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Preparing guiding planes for removable partial dentures: an in vitro comparison between assisted CAD-CAM template procedure and freehand preparation

Hefei Bai [a], Hongqiang Ye [b,*], Hu Chen [a], Yong Wang [a], Yongsheng Zhou [b], Yuchun Sun [a,*]

[a] Center of Digital Dentistry, Faculty of Prosthodontics, Peking University School and Hospital of Stomatology & National Center of Stomatology & National Clinical Research Center for Oral Diseases & National Engineering Research Center of Oral Biomaterials and Digital Medical Devices & Beijing Key Laboratory of Digital Stomatology & Shanxi Province Key Laboratory of Oral Diseases Prevention and New Materials, 22Zhongguancun Nandajie, Haidian District, Beijing 100081, PR China

[b] Department of Prosthodontics, Peking University School and Hospital of Stomatology & National Center of Stomatology & National Clinical Research Center for Oral Diseases & National Engineering Research Center of Oral Biomaterials and Digital Medical Devices & Beijing Key Laboratory of Digital Stomatology & Shanxi Province Key Laboratory of Oral Diseases Prevention and New Materials, Beijing, PR China

A R T I C L E I N F O

Keywords:
Removable partial denture
Tooth preparation
Cobalt-chromium alloys
3D printing
CAD-CAM
3D comparison

A B S T R A C T

Objectives: To compare the trueness of computer-aided design and computer-aided manufacturing (CAD-CAM) assisted procedure and freehand procedure for preparing guiding planes for removable partial dentures (RPDs).
Methods: Forty identical mandibular resin casts were divided into two groups in which the guiding planes of two abutment teeth were prepared freehand (control group, $n = 20$) and using rigidly constrained templates (test group, $n = 20$). The template was designed on a digital cast of virtually prepared guiding planes and fabricated by selective laser melting using cobalt-chromium alloy. To assess the 3D trueness, all prepared guiding planes (Test data) were digitized using a laboratory scanner and compared to the virtually designed guiding planes (Reference data). The angle deviation between the Test data and the designed direction of the path of placement was measured for assessing the direction trueness of guiding plane preparation.
Results: The 3D trueness of guiding plane preparation was significantly better in the Test group (48.4 ± 12.9 μm) than in the Control group (128.5 ± 37.6 μm, $p < 0.01$). The direction trueness of guiding plane preparation was also significantly better in the Test group (1.20 ± 0.55°) than in the Control group (7.68 ± 3.00°, $p < 0.01$).
Conclusions: The CAD-CAM template assisted procedure can significantly improve tooth preparation of the guiding planes compared to the freehand preparation. The CAD-CAM template could help clinicians prepare parallel guiding planes in a predictable manner.

1. Introduction

Preparation of guiding planes is essential for successful treatment of removable partial dentures (RPDs) [1]. Guiding planes are two or more vertically parallel surfaces on abutment teeth and/or fixed dental prostheses oriented to contribute to the direction of the path of placement of RPDs. Parallelly prepared guiding planes maintain retention and stability for RPDs, eliminate harmful stresses to abutment teeth, and avoid significant food traps between the abutment teeth and prostheses [1–3]. These parallel planes seldom occur naturally and must be prepared in the enamel or on prostheses [4]. Freehand paralleling preparation is generally difficult and imprecise, especially for preparing guiding planes of bilateral abutment teeth, because it is hard to assess whether the essential modification has been made intraorally [5]. The freehand preparation procedure is over-reliant on the clinician's experience and precision of visual perception, and also affected by the intraoral environment [4]. Many intraorally prepared guiding planes may be divergent to decrease the retention and stability of RPDs [6,7].

In recent years, digital assistance software has been employed to instruct dental students to enhance crown preparation and the learning process, which may assist clinicians to improve their visual inspection [8–10]. Microscope assistance in preclinical education has been shown to help students in attaining improved crown taper, with an average reduction of 7° in mesio-distal taper [10]. However, the minimal discrepancies during preparation perceived by clinicians are expected to in range of 100−200 μm. Smaller discrepancies cannot be distinguished by

* Corresponding authors.
E-mail addresses: yehongqiang@hsc.pku.edu.cn (H. Ye), kqsyc@bjmu.edu.cn (Y. Sun).

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the naked eye [8]. Furthermore, it is difficult to determine whether intraoral surfaces are parallel with one another using stereoscopic vision [10].

In clinical practice, new dental materials and digital procedures can help clinicians to improve the preparation of guiding planes [11–13]. Verification devices [6,14], matrices [15], indexes [16], reciprocating handpieces [17], intraoral surveyors [18], and parallel devices [7] have all been developed. Most of these techniques provide image markers to indicate the cutting position or the direction of the path of placement, however, there is no restriction on handpiece and cutting instruments so that may result in aggressive preparation. Another technique is ParalAB, which is an intraoral device with pantographic movements that attempts to draw, validate, and aid in the preparation of guiding planes [7]. It can keep cutting tools parallel to the path of placement but is unable to control the depth of the guiding plane preparation. Therefore, it cannot assist clinicians to accurately prepare the designed guiding plane. Despite the presentation of numerous novel techniques, few studies had quantitatively analyzed the preparation of guiding planes [14,18]. High-resolution scanners and 3D analysis software, in this regard, can be used to thoroughly assess preparation of guiding planes in a quantitative way [19].

