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ORIGINAL RESEARCH

Machining accuracy of pediatric partial dentures using computer-aided design-computer aided manufacturing (CAD-CAM) system

Kaori Kohi[1], Yumi Tsuchida[2], Kanae Wada[1,*], Yumiko Nakashima[1], Tsutomu Iwamoto[1], Hidekazu Takahashi[3]

[1]Department of Pediatric Dentistry/Special Needs Dentistry, Institute of Science Tokyo, 113-8549 Tokyo, Japan
[2]Department of Digital Dentistry, Institute of Science Tokyo, 113-8549 Tokyo, Japan
[3]Department of Basic Oral Health Engineering, Institute of Science Tokyo, 113-8549 Tokyo, Japan

***Correspondence**
wadadohs@tmd.ac.jp
(Kanae Wada)

Abstract

Background: The complete digitalization of pediatric partial denture (PPD) is progressing rapidly and holds promise for pediatric dentistry. However, the machining accuracy of subtractive manufacturing (SM) and additive manufacturing (AM) produced by computer-aided design-computer aided manufacturing (CAD-CAM) systems has not been clarified. Therefore, we aimed to evaluate the machining accuracy of PPD manufactured by SM and AM. **Methods**: The machining accuracy was evaluated based on the accuracy of mucosal surface fitting of the three types of PPDs (control-PPD, SM-PPD, and AM-PPD) and the accuracy of the design data for SM-PPD (n = 6) and AM-PPD (n = 6). Standard Tessellation Language (STL) data of the digital design, the mucosa surface of the jaw model, and the polished surface of each PPD (control, SM, AM), as well as the scanned STL data of each PPD produced by CAD-CAM were superimposed using Artec Studio 12 Professional software (Luxembourg). The data were superimposed and displayed in a color map. The mean root mean square (RMS) values standard deviation (SD) (mm) of the fit between the mucosal surface fitting of the control-PPD and the PPD fabricated using the CAD-CAM system and the jaw model were statistically compared using the Kruskal-Wallis test (α = 0.05). The average RMS values of the two design data accuracies were statistically compared using the Mann-Whitney U test (α = 0.01). **Results**: No significant difference was observed in the accuracy of mucosal surface fitting in the control-PPD, AM-PPD and SM-PPD. The mean RMS values (SD) (mm), which indicate the precision of design data, were 0.09840 (0.00315) and 0.06389 (0.00371) for the AM-PPDs and SM-PPDs, respectively. SM-PPDs showed significantly higher accuracy than the AM-PPDs (p = 0.002). **Conclusions**: Both methods achieved acceptable mucosal surface fitting; however, SM-PPDs showed higher machining accuracy than AM-PPDs. These findings support the integration of SM-based CAD-CAM systems in pediatric prosthetic practice.

Keywords

Additive manufacturing; Pediatric partial denture; Subtractive manufacturing; CAD-CAM

1. Introduction

Digital technology has undergone significant development in recent years, and its application in dental treatment, such as dental prosthesis devices, implants, and orthodontics, has proven reliable. However, compared to other fields, the extent to which digital technology is applied in pediatric dentistry is limited [1–5].

In pediatric dental clinics, a removable space maintainer is used to maintain the space between teeth, restore masticatory and swallowing functions, and maintain esthetics. In this study, the removable space maintainer is referred to as a pediatric partial denture (PPD). Dental issues are often caused by congenital anodontia, multiple dental caries, or early loss of teeth due to trauma. A PPD is the only device capable of maintaining the space between the teeth both vertically and horizontally; however, recording an impression for PPD fabrication is often difficult due to factors such as the pharyngeal or gag reflex and the patient's young age. Thus, hampering PPD production. Moreover, PPDs become incompatible as children grow, often requiring the device to be remade or repaired and repeated impression recording. Recording an intraoral optical impression is simple, causes less discomfort, and poses no risk of ingestion and aspiration. Therefore, this technology will likely be applied clinically to pediatric patients. In recent years, numerous studies have reported the accuracy of impressions acquired using an intraoral scanner.

These reports concluded that the accuracies of intraoral optical impressions were better or comparable to those of conventional impressions [6, 7].

The complete digitalization of PPD fabrication offers several advantages, including increased productivity and an improved work environment for dental technicians, enhanced storage and rapid transmission of information, and increased design reliability. In addition, vast amounts of data obtained from optical impressions can be stored, making it easy to compare these data over time as the patient grows. The complete digitalization of PPD fabrication is advancing rapidly and will likely be incorporated into dental practice; however, research on this method in pediatric dentistry is limited [1]. Pediatric patients undergo continuous growth and development; hence, the fit of removable prostheses can significantly impact masticatory function and craniofacial development. Therefore, ensuring high fabrication accuracy is crucial. In recent years, the spread of CAD-CAM technology has led to the introduction of denture fabrication for congenital anodontia in pediatric dentistry [4]. However, challenges in accuracy and workflow persists [5].

