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RESEARCH AND EDUCATION

Design parameters of polylactic acid custom trays manufactured by fused deposition modeling for partial edentulism: Consideration of the accuracy of the definitive cast

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ABSTRACT

Statement of problem. The effects of design parameters of polylactic acid (PLA) custom trays manufactured by fused deposition modeling (FDM) on the accuracy of partially edentulous definitive casts have not been thoroughly explored.

Purpose. The purpose of this in vitro study was to explore the effects of the impression gap and base thickness of FDM-printed PLA custom trays on the accuracy of maxillary and mandibular definitive casts with Kennedy class II, modification I partial edentulism and to optimize these 2 design parameters.

Material and methods. Custom trays with a 1-mm, 2-mm, or 3-mm impression gap and 1-mm, 1.5-mm, or 2-mm base thickness were designed on a pair of maxillary and mandibular resin casts and printed with PLA materials by using an FDM printer. Two-step silicone impressions were made by using these custom trays or stock metal trays on resin casts. Digital scans of definitive casts from these impressions were aligned one by one with those of resin casts. Three-dimensional deviations of the tooth area, mucosal area, and overall area were analyzed by using root mean square (RMS) as a metric. Two-way and 1-way analyses of variance with the RMSs as the dependent variable were carried out (α=.05).

Results. The accuracy of definitive casts from custom trays with a 2.0-mm or 3.0-mm impression gap and 1.5-mm or 2.0-mm base thickness was significantly better than that of definitive casts from custom trays with a 1.0-mm impression gap or 1.0-mm base thickness and was not significantly different from that of definitive casts from stock metal trays.

Conclusions. Considering the accuracy of definitive casts, the optimal base thickness of FDM-printed PLA custom trays was 1.5 mm or 2.0 mm and the optimal impression gap was 2.0 mm or 3.0 mm for Kennedy class II, modification I partial edentulism. (J Prosthet Dent 2022;127:288.e1-e11)

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Clinical Implications

The impression gap and base thickness of FDM-printed PLA custom trays affects the accuracy of definitive casts. FDM-printed PLA custom trays with a 2.0-mm or 3.0-mm impression gap and 1.5-mm or 2.0-mm base thickness should be used to make functional impressions for patients with Kennedy class II, modification I partial edentulism.

A functional impression helps prevent a distal-extension removable partial denture from displacing away from the residual ridge distal to the last abutment.[1] Unlike an anatomic impression, this type of impression cannot be easily obtained by using an intraoral scanner,[2] and a traditional impression made in a custom tray is still widely used for patients with Kennedy class I or II partial edentulism. Custom trays have been traditionally made of autopolymerizing or light-polymerizing acrylic resin, but these are time-consuming to make and may be of low accuracy.[1] The recent application of additive manufacturing technologies in the field of prosthodontics has led to fused deposition modeling (FDM) printers becoming popular because of their small size and biocompatible materials, for example, polylactic acid (PLA),[3,4] with good mechanical properties. To meet the International Organization for Standardization (ISO) 20795-1 standard, the ultimate flexural strength of light-polymerizing resin should be no less than 65 MPa and its flexural modulus at least 2000 MPa.[5] The flexural strength of 3D-printed PLA with an infill density of 80% is more than 80 MPa, and its flexural modulus is more than 3000 MPa.[6]

FDM-printed PLA custom trays have been introduced but mainly for complete dentures or implant restorations.[7-11] In addition, previous studies have mainly evaluated the printing accuracy of custom trays.[7,8] Compared with the printing accuracy of custom trays, the accuracy of impressions or definitive casts made by using custom trays has rarely been reported[9,10]; however, it is of greater clinical significance. The accuracy index usually refers to the gap between the intaglio surfaces of the impression and casts and, more generally, the 3D deviation of the intaglio surface of definitive casts from the resin casts.

Design parameters of custom trays, for example, impression gap, base thickness, relief, tissue stops, perforation hole spacing and diameter, and shape and orientation of tray handles, are important to determine the accuracy of definitive casts and affect the costs and build time of 3D printing.[12] Different studies have used different impression gap values of custom trays for partial edentulism; for example, 2 mm was recommend by Vitti et al [13] and 3 mm by Jain and Dhanaj.[14] Tavakolizadeh et al[10] concluded that there was no significant difference between the accuracy of casts from custom trays with a 2-mm impression gap and that from custom trays with a 4-mm impression gap for Kennedy class I partial edentulism. Jain and Dhanaj[14] suggested that the impression gap is related to the type of impression materials and presence of undercuts. The optimal impression gap values of custom trays for partial edentulism need additional study.

Unlike the impression gap, the effects of the base thickness of custom trays on the accuracy of impressions and definitive casts have attracted less research. Chen et al[7] stated that it was usual to fabricate 2-mm hand-made custom trays made of light-polymerizing resin for edentulous patients. Tavakolizadeh et al[10] used FDM-printed custom trays with a 2-mm base thickness for Kennedy class I partial edentulism. However, the strength and adhesion of PLA differ from those of the light-polymerizing resin used to make hand-made custom trays. Therefore, the base thickness value of hand-made custom trays should not be directly applied to the design of FDM-printed PLA custom trays, except with additional evidence. Therefore, the purpose of this in vitro study was to determine the effects of the

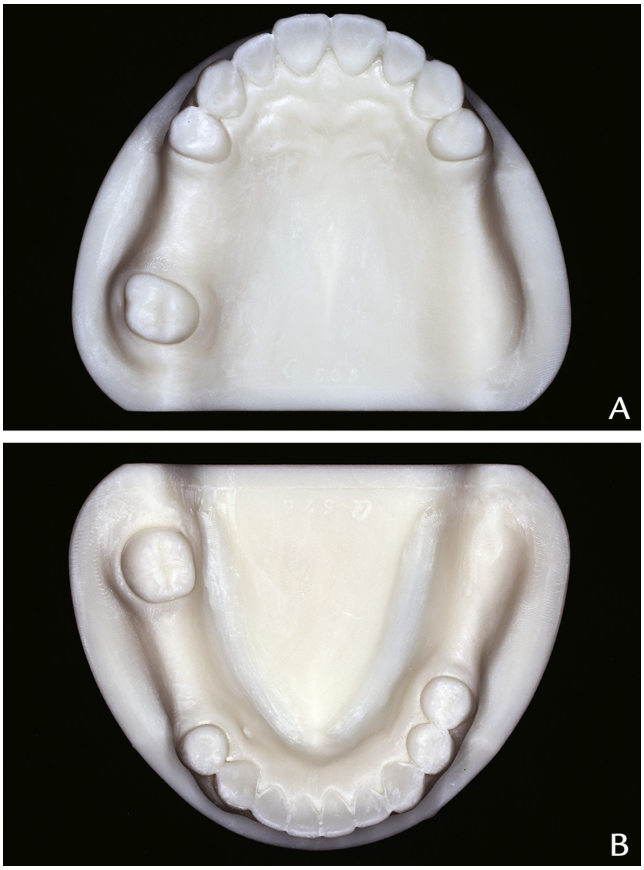

Figure 1. Partially edentulous resin casts. A, Maxillary. B, Mandibular.