The aim of the study was to compare the trueness of computer-aided design and computer-aided manufacturing (CAD-CAM) assisted procedure and freehand procedures for preparing guiding planes for RPDs. The null hypothesis was that the trueness of the prepared guiding planes would not be affected by the manner of preparation.

2. Materials and methods

2.1. Virtual preparation of Guiding planes

A digital mandibular cast with the right first molar (FDI #46) missing was 3D printed 40 times with an industrial stereolithography (SLA) printer (iSLA800, ZRapid, Shenzhen, China) (nominal accuracy was 50 μm) and compatible photopolymerizing resin material (ZR710, ZRapid, Shenzhen, China). The precision of the SLA printer provided by manufacturer was 10 μm. The thickness of printing layer was 50 μm. The path of placement of RPD was designed perpendicular to the mandibular occlusal plane after digital cast surveying. Then the distal guiding plane of the right mandibular second premolar (FDI #45) and the mesial guiding plane of the right mandibular second molar (FDI #47) were virtually prepared using CAD software (Rhinoceros 6.0, Robert McNeel & Assoc, Washington, USA) (Fig. 1). Guiding planes were designed to be planar in order to prepare the same shape guiding planes in both experimental groups.

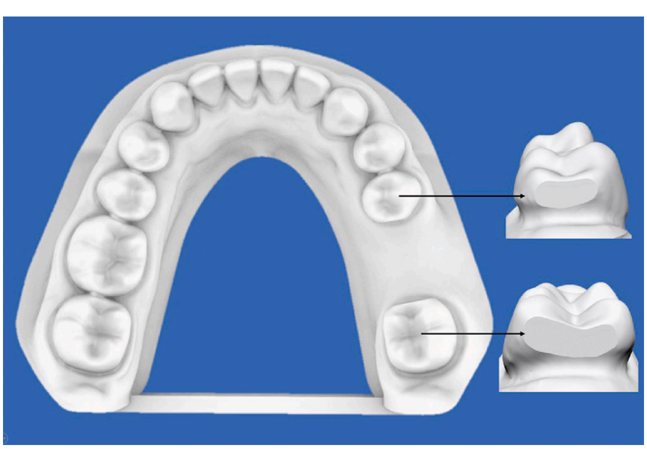

Fig. 1. Virtually prepared guiding planes of the two abutment teeth (FDI #45 and #47).

2.2. Design and fabrication of triple-rigidly constraint template

A triple-rigidly constraint template was designed as described by Hongqiang Ye et al. (Fig. 2a–e) [19]. A diamond rotary instrument has six degrees of freedom during preparation [20]. The template could guide the movement of the diamond rotary instrument through triple rigid constraints: the first constraint is the upper surface of the guide rails, which limits the diamond rotary instrument's occlusal gingival preparation depth and protects the gingiva; the second and third constraints are the inner axial surfaces of the guide rails and the track grooves of the retainer, which prevent the diamond rotary instrument from rotating in the distal and mesial directions. To prepare the guiding planes, a straight flat-end diamond rotary instrument (SF-31, MANI, Tokyo, Japan) was used. According to manufacturing guidelines, the template retainer thickness was 0.9 mm, the offset from the teeth to the template was 0.05 mm, the guide rail thickness was 1.2 mm, and the offset from the diamond rotary instrument to the template was 0.05 mm. Buccal passageways of the guide rail were developed to decrease the need for excessive mouth opening to apply the diamond rotary instrument from the occlusal side. Inspection windows were designed for checking the seating position of the template, and the lingual plate was designed for protecting the lingual tissue during preparation [19].

A selective laser melting (SLM) printer (Ti200, Profeta, Nanjing, China) was used to 3D print twenty templates out of cobalt-chromium (Co-Cr) alloy (MetcoAdd 78A, Oerlikon, Zurich, Switzerland). The specifications of the SLM printer were as follows: fiber laser, 200 W; diameter of the beam, 30 μm; and thickness of printing layer, 20 μm. The particle size of the Co-Cr alloy powder ranged between 10 and 30 μm. Next, the supports were removed, and the intaglio surfaces were sandblasted with 50 μm of aluminum oxide powder and then polished.

2.3. Internal adaptation analysis of templates

The internal adaptation of the templates was evaluated using a digitized version of the silicone replica technique (dual-scan) [21]. The intaglio surfaces of the templates were evenly filled with light-body polyvinyl siloxane impression materials (Type 3 Light Body, HUGE, Shanghai, China). Thereafter, the templates were seated on the resin casts and continuously pressed perpendicular to the occlusal surface of the abutment teeth for 4 min with a constant pressure of 20 N (Fig. 3a and b). Following the polymerization of the impression material, the templates were removed from the resin cast and replaced with a layer of silicone replica. The intaglio surfaces of the templates with and without the silicone replica were scanned twice consecutively using a laboratory scanner (D2000, 3Shape A/S, Copenhagen, Denmark) and aided by a thin homogenous layer of scan spray (Easy scan, Alphadent, Goyang, Korea). The precision of the scanner was 5 μm (ISO 12836), while the average particle size of the scan spray was 3 μm [22]. The thickness of the silicone replica at the occlusal area was measured in reverse engineering software (Geomagic Control 2014, 3D System, Washington, USA) to indicate the internal adaptation of the template (Fig. 4).