Furthermore, the machining accuracy of subtractive manufacturing (SM) and additive manufacturing (AM) fabricated using computer-aided design-computer aided manufacturing (CAD-CAM) systems with a focus on the clinical applications of digital technology in pediatric dentistry has not been clarified. Therefore, in this study, we aimed to evaluate the machining accuracy of the PPD manufactured by SM and AM. We hypothesized that no difference exists between the machining accuracies of AM-PPD and SM-PPD (null hypothesis).

2. Materials and methods

2.1 Sample preparation

The sample size for this study (n = 6) was set based on previous studies [8, 9].

2.2 PPD fabrication methods

2.2.1 Materials and PPD digital designing and manufacturing methods

Table 1 shows the materials used in this study. An anatomical model (Nissin Dental Product, Kyoto, Japan) of the jaw, depicting the intraoral cavity with a mucous membrane, was used (Fig. 1). Three teeth were missing bilaterally: the first primary molar (#84) on the right side and the first and second primary molars (#74 and #75) (thus, two missing teeth in total) on the left side.

2.2.2 PPD fabrication by conventional method

Impressions were recorded on a jaw model by mixing 16.4 g of alginate impression material (AROMA FINE PLUS, GC, Tokyo, Japan) and 40 mL of cold water for 14 s using an automatic mixer (MIKRONA MIXER, MIKRONA TECHNOLOGY AG, Zurich, Switzerland), and then a stock tray (Impression tray, Dentsply Sirona Japan). After the impressions were recorded, a dental stone (NEW PLASTONEII, GC) was cast into the impression, and a working model was made. The undercut area of the working model was blocked out and coated with a resin separator (NEW ACROSEP, GC). Autopolymerizing resin was applied using the brush-dip technique (Metafast #2, Sunmedical CO, Siga, Japan). After the autopolymerizing resin was built up, the PPDs were immersed in water for 1 h, and morphological correction and polishing were performed. The mucosal surfaces were not morphologically modified and polished. Six PPDs were fabricated by one dentist using the above-mentioned method as the conventional method (control-PPD; Fig. 2).

2.2.3 PPD digital designing and manufacturing methods

An optical impression of the one jaw model was recorded using an intraoral scanner (TRIOS 3, 3Shape A/S, Copenhagen, Denmark) (Fig. 3a) and saved as a Standard Tessellation Language (STL) file. The PPDs were digitally designed using CAD software (ver. 2019, S-WAVE, 3Shape A/S, Copenhagen, Denmark) with the scanned STL file. The PPD was designed using the partial denture design mode. First, the undercut part of the model was blocked out (Fig. 3b), and the PPD outline was set (Fig. 3c). A virtual wax-up was performed on the outline of the designed PPD so that the plate thickness was 0.2 mm, using the major connector design mode (Fig. 3d). Thereafter, to simplify the outer shape of the PPD, the height of the areas with missing teeth was designed to be parallel to the occlusal surface, and a virtual wax-up was performed. In the added wax-up section, additional smoothing was conducted such that the plate of the PPD was transitional (Fig. 3e,f). The designed PPD data were saved as an STL file.

The designed PPD was manufactured using two machining methods, SM and AM. SM-PPD was fabricated from a poly methul meth acrylate (PMMA) resin disc (M-PM-Disc, Shofu, Kyoto, Japan) by using a milling machine (DWX-50, DGSHAPE, Shizuoka, Japan) with a CAM software (Go2Dental, Go2cam, Lyon, France) (Fig. 4). AM-PPD

TABLE 1. Pediatric partial denture materials and machining equipment.

	Material			Processing Machines	
	Material Name	Code	Manufacturer	Name	Manufacturer
AM-PPD	Dima Print Denure Base Light Pink	3D-printable ink	KULZER, Germany	cara Print 4.0	KULZER, Germany
SM-PPD	M-PM Disc	PMMA-disk	Shofu, Japan	Roland DWX-50	Roland, Japan
Control-PPD	Metafast #2	Self-curing resin	Sunmedical CO, Japan		

Abbreviations: AM: additive manufacturing; PPD: pediatric partial denture; SM: subtractive manufacturing.

FIGURE 1. Anatomical model of the jaw depicting the intraoral cavity with mucous membrane. Three teeth are missing bilaterally: the first primary molar on the right side and the first and second primary molars on the left side (a total of 3 missing teeth).