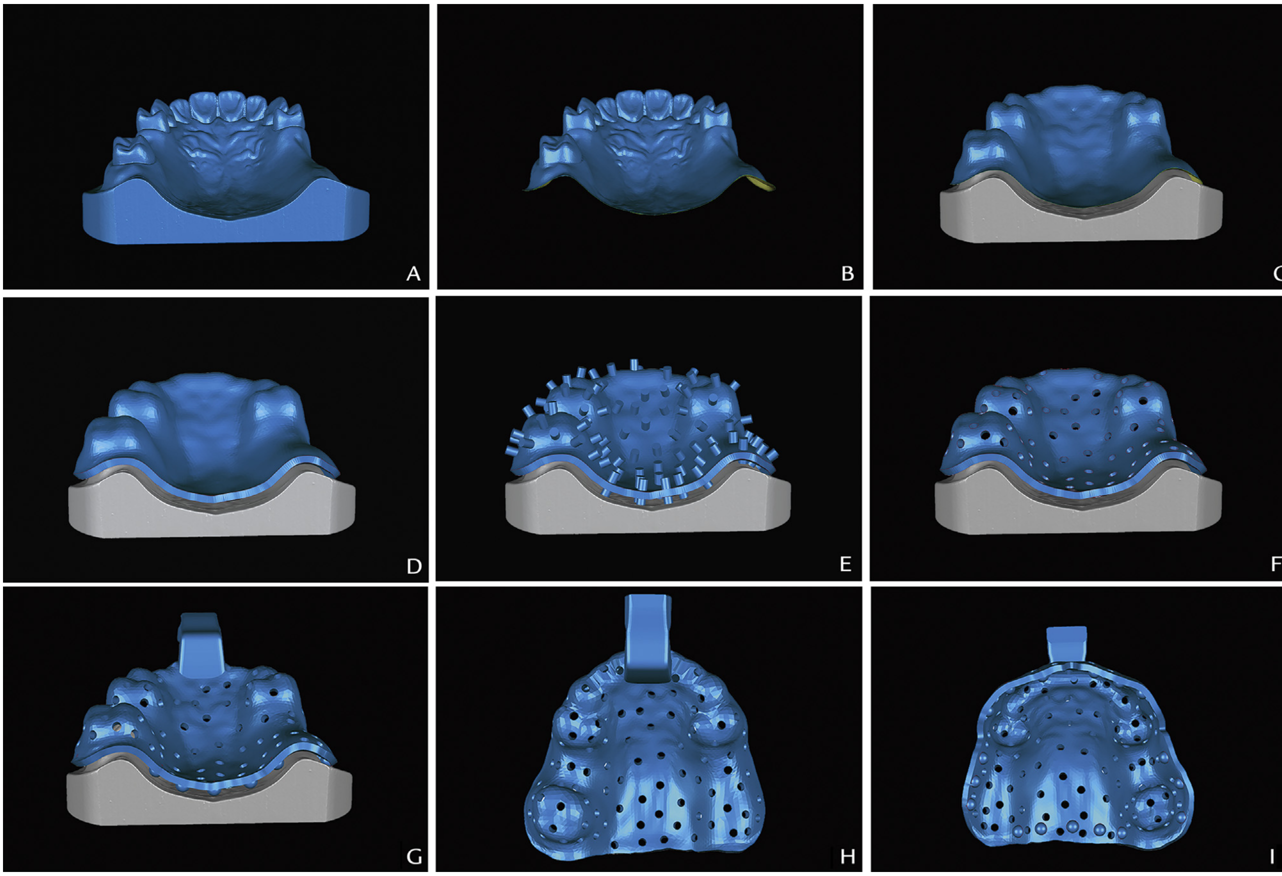

Figure 2. CAD procedure of maxillary custom tray. A-C, Digital scan of resin cast trimmed and offset to preserve impression gap. D, Offset surface shelled to form tray base. E, F, Cylinders subtracted from tray base to form perforations. G, Handle created in custom tray CAD software program merged with tray base and hemispheric tissue stops added on margin area of intaglio surface to hold impression gap during impression making. H, I, Top view and bottom view of finished maxillary custom tray. CAD, computer-aided design.

impression gap and base thickness of FDM-printed PLA custom trays on the accuracy of maxillary and mandibular definitive casts with Kennedy class II, modification I partial edentulism, to optimize these 2 design parameters, and to compare the accuracy of definitive casts from FDM-printed custom trays with that of definitive casts from stock metal trays. The null hypotheses were that the impression gap and base thickness would have no significant effect on the accuracy of partially edentulous definitive casts and that definitive casts from different groups of trays would have similar accuracy.

Table 1. Factorial experiment design

ID	Group	Model (n=5)	Impression Gap (mm)	Base T hickness (mm)
0	Control	Con.	-	-
1	Experimental	G_1T_1	1.0	1.0
2	Experimental	$G_1T_{1.5}$	1.0	1.5
3	Experimental	G_1T_2	1.0	2.0
4	Experimental	G_2T_1	2.0	1.0
5	Experimental	$G_2T_{1.5}$	2.0	1.5
6	Experimental	G_2T_2	2.0	2.0
7	Experimental	G_3T_1	3.0	1.0
8	Experimental	$G_3T_{1.5}$	3.0	1.5
9	Experimental	G_3T_2	3.0	2.0

MATERIAL AND METHODS

A pair of partially edentulous resin casts with missing second premolars, first molars, and left second molars (Fig. 1) were scanned (IScan D104i; Imetric 3D SA) as the reference data. The scans were imported into a reverse engineering software program (Geomagic Studio 2014; 3D Systems Corp). The procedure for designing the maxillary custom trays is illustrated in Figure 2. The radius of tissue stop hemispheres was equal to the impression gap. Custom trays with a 1.0-mm, 2.0-mm, or 3.0-mm impression gap and 1.0-mm, 1.5-mm, or 2.0-mm base thickness were designed (Table 1). Mandibular custom trays were designed in a similar manner. The custom trays were printed by using an FDM printer (Flashforge Dreamer NX; Zhejiang Flashforge 3D Technology Co, Ltd) and with PLA filament materials