2.4. Tooth preparation for guiding planes

All guiding planes of the two abutment teeth (FDI #45 and #47) were prepared by the same dental postgraduate student (H.B.) in a phantom head simulator (NISSIM Type I, NISSIN, Kyoto, Japan) (interincisal opening of 50 mm). All preparations were performed with an identical high-speed handpiece (Boralina 1600373-001, Bien Air Dental, Bienne, Switzerland), which has a power output of 12W, 310000 revolutions per minute, and 2*1 separate spray outlet. In the control group ($n = 20$), the guiding planes were prepared by freehand after the operator observed and simulated the virtually prepared guiding planes (Fig. 5a). In the test group ($n = 20$), the guiding planes were prepared assisted by triple-rigidly constraint templates (Fig. 5b and c). Each guiding plane was prepared into flat for precisely comparing the two

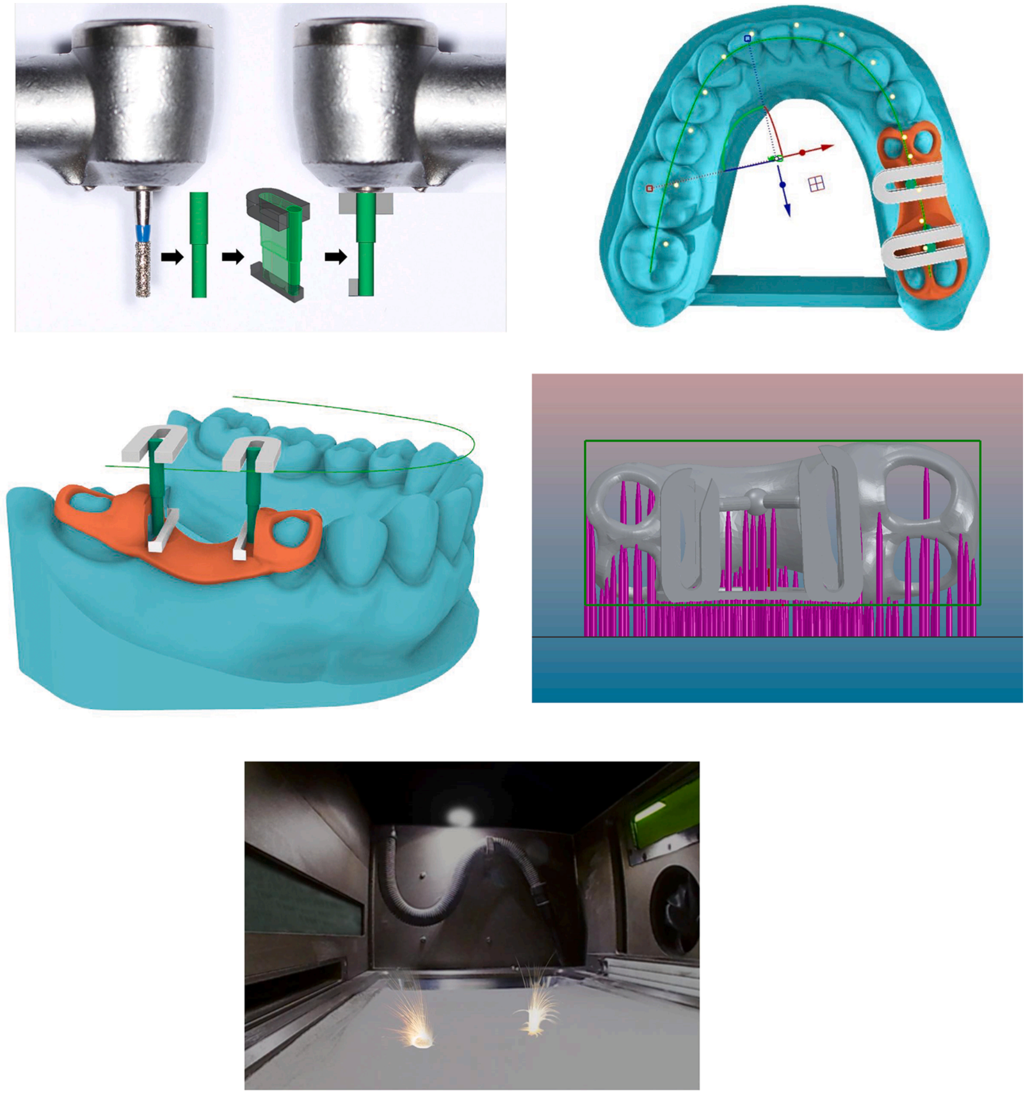

Fig. 2. Design and fabrication of template. (a) Design of the diamond rotary instrument (green) and guide rail (gray). (b) Adjusting the diamond rotary instrument and guiding rails to the position of virtually prepared guiding planes. (c) Buccal view of template. (d) Adding support structures. (e) Templates were printed with Co-Cr alloy and SLM printer. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.).

tooth preparation procedures. And each template was used to prepare one cast using a new diamond rotary instrument for limiting the influence of abrasion between the template and diamond rotary instrument. All prepared resin casts were then digitalized using a D2000 laboratory scanner.