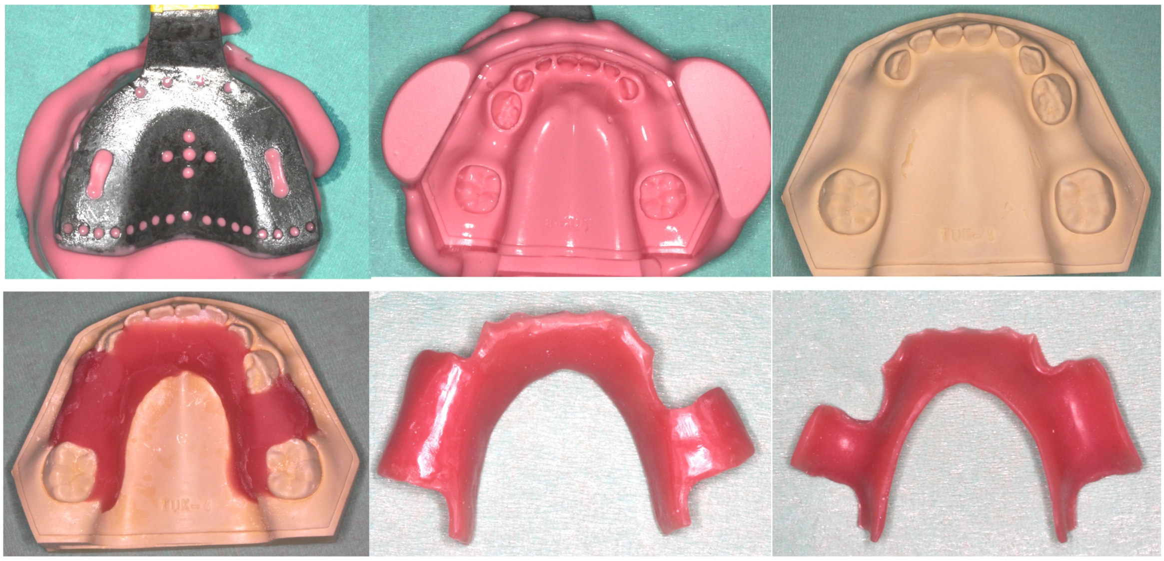

FIGURE 2. Manufacturing of the pediatric partial denture using conventional method (control).

was fabricated using a digital light projection machine (Cara Print 4.0, Kulzer GmbH, Hanau, Germany) with a monomer for denture base (dima Print Denture Base Light Pink, Kulzer GmbH). The designed STL was assigned to a platform at an angle of 45°, and supporters were attached (Fig. 5). Fabrication, cleaning, and post-polymerization of the AM-PPD were performed according to the manufacturer's instructions. Isopropyl alcohol (99.9%) was used for ultrasonic cleaning, which was performed twice for 5 min each. Next, post-polymerization was conducted in glycerin using a xenon post-polymerization apparatus (HiLite power 3D, Kulzer GmbH, Hanau, HE, Germany) for the mucosal and occlusal surfaces for 10 min each. All procedures were standardized using the same equipment and settings, and a single operator performed all processing steps to minimize variability. Six SM-PPDs and AM-PPDs (12 in total/n = 6 in each group) were fabricated in this manner.

2.3 Measurement and analysis methods

2.3.1 Machining accuracy

In this experiment, "Accuracy", "trueness" and "precision" were defined based on the ISO 5725 definitions. Accuracy includes "trueness" and "precision". This study's root mean square (RMS) corresponds to trueness, and the standard deviation (SD) of the RMS corresponds to precision. The accuracy of the mucosal surface fitting of the three PPDs and the accuracy of the design data of the SM-PPD and AM-PPD were considered as machining accuracy by assessing the trueness from the RMS and precision from the SD of the RMS.