Table 2. Basic printing parameters of polylactic acid custom trays

Layer Height	Fill Density	Printing Speed	Printing Temperature	Support Type	Filament Diameter	Filament Flow
0.18 mm	100%	80 mm/s	200 °C	Lines	1.75 mm	100%

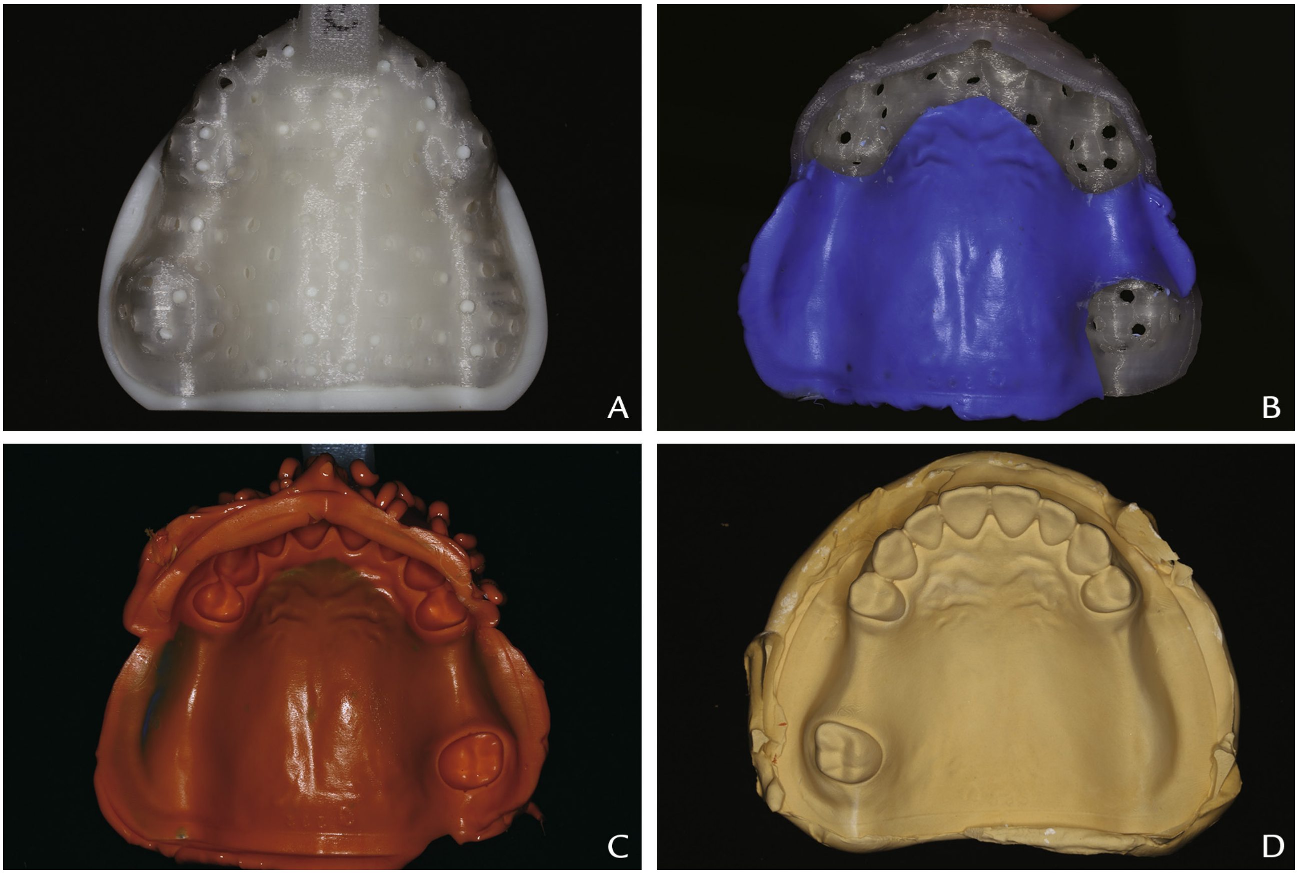

Figure 3. Workflow of making maxillary definitive casts by using custom trays. A, FDM-printed custom tray on resin cast. B, Preliminary impression. C, Definitive impression. D, Definitive cast. FDM, fused deposition modeling.

(Flashforge PLA; Zhejiang Flashforge 3D Technology Co, Ltd). Each custom tray was oriented at the same angle with the handle at the bottom and the base at the top during printing. Table 2 shows printing settings and properties of the PLA filament materials.

The fit of maxillary custom trays on partially edentulous resin casts is seen in Figure 3A. A heavy-body polyvinyl siloxane impression material (Type 1; Huge Co, Ltd) was automixed from the cartridge tips and injected on the mucosal area of the maxillary custom trays and seated precisely on the maxillary resin cast with the tissue stop hemispheres contacting and then held without movement until the impression material had polymerized at room temperature. The tray and preliminary impression were removed from the resin cast, the impression material of the tooth area was removed (Fig. 3B), an automixed light-body polyvinyl siloxane impression material (Type 3; Huge Co, Ltd) was injected over the preliminary impression, and the definitive impression was made to simulate functional impression making (Fig. 3C). The dried impression was poured with vacuum-mixed stone (profilare 100; dentona AG) over a vibrator and then allowed to set to make maxillary definitive casts (Fig. 3D). Mandibular definitive casts were made in a similar manner, as seen in Figure 4. The control group was 2-step impressions made with putty (Rapid Soft; Coltène) and light-bodied (Type 3; Huge Co, Ltd) polyvinyl siloxane impression materials in stock trays (Stainless steel tray; Wuhan Jinguang Electronic Appliance Co, Ltd), reported to be of high accuracy[15-20] (Fig. 5).

Digital scans of the definitive casts were obtained by using the same scanner. The definitive casts were aligned initially with the resin casts through the N-point alignment command in the reverse engineering software program (Geomagic Studio 2014; 3D Systems Corp). Curves were drawn on the resin casts to select the tooth area and mucosal area and then projected onto definitive