2.5. Three-dimensional trueness analysis

The “Manual Registration-n-Point Registration” and “Best Fit Alignment” were performed in succession to align the 3D images of the prepared casts (test) to the virtually prepared guiding plane preparation cast (reference) using the Geomagic Control 2014 software. Five pairs of points were manually defined at the incisal ridge of the left mandibular central incisor (FDI #31), the buccal cusp of the bilateral mandibular second premolars (FDI #35 and #45), and the central fossa of the bilateral mandibular second molars (FDI #37 and #47) for preliminary matching. And then the abutment tooth surface areas neighboring the prepared guiding planes of the two datasets were selected for further matching. Trueness represents how the measurements deviate from the actual objects measured (the "correct value" of the "standard value") (ISO 5725-1) [23,24]. In the present study, the deviation between the prepared guiding planes and the virtually prepared guiding planes was measured to assess the 3D trueness of guiding planes preparation. 3D compare analysis was performed to calculate the root-mean-square (RMS) estimation values of 3D deviation between the prepared guiding planes and the virtually prepared guiding planes. Color-coded maps were also generated to directly illustrate 3D deviations between the prepared and designed guiding planes, with green indicating precise preparation with a minor 3D deviation (≤50 μm). Colors ranging from yellow to red indicate insufficient preparation, and colors ranging from cerulean blue to midnight blue imply aggressive preparation. The RMS was calculated using the following formula [25]:

$$RMS = \frac{1}{\sqrt{n}} = \sqrt{\sum_{i=1}^{n} \left(x_{1,i} - x_{2,i}\right)^2}$$

where $x_{1,i}$ is the measuring point i in the test data, $x_{2,i}$ is the measuring point i in the Reference data, and n is the total number of measuring points.

2.6. Direction trueness analysis

The direction trueness of guiding plane preparation was assessed in the Geomagic Control 2014 software after the accurate registration was

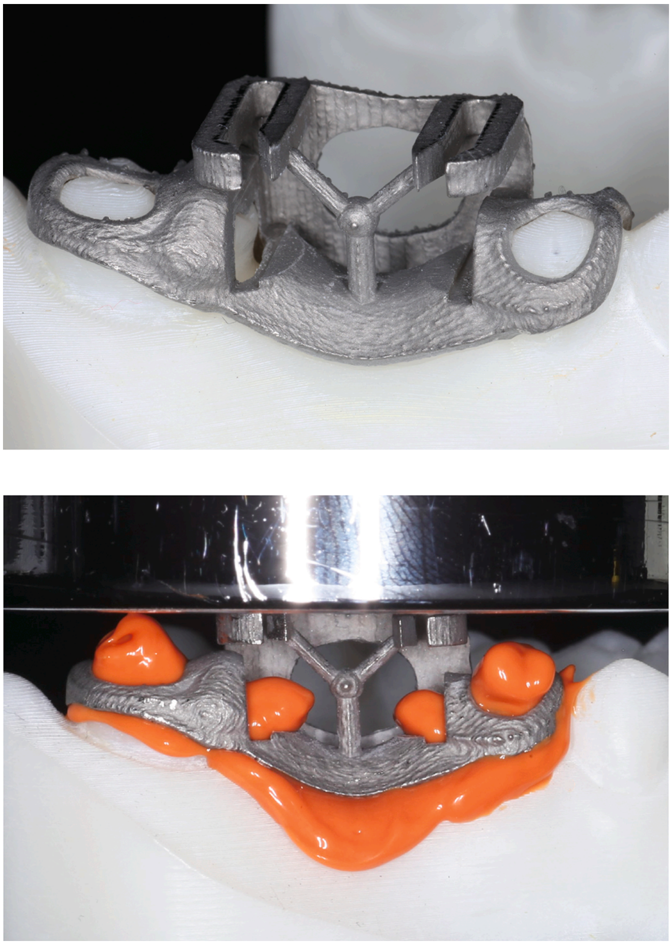

Fig. 3. Internal adaptation assessment of template. (a) Visual inspection was first performed to confirm that the template had no gross misfit. (b) The internal gap between the template and the teeth was replicated by silicone (20 N for 4 min).

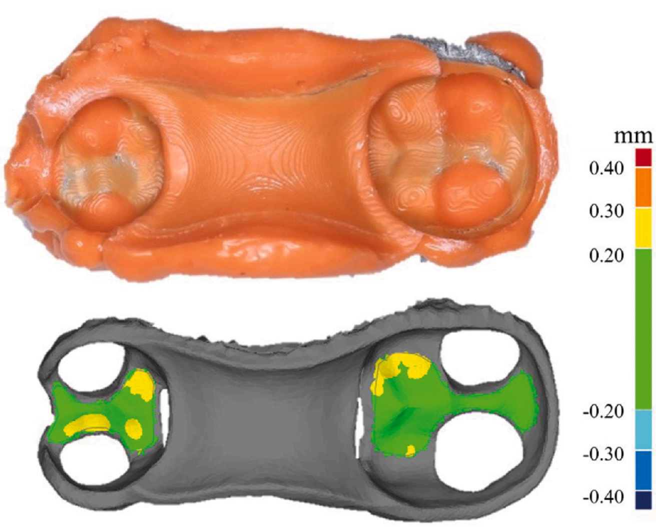

Fig. 4. Internal adaptation was assessed using the digital replica technique (dual-scan). Green indicates internal gaps no more than 200 μm.