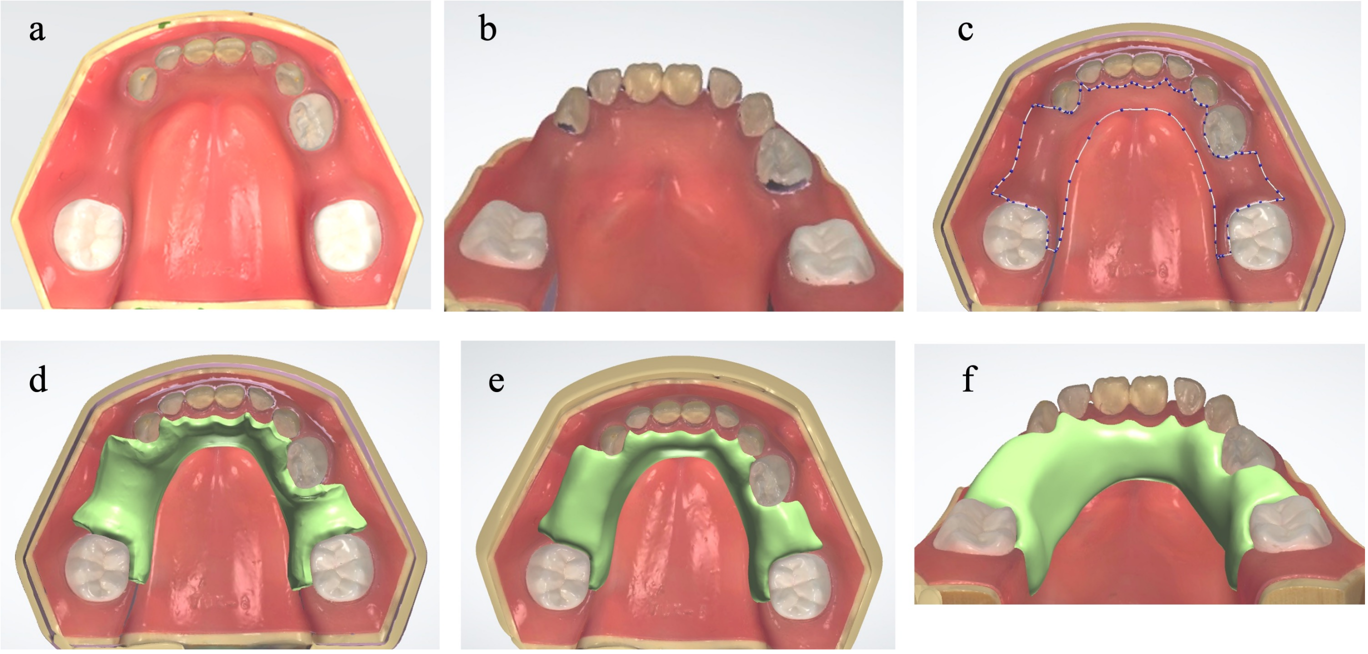

FIGURE 3. Pediatric partial denture design using computer-aided design software. (a) An optical impression of the mucosal anatomical jaw model was recorded using an intraoral scanner. (b) Blocking out of the undercut area. (c) Pediatric partial denture outline settings. (d) A 0.2-mm wax-up was applied to the outline. (e) Occlusal view of the completed design. (f) Lingual view of the completed design.

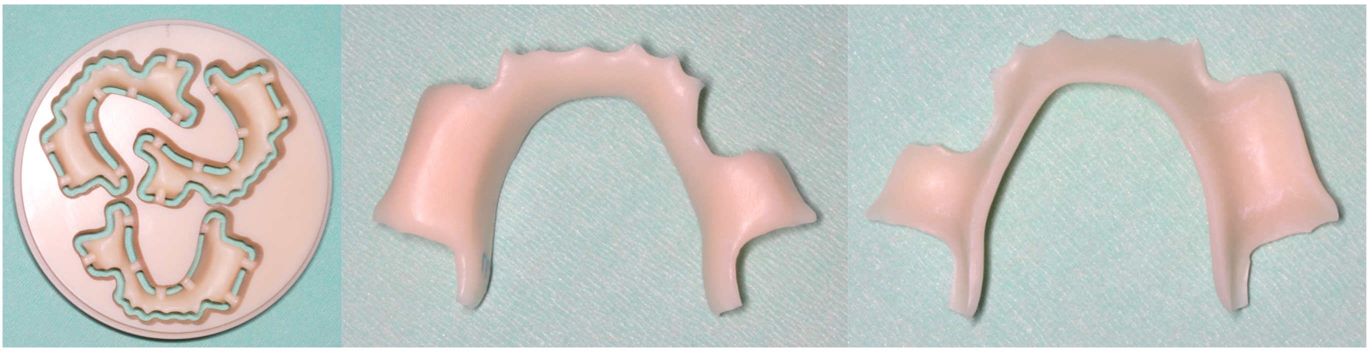

FIGURE 4. Manufacturing of the pediatric partial denture using subtractive manufacturing.

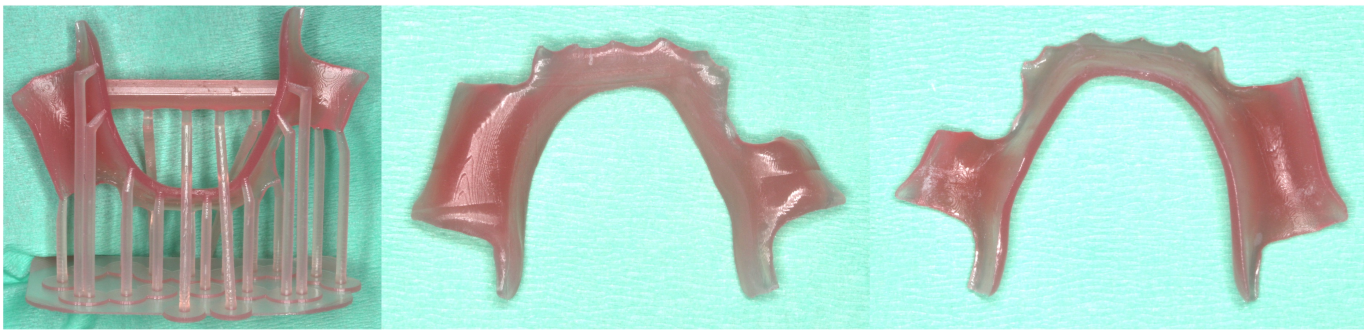

FIGURE 5. Manufacturing of the pediatric partial denture using additive manufacturing.