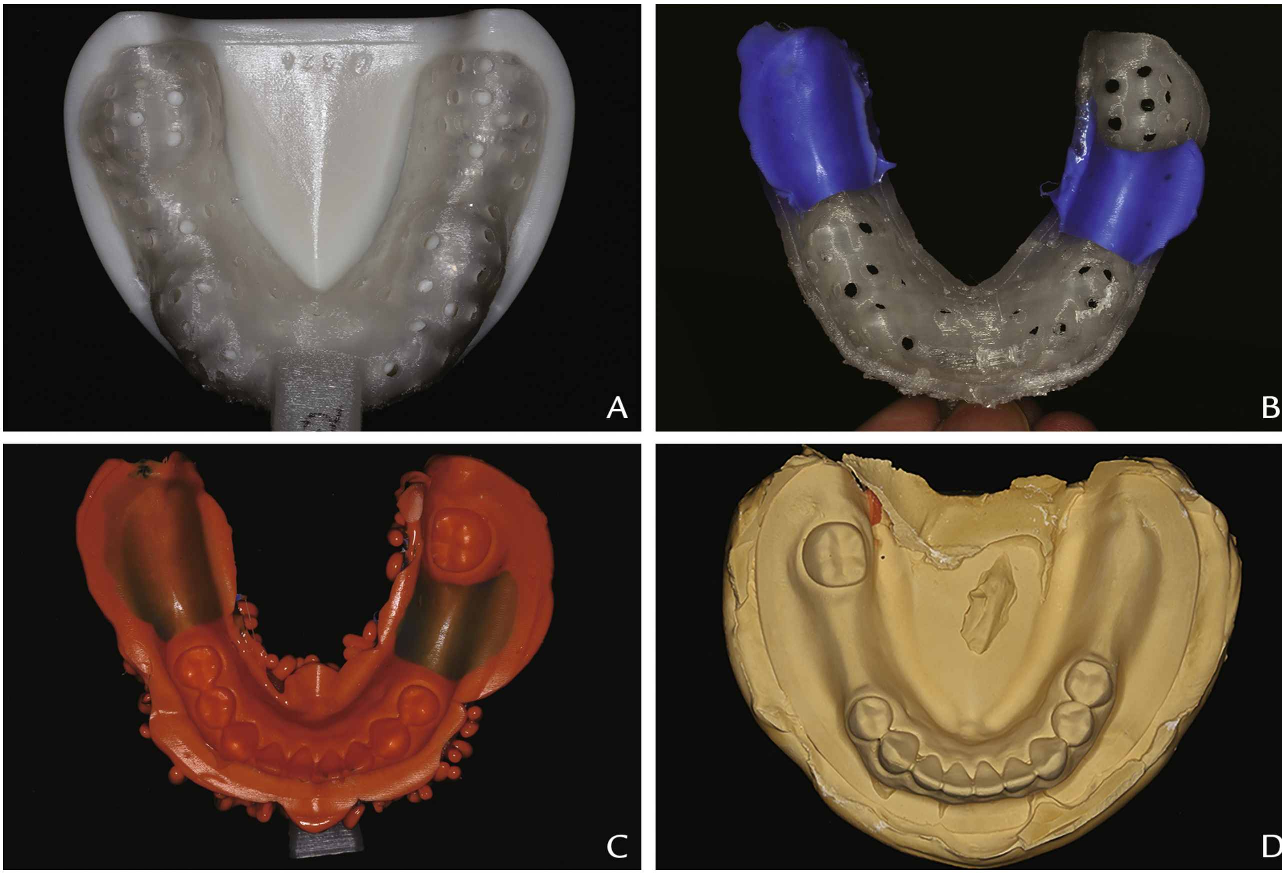

Figure 4. Workflow of making mandibular definitive casts by using custom trays. A, FDM-printed custom tray on the resin cast. B, Preliminary impression. C, Definitive impression. D, Definitive cast.

casts. The selected tooth area of each definitive cast was aligned with that of the resin cast through the best-fit alignment command. Root mean square (RMS) representing 3D deviation between the tooth area of each maxillary definitive cast and that of the maxillary resin cast ($RMS_{max.\_tee.}$) and the one between the mucosal area of each maxillary definitive cast and that of the maxillary resin cast ($RMS_{max.\_muc.}$) were calculated (Fig. 6A, 6B). Subsequently, the overall area, including the tooth area and mucosal area, of each maxillary definitive cast was best-fit aligned with that of the maxillary resin cast. RMS between the overall area of each maxillary definitive cast and that of the maxillary resin cast ($RMS_{max.}$) was calculated (Fig. 6C). Similarly, the RMSs for mandibular casts were defined and named as $RMS_{man.\_tee.}$, $RMS_{man.\_muc.}$, $RMS_{man.}$ (Fig. 6D-F).

Factorial 2-way analyses of variance (ANOVAs) with $RMS_{max\_tee.}$, $RMS_{max\_muc.}$, $RMS_{max.}$, $RMS_{man.\_tee.}$, $RMS_{man.\_muc.}$, and $RMS_{man.}$ as the dependent variables and the impression gap and base thickness as classification variables were carried out in a statistical analysis system (SAS 9.4; SAS Institute Inc). Plots of residuals showed that the experiment results accorded with the assumptions of independence, normal distribution, and homogeneity of variances. If the F test of the factorial 2-way ANOVA was significant ($P<.05$), the Bonferroni tests were carried out to compare least squares means for the different levels of the significant design parameters. The comparison results were plotted in a data analysis and graphing software program (Origin 2020b; OriginLab Corp). Thereafter, 1-way ANOVAs with $RMS_{max.\_tee.}$, $RMS_{max.\_muc.}$, $RMS_{max.}$, $RMS_{man.\_tee.}$, $RMS_{man.\_muc.}$, $RMS_{man.}$ as the dependent variables and groups as the categorical variable were carried out in the statistical analysis system (SAS 9.4; SAS Institute Inc), where experimental groups were compared with the control group through planned comparisons. The assumptions of independence, normal distribution, and homogeneity of variances were checked through residual analyses.

RESULTS

No significant interaction effect between the impression gap and base thickness was found on the accuracy of partially edentulous maxillary definitive casts ($P>.05$). The impression gap and base thickness of custom trays had significant effects on the accuracy of the tooth area of maxillary definitive casts and no significant effect on the