performed for the Test data and the Reference data. Six mesio-distal cross-sections were produced equidistantly on each prepared guiding plane from the buccal to the lingual side, parallel to each other, and parallel to the direction of the path of placement. By recording the direction vector (x, y, z) of the prepared guiding plane on each cross-section, the angle (α) between the prepared guiding plane and the direction of the path of placement (0, 0, 1) was calculated. The direction trueness of the guiding plane preparation was demonstrated by the average angle derived from six cross-sections (Fig. 6a–c). A fully trained investigator performed all scanning and evaluation procedures (H.B.). The angle (α) was calculated using the following formula:

$$\alpha = \left|\arccos\left\langle \overrightarrow{Nv}, \overrightarrow{Pp} \right\rangle = \left|\arccos\frac{1}{x^2 + y^2 + z^2}\right|\right|$$

where $\overrightarrow{\mathrm{Nv}}$ is the 3D vector of the prepared guiding plane on each cross-section and $\overrightarrow{Pp}$ is the 3D vector of the path of the placement direction in the software.

2.7. Statistical analysis

A pilot study was firstly conducted (n =5) to perform a sample calculation using statistical software (G*Power 3, Heinrich Heine, Universität Düsseldorf, Germany). The mean and standard deviation of direction trueness of guiding plane preparation of the pilot study (allocation ratio N1/N2 = 1) were used to calculate the effect size (3.09). The type-I and type-II error possibilities of 0.05 and 0.95. The results indicated that at least 8 specimens (4 per group) were required. The actual power of the calculation was 95.02%. The sample size was expanded to 20 specimens per group in this *in vitro* study for minimizing the possibility of type-I and type-II errors.

Statistical analysis was performed using statistical software (IBM SPSS Statistics 19, IBM, Armonk, USA). The Shapiro–Wilk test and Levene's test were used to check the normality and the equivalence for variance of the data. Independent-sample *t*-tests were used to compare the 3D deviation and angle deviation of the guiding plane preparation. The significance level was set at 0.05.

3. Results

The Shapiro–Wilk test indicated that the collected data conformed to a normal distribution. The post-hoc power was calculated using the mean and standard deviation per group in the Tables 1 and 2 at the "two-sample *t*-test allowing unequal variance" module of the statistical software (Power Analysis and Sample Size 15.0, NCSS Statistical Software, Utah, USA). Group sample sizes of 20 and 20 achieved 100% power for each calculation at a significance level of 0.05 and two-sided test direction.

3.1. Internal adaptation of templates

The internal occlusal gap between the occlusal surface of the abutment teeth and the intaglio surface of the template was normally distributed. The internal occlusal gap of the template was 198.5 ± 33.2 μm, the minimum value and maximum value were 142.9 μm and 253.2 μm, and the 95% confidence interval was 183.0 μm−214.0 μm.

3.2. Three-dimensional trueness of guiding plane preparation

The 3D trueness of the guiding plane preparation for the two groups was presented in Table 1. Independent-sample *t*-tests revealed that the test group showed significantly better 3D trueness (48.4 ± 12.9 μm) than the control group (128.5 ± 37.6 μm, $p < 0.01$). For distal guiding planes of the second premolars, 3D deviation of the test group (51.0 ± 13.1 μm) was significantly lower than that of the control group (123.2 ± 41.3 μm, $p < 0.01$). As for mesial guiding planes of the second molars, 3D deviation of the test group (41.0 ± 14.5 μm) was significantly lower than that of the control group (136.7 ± 55.6 μm, $p < 0.01$). Representative color-coded maps of 3D compare analysis were illustrated in