2.3.2 Evaluation of the accuracy of mucosal surface fitting

Fig. 6 shows the protocol for the accuracy of mucosal surface fitting. Mucosal surface STL data of jaw models and each PPD were superimposed using image processing software (Artec Studio 12 Professional, Artec 3D, Luxemburg), and the two-dimensional discrepancies of two images were calculated as the average value of the RMS (mm), which is a representative value indicating the accuracy of mucosal surface fitting. The mucosal surface of the PPD was cut from the STL data of the jaw model using image processing software (Artec Studio 12 Professional, Artec 3D, Luxemburg, and Geomagic Freeform, 3DSystems, USA). Each PPD (control, SM and AM) was scanned with a laboratory scanner (D2000, 3Shape, Copenhagen, Denmark) and converted to STL data. The converted STL data was transferred to an image processing software (Artec Studio 12 Profession; Artec 3D, Luxemburg, and Geomagic Freeform, 3DSystems, USA), and the STL data was separated into the polished and mucosal surfaces of the PPD. The mean deviation of these discrepancies was also displayed as color maps. The scale error was set to 0.2 mm. The color map shows the mean deviation between the digital design STL data and the scanned STL data from the PPDs. The permissible range for conformance accuracy is green (±0.1 mm). Negative deviations are shown in blue (−0.1 to −0.2 mm; the scanned PPD STL is smaller than the digital design), and positive deviations are shown in red (+0.1 to +0.2 mm; the scanned PPD is larger than the digital design).

2.3.3 Evaluation of the accuracy of design data

The accuracy of the SM-PPD and AM-PPD design data was examined. Fig. 7 shows the flowchart of the PPD accuracy verification protocol. For PPDs manufactured using the CAD-

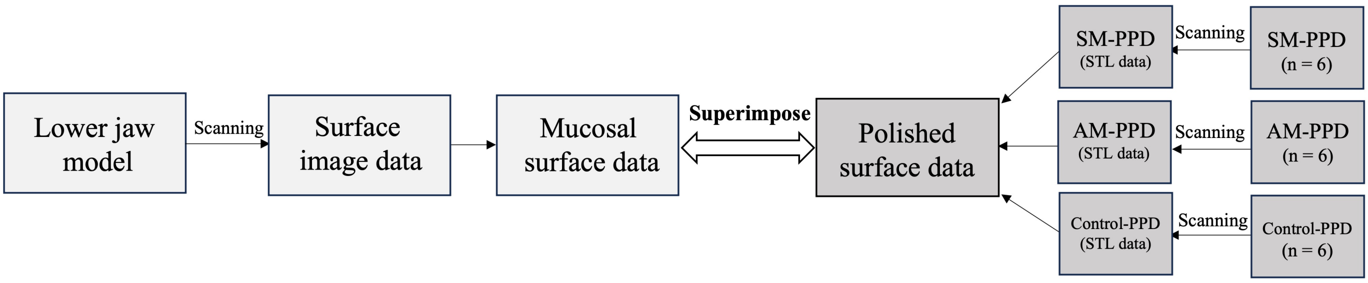

FIGURE 6. Protocol for the accuracy of mucosal surface fitting. AM: additive manufacturing; PPD: pediatric partial denture; SM: subtractive manufacturing; STL: Standard Tessellation Language.

