perform well in this analysis method. As for the HM group, although there is no connection with the design data in the process of production, the alignment was relatively smooth. The main error may be that their handle shapes were quite different.

In order to control printing errors, a special 3D dental scanner (DS 100+), which was suitable for small-scale model scanning and had higher accuracy, was adopted. Considering the space reserved for this experiment was 1 mm, the accuracy of the selected scanner, which was less than 0.015 mm, could meet the experimental requirements. In this study, edentulous gypsum models and custom trays were scanned by the same scanner to reduce errors. In the calculation of reserved space of custom trays, the design data and handmade trays were aligned using the "Best Fitting Command." In order to reduce the error of best fit, the number of sampling points was set to 1,000, and the tolerance was set to 0.001 mm. The accuracy of the SLA printer and FDM printer used in this experiment were both 0.1 mm. In this study, the accuracy of the SLA printer was better than that of the FDM printer, as shown in Table 3 and Figs 5a and 5b.

As for manufacturing time, the finished product time of FDM printing was about 45 minutes, and that of SLA was about 30 minutes. The time for 3D scanning and software design was about 10 minutes, while the total time for traditional manual production was about 20 minutes. Although the total time for 3D printing technology was longer, this was mainly because of the 3D printer working hours, and the manual time was less than the traditional manual method. From the perspective of material cost, these three methods were not very different, but the 3D printing processes could save the impression material and model material costs because it did not need to pour the initial impression.

This research only studied the custom trays of standard edentulous arches. In the future, edentulous arches with various conditions of the alveolar ridge should be studied in the clinic. The tissue surface data of the model deviated by 1.00 mm evenly, but the buffer zone was not considered. A larger offset should be set at the osteoid process or the soft alveolar ridge, where the buffer was needed. It was necessary to spray the imaging agent during the tray scanning process. The uneven spraying during the operation may lead to data error of the tray tissue surface; therefore, more accurate scanning methods are expected in the future.

CONCLUSIONS

Custom trays produced by 3D printing technology can meet clinical needs in the adaptability of the tissue surface. SLA technology using photosensitive resin as a fabrication material results in smoother surfaces than FDM technology using PLA. Although no significant results implied that the SLA method was more precise, the use of an SLA 3D printer to make custom trays showed clinically acceptable reserved space and is worth promoting in the clinic.

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Literature Abstract

Saliva in the Diagnosis of COVID-19: A Review and New Research Directions

This review presents literature that highlights saliva's utility as a biofluid in the diagnosis and monitoring of COVID-19. A systematic search was performed in five electronic databases (PubMed, Embase, LILACS, Scopus, and Web of Science). Studies were eligible for inclusion if they assessed the potential diagnostic value and/or other discriminatory properties of biologic markers in the saliva of patients with COVID-19. As of July 22, 2020, a total of 28 studies have investigated the presence of SARS-CoV-2 RNA in saliva. Several of those studies confirmed reliable detection of SARS-CoV-2 in the saliva of patients with COVID-19. Saliva offered sensitivity and specificity for SARS-CoV-2 detection comparable to that of the current standard of nasopharyngeal and throat swabs. However, the utility of saliva in diagnosing COVID-19 infection remains understudied. Clinical studies with larger patient populations that measure recordings at different stages during the disease are still necessary to confirm the accuracy of a COVID-19 diagnosis with saliva. Nevertheless, the utility of saliva as a diagnostic tool opens the possibility of using rapid and less invasive diagnostic strategies by targeting bioanalyses rather than the pathogen.

Fernandes LL, Pacheco VB, Borges L, et al. *J Dent Res* 2020;99:1435–1443. **References:** 57. **Reprints:** D. Heller, Debora.heller@cruzeirodosul.edu —*Steven Sadowsky, USA*

Literature Abstract

Risk for Dental Healthcare Professionals During the COVID-19 Global Pandemic: An Evidence-Based Assessment

Heightened anxiety among dental health care professionals (DHPs) during the COVID-19 pandemic stems from uncertainties about the effectiveness of personal protective equipment (PPE) against dental aerosols and the risk levels of asymptomatic patients. The objective of this study was therefore to assess the risks for DHPs providing dental care during the pandemic based on available scientific evidence. The best available evidence was reviewed, and the annual risk was estimated ($p = d_a s(1 - 1 - p_0 p_1 (1 - e)^{yn})$ for a DHP during the COVID-19 pandemic based on the following basic parameters: p_0 = the prevalence of asymptomatic patients in the local population; p_1 = the probability that a DHP becomes infected by an asymptomatic patient; e = the effectiveness of the PPE; s = the probability of becoming symptomatic after becoming infected from an asymptomatic patient; d_a = the probability of dying from the disease in age group a; n = the number of patients seen per day; and y = the number of days worked per year. With the assumption that DHPs work full time and wear an N95 mask, the annual probability for a DHP to acquire COVID-19 infection in a dental office, become symptomatic, and die from the infection is estimated at 1:13,000 (0.008%) in a medium-sized city in the US at the peak of the pandemic. The risk estimate is highly age-dependent. Risk to DHPs under the age of 70 is negligible when the prevalence of asymptomatic cases is low in the local community. The risk of COVID-19 transmission in the dental office is very low based on available evidence on the effectiveness of PPE and the prevalence of asymptomatic patients. Face shields and preprocedure oral rinses may further reduce the risks.

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