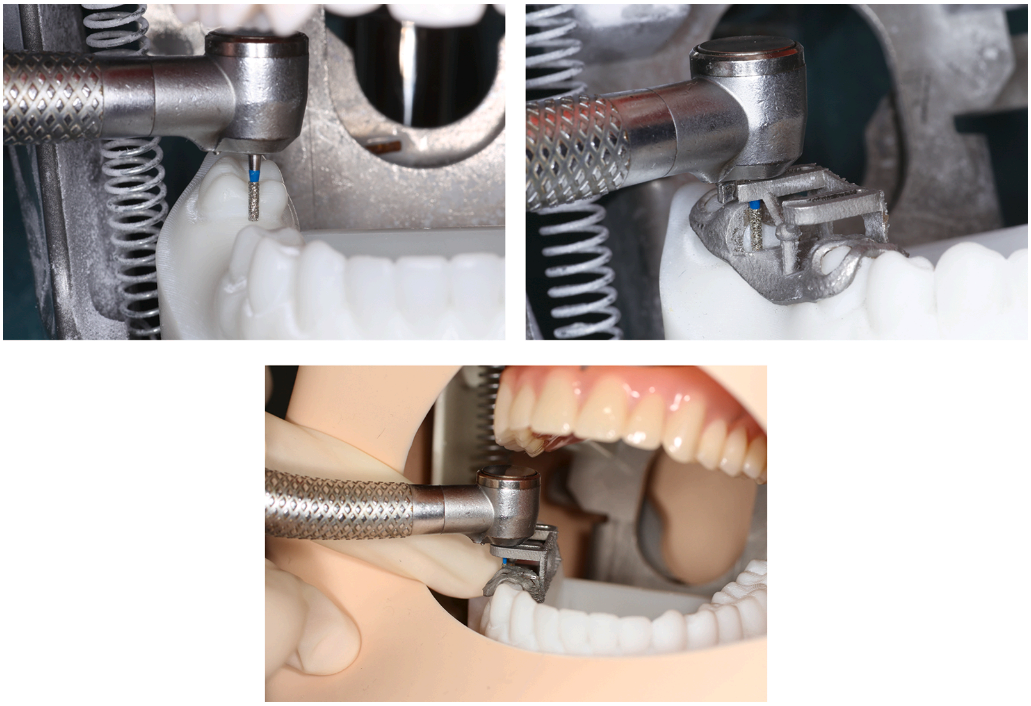

Fig. 5. Guiding planes were prepared in a phantom head simulator. (a) Freehand preparation. (b) CAD-CAM template assisted preparation. (c) Retention and stability of template was obtained with finger pressure.

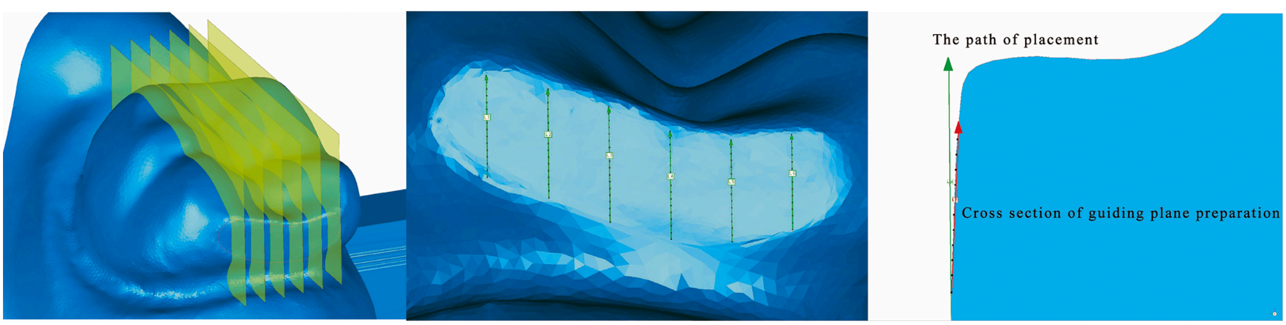

Fig. 6. Assessment of direction trueness. (a) Six cross-sections were virtually constructed parallel to the path of placement. (b) Recorded direction of the prepared guiding planes at each cross-section. (c) Calculation of the angle between the direction of the path of placement and the prepared guiding planes.

Table 1
3D trueness of guiding plane preparation (μm).

	Premolar			Molar			Overall		
Group	Mean ± S.D.	Maximum	Minimal	Mean ± S.D.	Maximum	Minimal	Mean ± S.D.	Maximum	Minimal
Template	51.0 ±13.1	74.6	20.9	41.0 ±14.5	70.2	20.9	48.4 ±12.9	76.8	21.7
Freehand	123.2 ±41.3	203.5	63.2	136.7 ±55.6	265.1	65.4	128.5 ±37.6	196.8	68.4
F	28.40			16.08			22.50		
df	22.78			21.57			23.41		
p	< 0.001			< 0.001			< 0.001		
power	1.00			1.00			1.00		

Significant difference at $p < 0.05$ (Independent-sample *t*-tests).
F: the test statistic of Leven's test for equality of variances.
df: degree of freedom.

Fig. 7. Insufficient preparation or aggressive preparation of guiding planes were founded more in the control group than that in the test group.

3.3. Direction trueness of guiding plane preparation

The direction trueness of the guiding plane preparation of the two groups was shown in Table 2. Independent-sample *t*-tests revealed that the direction trueness of preparation in the test group (1.20 ± 0.55°) was significantly better than that in the control group (7.68 ± 3.00°, $p <$

Table 2
Direction trueness of guiding plane preparation (degree).

	Premolar			Molar			Overall		
Group	Mean ± S.D.	Maximum	Minimal	Mean ± S.D.	Maximum	Minimal	Mean ± S.D.	Maximum	Minimal
Template	1.04 ±0.51	2.26	0.36	1.36 ±0.55	2.33	0.36	1.20 ±0.55	2.33	0.36
Freehand	8.08 ±3.12	13.69	0.42	7.28 ±2.84	14.96	2.86	7.68 ±3.00	14.69	0.42
F	22.27			18.61			45.31		
df	20.00			20.44			41.64		
p	< 0.001			< 0.001			< 0.001		
power	1.00			1.00			1.00		

Significant difference at $p < 0.05$ (Independent-sample *t*-tests).
F: the test statistic of Leven's test for equality of variances.
df: degree of freedom.