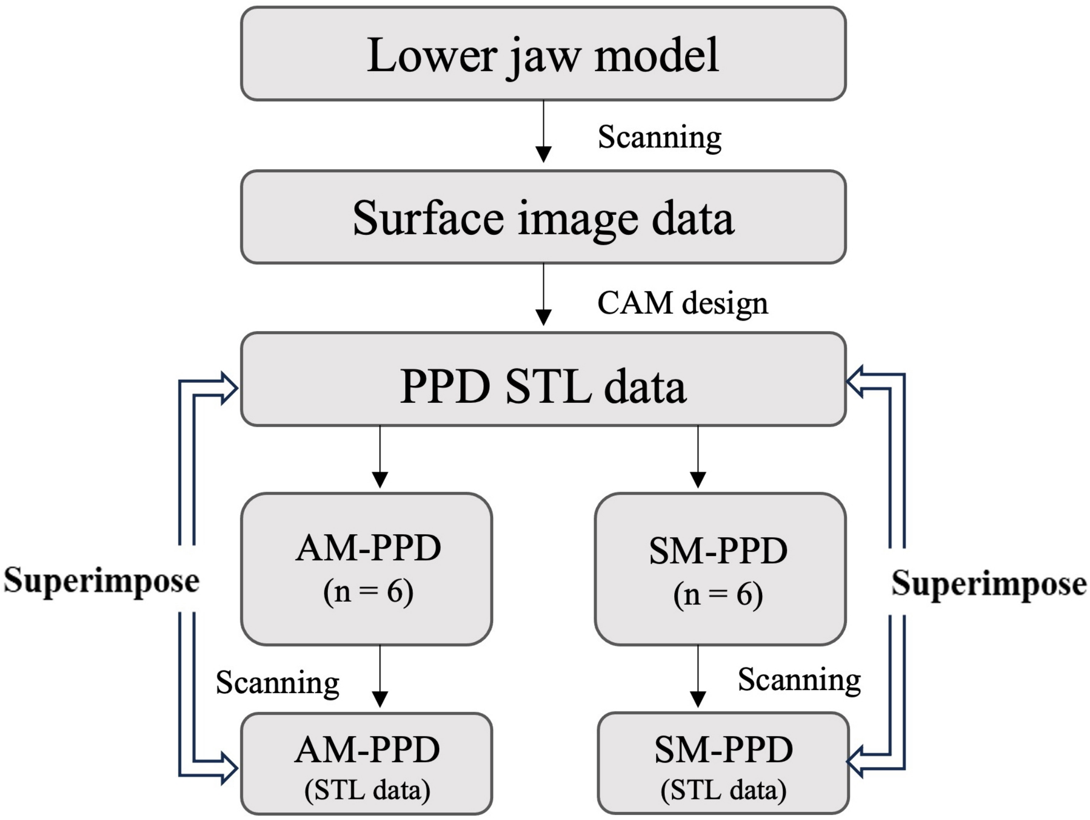

FIGURE 7. Machining accuracy verification protocol. AM: additive manufacturing; PPD: pediatric partial denture; SM: subtractive manufacturing; STL: Standard Tessellation Language; CAM: computer-aided manufacturing.

CAM system, the supporting parts were cut and polished. The SM-PPD and AM-PPD were scanned with a laboratory scanner (D2000, 3Shape, Copenhagen, Denmark), and the information was converted into STL data. The digital design STL data and the STL data from each scanned PPD were superimposed using Artec Studio 12 Professional software (Luxembourg). The average value of the RMS (mm) was calculated as a representative value indicating machining accuracy. The accuracy of AM-PPD and SM-PPD was superimposed to show a color map.

2.4 Statistical analysis

The mean RMS values of the fit between the mucosal surface fitting of the control-PPD and the PPD fabricated using the CAD-CAM system and the jaw model were statistically compared using the Kruskal-Wallis test at a significance level of α = 0.05.

The average RMS values of the two accuracies of design data were statistically compared at the significance level of α = 0.01 using the Mann-Whitney U test using SPSS V 24.0 (IBM Corp., Armonk, NY, USA).

3. Results

3.1 Evaluation of the accuracy of mucosal surface fitting and superimposed color mapping

The mean RMS (SD) (mm) was compared to the fit between the mucosal surface of the jaw model and each PPD. The mucosal surface fitting of the three PPDs was evaluated in terms of machining accuracy, with RMS indicating trueness and the SD of RMS indicating precision. The probability of significance for control-PPD, AM-PPD, and SM-PPD determined by the Kruskal-Wallis test was 0.834, which suggested no significant difference among the three groups. The conformation of the mucosal surface of the jaw model and each PPD is shown in Fig. 8.

3.2 Evaluation of the accuracy of design data and superimposed color mapping

Machining accuracy for SM-PPD and AM-PPD designs were evaluated by assessing the trueness of the RMS and precision of the SD of the RMS. The mean RMS values (SD) (mm), which indicate the precision of design data, were 0.09840 (0.00315) and 0.06389 (0.00371) for the AM-PPDs and SM-PPDs, respectively. SM-PPDs showed significantly higher accuracy than the AM-PPDs (p = 0.002, Fig. 9). The color map results of the accuracy of design data of AM-PPD and SM-PPD are shown in Fig. 10.

4. Discussion

In prosthodontics, the use of digital technology has led to implementing CAD-CAM technology for adults with complete or partial plated dentures. However, research on this topic in pediatric dentistry is limited. Soni [1] published a case report where band loops made using CAD-CAM technology were used. In contrast Guo *et al.* [2] reported a study where PPDs were made using poly ether keton material. Shin *et al.* [10] reported that the wear of three-dimensional (3D) printed artificial teeth is suitable for primary teeth. In this study, we first examined whether there was a difference in fit between control-PPDs made using a conventional method and PPD fabricated using a CAD-CAM system when applying this digital technology clinically in pediatric dentistry. No significant difference was found in the fit of the mucosal surfaces across the methods. The color map showed blue (negative deviation) in the area corresponding to the part of the alveolar ridge apex in control-PPDs, suggesting that polymerization shrinkage of the immediate-curing resin occurred at the area corresponding to the alveolar ridge apex. All PPDs showed yellow or red (positive deviation) in the transition area from