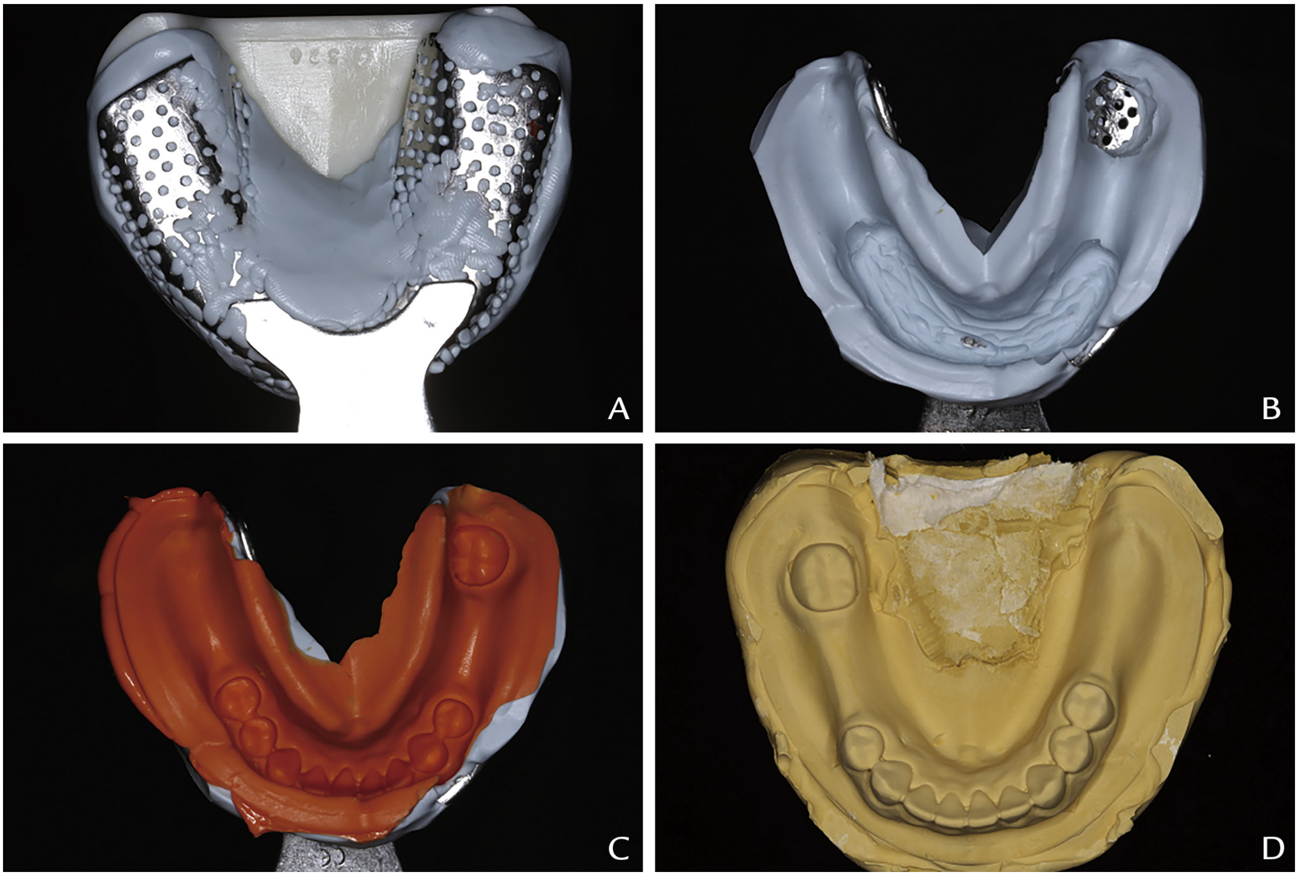

Figure 5. Workflow of making definitive casts by using stock trays. A, Stock tray with impression materials on resin cast. B, Preliminary impression. C, Definitive impression. D, Definitive cast. FDM, fused deposition modeling.

accuracy of the mucosal area or overall area of maxillary definitive casts (*P*<.05) (Table 3). The tooth area of maxillary definitive casts from custom trays with a 3.0-mm impression gap had significantly higher accuracy than that of maxillary definitive casts from custom trays with a 1.0-mm impression gap under the same base thickness (*P*<.05). The tooth area of maxillary definitive casts from custom trays with 1.5-mm or 2.0-mm base thickness had significantly higher accuracy than that of maxillary definitive casts from custom trays with a 1.0-mm base thickness under the same impression gap (*P*<.05) (Fig. 7A).

No significant interaction effect between the impression gap and base thickness was found on the accuracy of partially edentulous mandibular definitive casts (*P*>.05). The impression gap and base thickness of custom trays had significant effects on the accuracy of the tooth area and overall area of mandibular definitive casts (*P*<.05) (Table 4). The tooth area of mandibular definitive casts from custom trays with a 2.0-mm or 3.0-mm impression gap had significantly higher accuracy than that of mandibular definitive casts from custom trays with a 1.0-mm impression gap under the same base thickness (*P*<.05). The tooth area of mandibular definitive casts from custom trays with 1.5-mm or 2.0-mm base thickness had significantly higher accuracy than that of mandibular definitive casts from custom trays with 1.0-mm base thickness under the same impression gap (*P*<.05) (Fig. 7B). The overall area of mandibular definitive casts from custom trays with a 2.0-mm impression gap had significantly higher accuracy than that of mandibular definitive casts from custom trays with a 1.0-mm impression gap under the same base thickness (*P*<.05). The overall area of mandibular definitive casts from custom trays with 1.5-mm or 2.0-mm base thickness had significantly higher accuracy than that of mandibular definitive casts from custom trays with 1.0-mm base thickness under the same impression gap (*P*<.05) (Fig. 8A). The impression gap of custom trays had no significant effect on the accuracy of the mucosal area of mandibular definitive casts (*P*>.05), whereas the base thickness of custom trays had significant effects (*P*<.05) (Table 4). The mucosal area of mandibular definitive casts from custom trays with 1.5-mm or 2.0-mm base thickness had significantly higher accuracy than that of mandibular definitive casts from custom trays with 1.0-mm base thickness under the same impression gap (*P*<.05) (Fig. 8B).