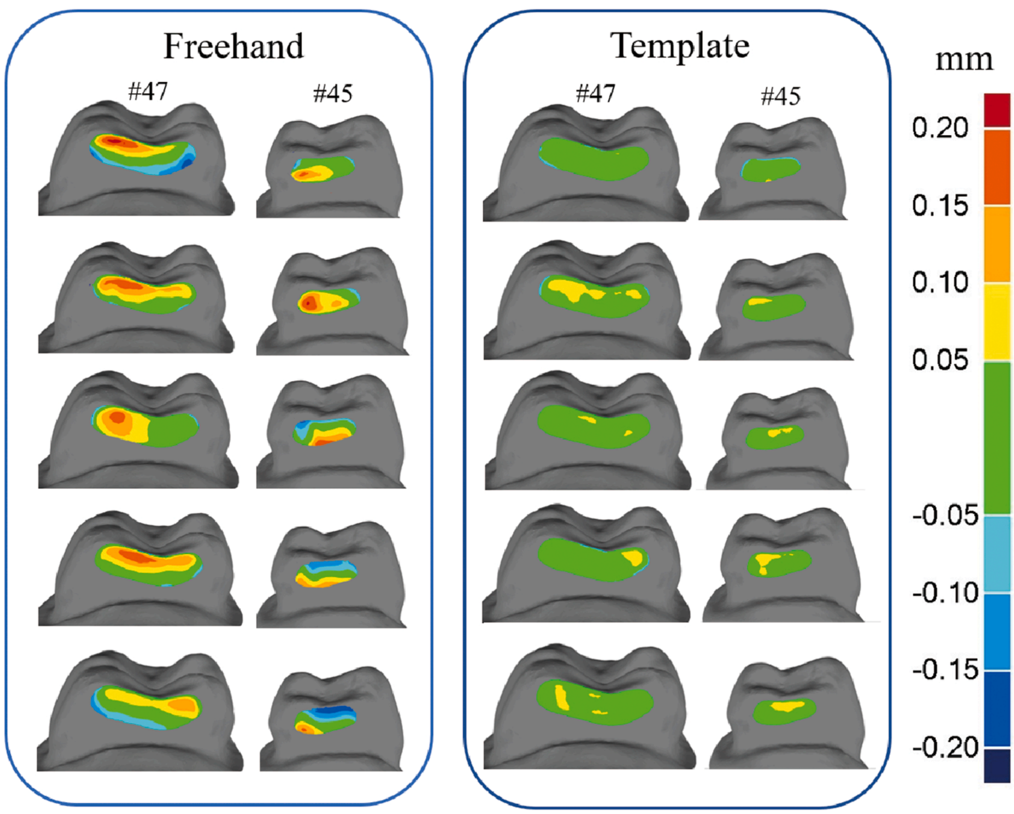

Fig. 7. Representative color-coded maps of 3D trueness between the prepared guiding planes (Test) and the virtually prepared guiding planes (Reference).

0.01). For distal guiding planes of second premolars, angle deviation of the test group (1.04 ± 0.51°) was significantly lower than that of the control group (8.08 ± 3.12°, $p < 0.01$). As for mesial guiding planes of second molars, 3D deviation of the test group (1.36 ± 0.55°) was significantly lower than that of the control group (7.28 ± 2.84°, $p < 0.01$).

4. Discussion

The null hypothesis was rejected as, the test group and the control group showed significant differences in trueness of guiding plane preparation.

The internal adaptation of templates was first examined because good internal adaptation was a prerequisite for utilizing the template to prepare guiding planes. The digital replica technique has been approved for examining the internal adaptation of prostheses regardless of the measurement site [21,22]. In this study, the template was designed according to major connector of RPD and fabricated by an SLM printer. SLM technology has been used to fabricate RPD frameworks with clinically acceptable internal adaptations. A gap from 0 μm to 50 μm was considered close contact (no gap) [26]. A gap of 50 μm to 311 μm was defined as a clinically acceptable fit [22,27,28]. The internal gaps assessed in this study (198.5 ± 33.2 μm) yielded similar results to the internal occlusal adaptation of a 3-unit Co-Cr alloy framework fabricated using SLM technology (148–218 μm) [29]. In the present study, the templates fabricated with Co-Cr alloy and SLM technology had clinically acceptable internal adaptation.

Previous studies did not investigate the reduction depth of the guiding planes [14,18]. Digital scanning and 3D analysis software for registering the resultant STL datasets offer an effective approach for assessing the accuracy of preparation depth [28,30,31]. The 3D trueness of guiding plane preparation in the test group indicated that the rigidly constrained template could assist clinicians in controlling the reduction depth of the guiding plane in a more precise and stable manner. Furthermore, 3D deviations of the test group falling within a narrow range (20.9–76.8 μm), indicating CAD-CAM template assisted procedure for preparing guiding planes is minimally invasive and predictable [32,33]. Previous studies found that guide devices such as ParalAB were rigidly constrained in controlling the direction of the diamond rotary instrument [7,17]. However, these devices did not restrict the reduction depth of the preparation, which increased the risk of the aggressive preparation in the clinic, especially when preparing guiding planes without direct vision.