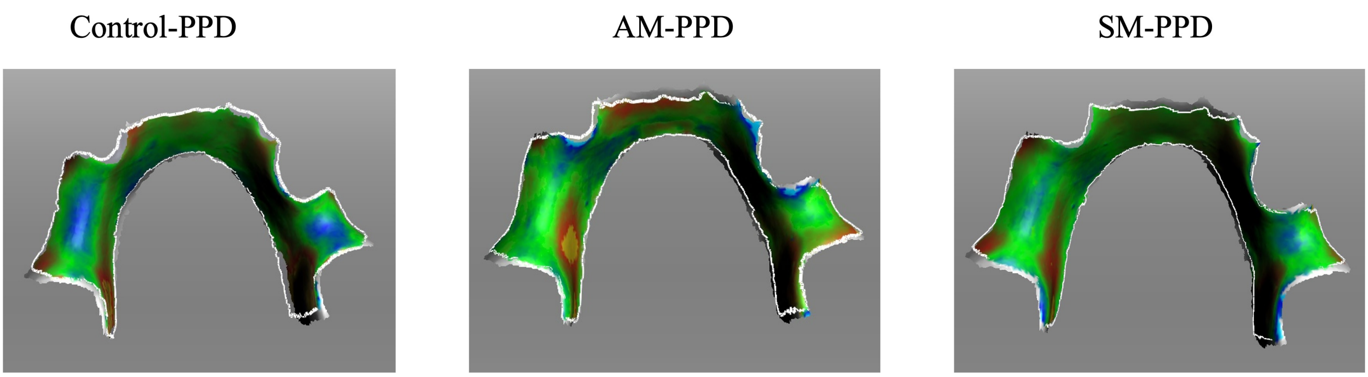

FIGURE 8. Mucosal surface of the jaw model and each PPD color mapping. Each color mapping shows the state of fit between the mucosal surface of the jaw model and each PPD. The control-PPD showed blue (negative deviation) at the area corresponding to the part of the alveolar ridge apex and yellow or red (positive deviation) in the transition area of the missing mandibular first molar from the lingual side. AM-PPD showed yellow or red (positive deviation) in the lingual crest of the anterior mandibular teeth and in the transition area from the lingual side of the mandibular first molars to the missing area. SM-PPD showed red (positive deviation) in the transition area of the missing mandibular first molar from the lingual side and in the labial floor margin of the missing area. AM: additive manufacturing; PPD: pediatric partial denture; SM: subtractive manufacturing.

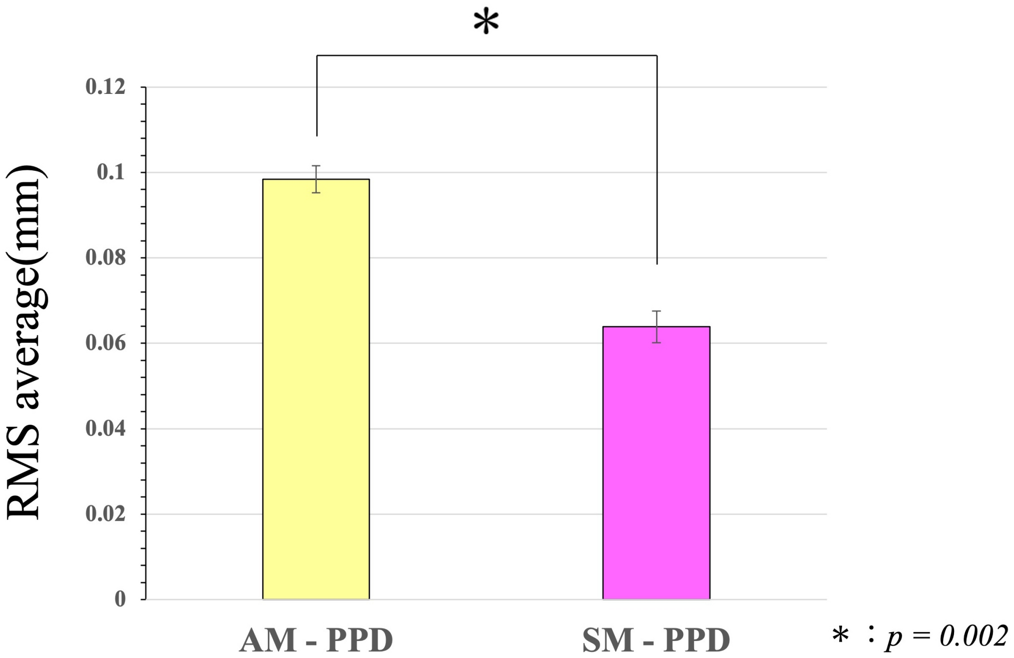

FIGURE 9. RMS average values for AM-PPD and SM-PPD. The SM-PPD showed significantly higher precision than the AM-PPD (p = 0.002). AM: additive manufacturing; PPD: pediatric partial denture; RMS: root mean square; SM: subtractive manufacturing.