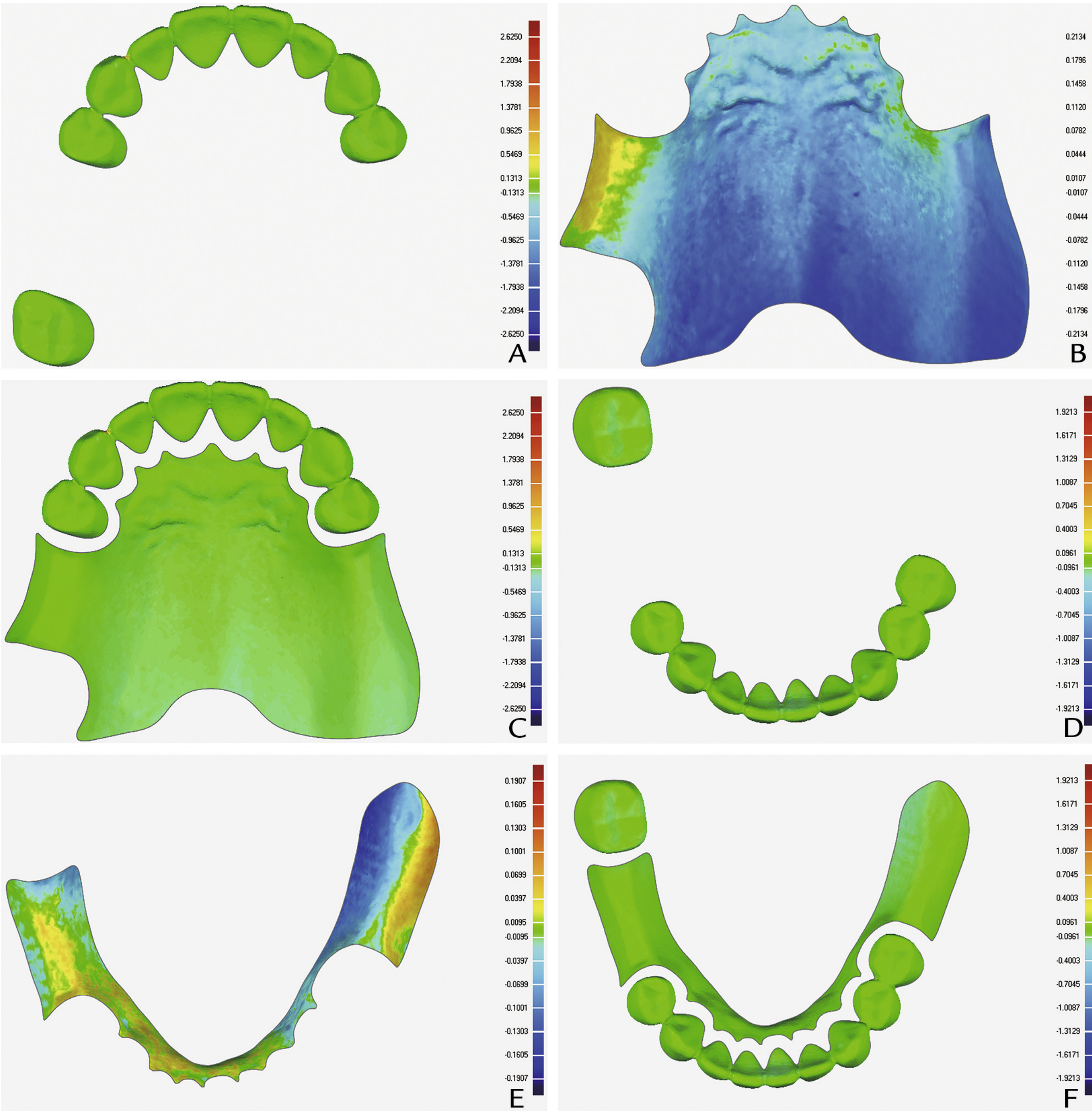

Figure 6. Workflow of accuracy measurement of definitive casts. A, Deviation between tooth area of maxillary definitive cast and that of maxillary resin cast. B, Deviation between mucosal area of maxillary definitive cast and that of maxillary resin cast. C, Deviation between overall area of maxillary definitive cast and that of maxillary resin cast. D, Deviation between tooth area of mandibular definitive cast and that of mandibular resin cast. E, Deviation between mucosal area of mandibular definitive cast and that of mandibular resin cast. F, Deviation between overall area of mandibular definitive cast and that of mandibular resin cast.

The tooth area of maxillary definitive casts from custom trays with a 1.0-mm impression gap and 1.0-mm base thickness had significantly lower accuracy than that of maxillary definitive casts from stock trays (P<.05) (control group), whereas other experimental groups were not significantly different from the control group (P>.05). The mucosal area of maxillary definitive casts from custom trays with a 3.0-mm impression gap and 1.0-mm base thickness had significantly lower accuracy than that of maxillary definitive casts from stock trays (P<.05), whereas other experimental groups were not significantly different from the control group (P>.05) (Fig. 9). The tooth area of mandibular definitive casts from custom trays with a 1.0-mm impression gap or 1.0-mm base

Table 3. Two-way ANOVA for maxillary custom trays

Dependent Variable	Source	Df	F	*P*
$RMS_{max.\_tee.}$	Model	8	4.20	.001*
	Impression gap	2	6.86	.003*
	Base thickness	2	8.66	<.001*
	Interaction	4	0.63	.645
$RMS_{max.\_muc.}$	Model	8	1.03	.430
$RMS_{max.}$	Model	8	1.63	.150

ANOVA, analysis of variance; RMS, root mean square. *Mean difference significant ($P<.05$).

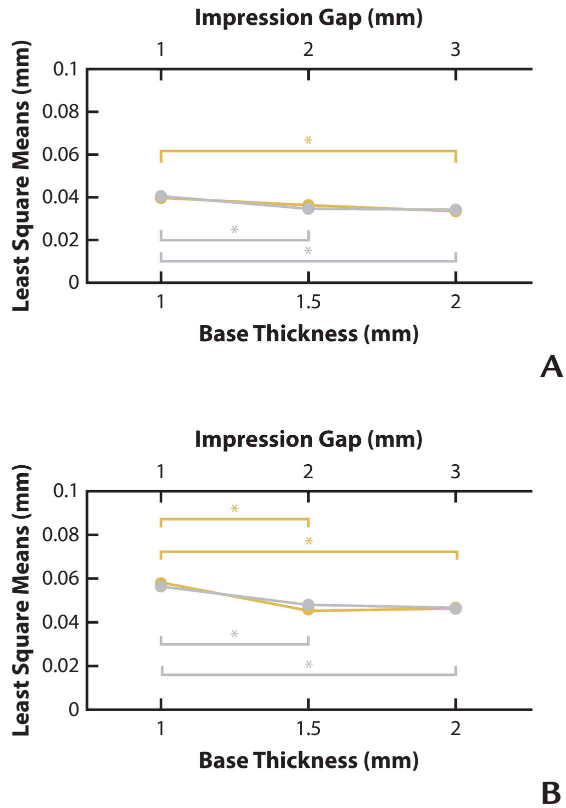

Figure 7. Least squares means for significant main effects. *Gray*: Base thickness; *Yellow*: Impression gap. A, $RMS_{max.\_tee}$. B, $RMS_{man.\_tee}$. *Mean difference significant ($P<.05$).

thickness had significantly lower accuracy than that of mandibular definitive casts from stock trays ($P<.05$), whereas other experimental groups were not significantly different from the control group ($P>.05$). The mucosal area of mandibular definitive casts from custom trays with a 1.0-mm base thickness had significantly lower accuracy than that of mandibular definitive casts from stock trays ($P<.05$), whereas other experimental groups were not significantly different from the control group ($P>.05$) (Fig. 10). The overall area of maxillary definitive casts from custom trays with a 1.0-mm impression gap and 1.5-mm base thickness had significantly lower accuracy than that of maxillary definitive casts from stock trays ($P<.05$), whereas other experimental groups were not significantly different from the control group ($P>.05$) (Fig. 11A). The overall area of mandibular definitive casts from custom trays with a 1.0-mm base thickness had lower accuracy than that of mandibular definitive casts from stock trays ($P<.05$), whereas other experimental groups were not significantly different from the control group ($P>.05$) (Fig. 11B).