The previous measurement method for guiding plane parallelism was described as follows: three noncollinear points on the prepared tooth surface were measured using a coordinate measurement machine (CMM) to create a plane, and the angle between the created plane and the direction of the path of the placement was calculated to represent the direction trueness of the guiding plane preparation. Although the aforementioned process was repeatedly performed three to five times and the average angle was calculated to eliminate random errors, only a few points were involved, and the point selection was susceptible to the operator's subjectivity. Furthermore, CMM is not an easily accessible piece of equipment in the clinic [14,18]. In this study, the prepared cast was quickly digitalized using a high-precision laboratory scanner and transferred to the 3D analysis software to calculate the direction deviation in a uniform and objective way [33,34]. Furthermore, templates can be designed to prepare guiding planes along the buccal and lingual curves of the abutment teeth, and the parallelism of the guiding planes can be assessed using the same method. More cross-sections can be virtually constructed to improve measurement reliability.

In the present study, the direction trueness of the control group (7.68 $\pm$ 3.00°) was similar to the results observed in Uemura et al.'s study (7.15 $\pm$ 5.80°) [14]. The standard deviation of the direction trueness in the freehand group (3.00°) was less than that reported by Uemura et al. (5.10°) [14], which could be attributed to all preparations in this study being performed in the phantom head simulator by one operator. The differences between these preparations may decrease as the number of preparations on identical casts increase. The direction trueness of the guiding planes prepared using templates was similar to that using ParalAB and surveying devices [14,35]. However, the ParalAB and surveying devices were difficult to fix and apply intraorally, but smaller template was easily applied in the clinic. With the aid of the template, the operator can prepare a guiding plane in 3–5 s without direct vision.

The entire tooth preparation process was performed in a phantom head simulator, which made the experiment more similar to a real clinical situation [36]. Tiu et al. found that intraoral crown preparations were more tapered with higher angle values than extraoral preparations, in addition, a clear pattern was observed in that the increasing angle values of the crown preparation as moving from the anterior teeth to the posterior teeth [37,38]. Hence, studies that utilize a real clinical environment are required in the future.

The development of digital technology has increased the design and manufacturing capabilities of RPDs, as well as the ability to prepare teeth. The goal is not only to improve trueness of tooth preparation but also to build a predictable tooth preparation procedure and, eventually, to immediately tried-in RPDs for patients that will save chairside time for both clinicians and patients [32,33]. Although the application of the template can improve the trueness of guiding plane preparation, the design and fabrication of the template requires additional time and cost. All of these design procedures will be fully automated in the future, resulting in a simple and efficient workflow. With the continued development of a broader distribution of lower-cost production units, clinicians and patients will benefit from lower operating costs and a more efficient workflow [39,40].

More details need to be considered in the clinical application of the template, such as the retention and stability of the template, water spraying and cooling during preparation, and the approach for designing the template when patients have limited mouth opening space [19]. In most cases, clinicians can manually press the template with their fingers to keep it fixed and secure intraorally. Additionally, the template can be designed with some clasps to aid in its retention, especially when preparing maxillary abutment teeth. In only a few cases, the cooling water cannot be sprayed directly onto the abutment tooth surface because of the template barrier, however, it can still flow along the template to the abutment teeth for cooling. Metals have high thermal conductivity, allowing them to successfully avoid heat injury caused by cutting [41,42]. When the patient has a small mouth opening, a shorter diamond rotary instrument should be used to minimize the height of the guide rails. The template is small and could be securely applied in clinical practice.

Limitations associated with the present study include that it did not considered tooth hardness, tooth mobility, soft tissue, patient mouth opening, and patient movement. Studies that utilize a real clinical environment are required in the future. In addition, all guiding planes were designed and prepared to be flat for conveniently assessing the 3D trueness of the guiding planes in both groups. In the clinic, the guiding planes can be prepared to conform the natural tooth morphology. In this study, guiding planes were prepared on the same mandibular cast by the same dental postgraduate student for avoiding unexpected interferences caused by different dentitions and operators. Hence, the influence of different dentitions and clinicians need to be further assessed. It's worth noting that, The angle deviation was calculated through creating six cross-sections, that may differ from the actual angle deviation between the proximal plate of RPD and the path of placement.

5. Conclusions

Within the limitations of this study, the following conclusions may be drawn:

1. This in vitro study preliminarily demonstrated that guiding planes prepared by the CAD-CAM template assisted procedure exhibited significantly higher trueness than those prepared by the freehand procedure.
2. With the aid of the CAD-CAM template, multiple guiding planes can be prepared precisely and predictably

CRediT authorship contribution statement

Hefei Bai: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Writing – original draft, Visualization. **Hongqiang Ye:** Resources, Writing – review & editing, Supervision. **Hu Chen:** Writing – review & editing, Supervision. **Yong Wang:** Writing – review & editing, Supervision. **Yongsheng Zhou:** Conceptualization, Methodology, Validation, Resources, Writing – review & editing, Project administration. **Yuchun Sun:** Conceptualization, Methodology, Software, Resources, Visualization, Project administration, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

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