DISCUSSION

From the results of 2-way ANOVAs and 1-way ANOVAs, the null hypotheses were rejected, as both the impression gap and the base thickness of custom trays had significant effects on the accuracy of the tooth area of partially edentulous maxillary definitive casts. Compared with stock metal trays, custom trays have advantages when border molding partially edentulous patients, a reason custom trays are widely used to make selective pressure impressions. Polyvinyl siloxane impression materials were used for making 2-step impressions because of their high accuracy, and PLA was used for printing custom trays in this study. However, the impressions were made at room temperature, and the thermal contraction of light-bodied polyvinyl siloxane impression materials that occurs from mouth to room temperature[21,22] was not modeled. It would have been more clinically relevant if the impressions had been made at 35 ±1 °C to simulate the oral temperature. Corso et al[23] showed that the dimensional change of a light-bodied polyvinyl siloxane impression material caused by thermal change was approximately 0.71% for horizontal dimensions and 0.20% for vertical dimension. Kim et al[24] reported that the dimensional change of 5 brands of light-bodied polyvinyl siloxane impression materials caused by thermal change was between 0.3% and 0.4%.

Table 4. Two-way ANOVA for mandibular custom trays

Dependent Variable	Source	Df	F	*P*
$RMS_{man.\_tee.}$	Model	8	6.02	<.001*
	Impression gap	2	12.64	<.001*
	Base thickness	2	8.45	.001*
	Interaction	4	1.51	.220
$RMS_{man.\_muc.}$	Model	8	4.81	<.001*
	Impression gap	2	1.08	.351
	Base thickness	2	17.5	<.001*
	Interaction	4	0.32	.861
$RMS_{man.}$	Model	8	7.44	<.001*
	Impression gap	2	3.65	.036*
	Base thickness	2	24.16	<.001*
	Interaction	4	0.97	.434

ANOVA, analysis of variance; RMS, root mean square. *Mean difference significant ($P<.05$).

Like with stock metal trays, the adhesion of the silicone impression and PLA custom tray relied mainly on the mechanical retention resulting from impression

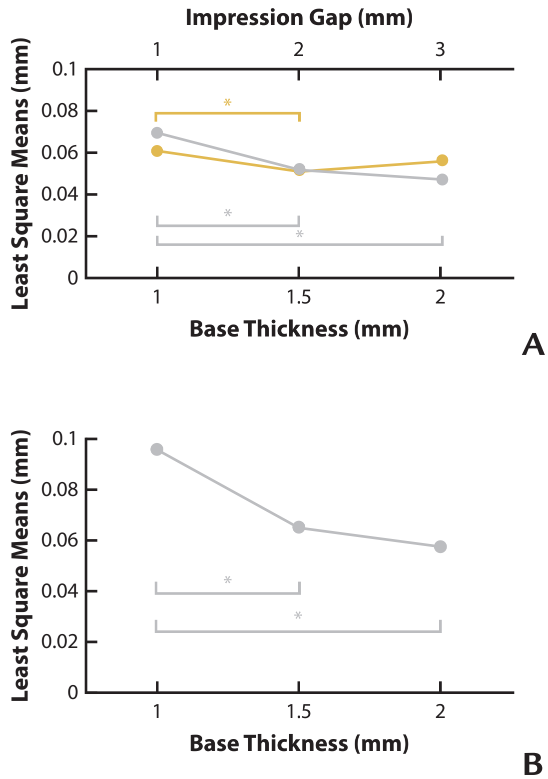

Figure 8. Least squares means for significant main effects. *Gray*: Base thickness; *Yellow*: Impression gap. A, RMS_{man}. B, $RMS_{man.\_muc}$. *Mean difference significant (P<.05).

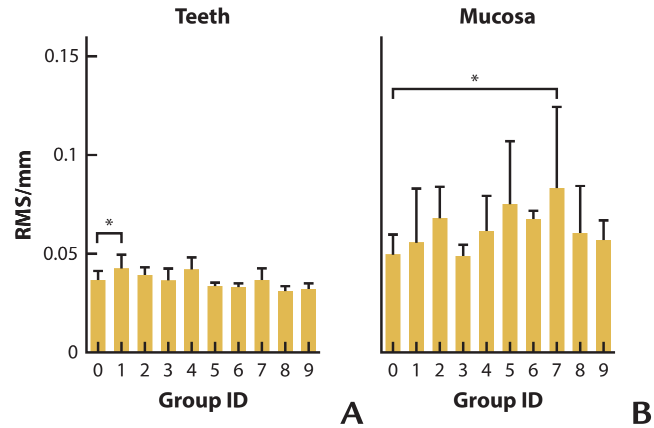

Figure 9. RMS of different groups after best-fit alignment with tooth area. A, Maxillary tooth area. B, Maxillary mucosal area *Mean difference significant (P<.05). 0, group Con. 1, group G_1T_1. 2, group $G_1T_{1.5}$. 3, group G_1T_2. 4, group G_2T_1. 5, group $G_2T_{1.5}$. 6, group G_2T_2. 7, group G_3T_1. 8, group $G_3T_{1.5}$. 9, group G_3T_2.

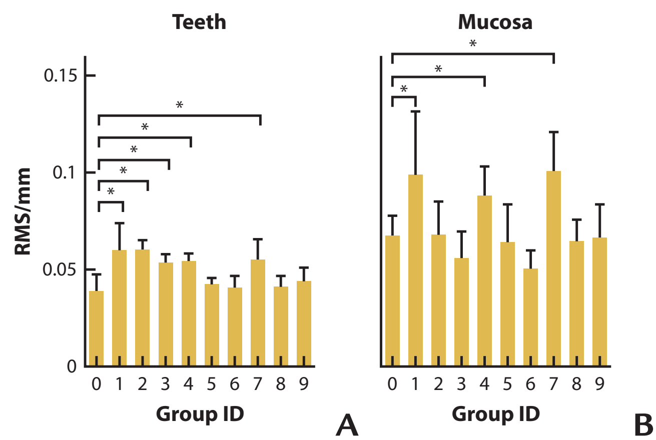

Figure 10. RMS of different groups after best-fit alignment with tooth area. A, Mandibular tooth area. B, Mandibular mucosal area. *Mean difference significant (P<.05). 0, group Con. 1, group G_1T_1. 2, group $G_1T_{1.5}$. 3, group G_1T_2. 4, group G_2T_1. 5, group $G_2T_{1.5}$. 6, group G_2T_2. 7, group G_3T_1. 8, group $G_3T_{1.5}$. 9, group G_3T_2.

insertion into perforations of custom trays, so all custom trays in this study were designed with the same number and size of perorations to ensure consistent retention of the impression material. Moreover, unlike with stock metal trays, the rough surface of FDM-printed PLA custom trays may help improve the impression retention. During the removal of a custom tray impression, deep-tissue undercuts might deform or even dislocate the impression from the tray, lowering the accuracy of the definitive cast.

The accuracy of silicone impression is related to the volume of impression materials, or more quantitatively, the impression gap of custom trays. Impressions with 2-mm to 4-mm thickness are usually acceptable in clinical practice.[10,13,14] The present results showed that to ensure the accuracy of the tooth area of maxillary or mandibular definitive casts, PLA custom trays with a 2.0-mm or 3.0-mm rather than 1-mm impression gap should be used for partially edentulous patients. Because there were always undercuts in tooth area, an excessively thin impression might be irreversibly deformed during removal.

The base thickness of custom trays had significant effects on the accuracy of the tooth area of definitive casts (P<.05). In terms of the accuracy of definitive casts, custom trays with 1.5-mm or 2.0-mm base thickness were better than those with 1.0-mm base thickness. The base thickness of light-polymerizing resin custom trays is typically 2 mm.[7,10] The flexural properties of 3D-printed PLA are better than those of light-polymerizing resin,[5,6] whereas it is weaker than stainless steel. If the base of a PLA custom tray is too thin, the PLA tray and impression might be deformed during insertion or removal. The base thickness of custom trays had significant effects on the accuracy of the mucosal area of mandibular definitive casts (P<.05) but not on that of the mucosal area of maxillary definitive casts (P>.05). Maxillary custom trays might have higher structural strength than mandibular custom trays under the same base thickness, helping to hold the shape of the impression material.

A functional impression for tooth tissue–supported removable partial dentures requires recording the

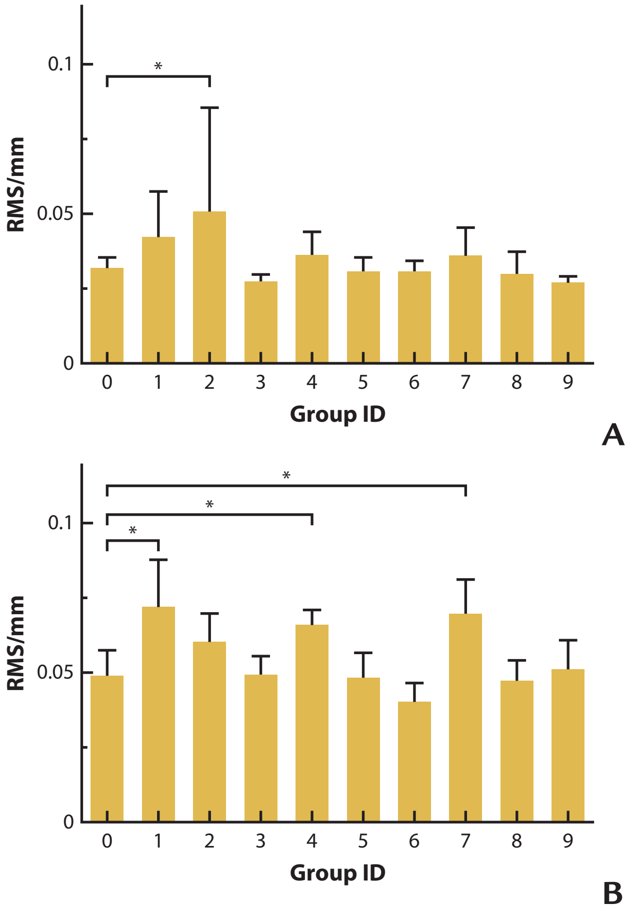

Figure 11. RMS of overall area of different groups after best-fit alignment with overall area (tooth area and mucosal area). A, Maxillary. B, Mandibular. *Mean difference significant (P<.05). 0, group Con. 1, group G_1T_1. 2, group $G_1T_{1.5}$. 3, group G_1T_2. 4, group G_2T_1. 5, group $G_2T_{1.5}$. 6, group G_2T_2. 7, group G_3T_1. 8, group $G_3T_{1.5}$. 9, group G_3T_2.

anatomic form of the teeth and the functional form of the residual ridge under occlusal load. Consequently, the intaglio surface of resin casts was divided into the tooth area and mucosal area in the present study. Compared with the mucosal area, which has a certain resiliency and can be displaced more under the loading of masticatory force, the accuracy of the rigid tooth area has a greater influence on the fit of removable partial dentures. Therefore, the tooth area rather than mucosal areas of definitive casts was aligned with that of resin casts, and 3D deviations were then measured. The accuracy of the overall area of definitive casts was also important to address the overall fit. Therefore, 3D deviations between the overall area of definitive casts and those of the resin casts were measured. The deviations of the overall area showed more consistency with 3D deviations of the mucosal area than with 3D deviations of the tooth area. The selected mucosal area was larger than the selected tooth area. Three-dimensional deviation of the tooth area tended to be balanced by that of the mucosal area.

Because of the defects of stone casts, such as bubbles on the incisal edge of teeth, small nodules on the occlusal surfaces of teeth, and the deformation of the gingival papilla areas, some outliers of maximum distance values might contribute to a biased conclusion. Consequently, RMS instead of maximum distances was regarded as the index of accuracy, which better represents the overall deviations of definitive casts from the resin casts.

Limitations of the present study included that only Kennedy class II and modification I partial edentulism was studied. More classes of partial edentulism should be researched in the future. Secondly, only the tooth and mucosal areas of definitive casts were studied. The features of guide plane and the rest seats of prepared abutment teeth were not studied. Finally, impression gap requirements of the remaining teeth, palate, and posterior palatal seal areas of a maxillary custom tray were different from each other. More detailed division of the intaglio surface of casts should be introduced to fully present features of the anatomic and functional morphology of the remaining teeth and mucosa of partially edentulous patients.

CONCLUSIONS

Based on the findings of this in vitro study, the following conclusions were drawn:

1. For accurate definitive casts, FDM-printed PLA maxillary and mandibular custom trays with a 2-mm or 3-mm impression gap and 1.5-mm or 2-mm base thickness are recommended.
2. No significant accuracy difference was found between definitive casts from custom trays with a 2-mm or 3-mm impression gap and 1.5-mm or 2-mm base thickness and those from stock metal trays.

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Hong Li: Methodology, Investigation, Experiments carrying and Manuscript editing. **Kenan Ma:** Methodology, Formal analysis, Investigation, Writing – original draft, Visualization. **Yuchun Sun:** Writing – review & editing, Supervision. **Hu Chen:** Conceptualization, Methodology, Investigation, Writing – review & editing, Project administration.

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