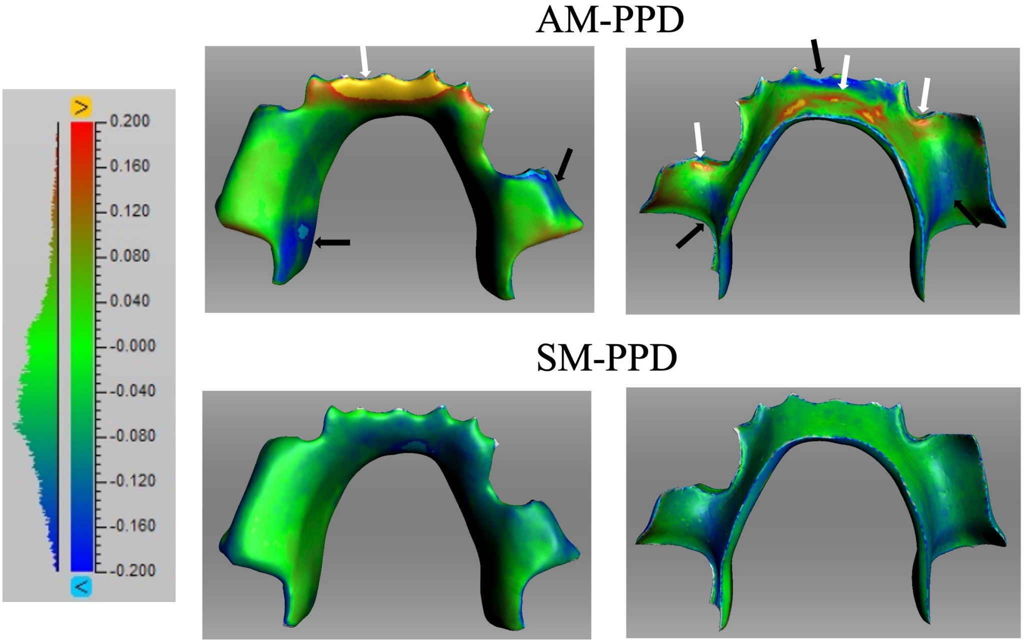

FIGURE 10. AM-PPD and SM-PPD color mapping. For AM-PPD, a yellow (positive deviation) color was observed on the mucosal surface in the mesial area that is in contact with the anterior mandibular teeth of the lingual alveolar ridge, left deciduous canine, and the right primary molar, as well as on the area corresponding to the anterior mandibular teeth on the polished surface (⇒). Blue (negative deviation) was observed in the anterior mandibular teeth, the area corresponding to the part of the alveolar ridge apex on the left side with missing teeth, and on the lingual side of the first molars on both sides of the mandible on the mucosal surface and the lingual side of the left first molar and the buccal side of the area with missing teeth, on the right side on the polished surface (→). For SM-PPD, no yellow or red (positive deviation) coloring was observed on the polished and mucosal surfaces, and overall, the map showed light green to green, which indicates that the deviation was within the allowable range. Blue (negative deviation) was observed on areas such as the mucosal surfaces of the parts of the alveolar crest with missing teeth and the polished surfaces of the anterior mandibular teeth. AM: additive manufacturing; PPD: pediatric partial denture; SM: subtractive manufacturing.

the lingual portion of the first molar to the defect, with a pronounced yellow (positive deviation) in the AM-PPDs and control-PPDs.

Our results showed that using an intraoral scanner to obtain a digital impression for manufacturing PPDs is feasible and SM-PPDs have superior accuracy compared to AM-PPDs. The null hypothesis was rejected because the results showed that SM-PPDs had significantly higher accuracy than AM-PPDs.

Various AM methods have been proposed for creating dental plates (ISO/ASTM 52900: 2021 Additive manufacturing—General principles—Fundamentals and vocabulary). However, among these methods, the most used AM system is vat photopolymerization (VAT). For the VAT used here, the pool of liquid resin was exposed to ultraviolet rays, curing each layer. The two types of VAT used are stereolithography (SLA), which uses laser light scanning, and digital light processing (DLP), which irradiates with a projector. Assuming a clinically acceptable range for the accuracy of SLA and DLP is 100–500 μm, the minimum and maximum SLA values were 3.3 μm and 579 μm, respectively, and most DLP values were 100 μm. Therefore, the models produced using VAT had an error within the permissible range, indicating no problems with accuracy.

Furthermore, various aspects of the production process, such as adjusting layer thickness, design, post-treatment, and storage, affect the model's accuracy [11]. The use of VAT in dental laboratories and clinics is expected to increase because the running cost for VAT is relatively low, and the time required for modeling is short and economical [12]. Therefore, in this study, we selected VAT because it is a DLP method commonly used in the dental field.

In contrast, SM is often used to produce prosthetic devices, such as fixed dental prostheses and implants, and its usefulness for adapting to the oral cavity has been confirmed. Furthermore, it can be adapted to dentures [13–15].

We used the mean RMS values and PPD color maps to evaluate machining accuracy. The mean RMS value was determined by calculating the distance between the measurement points of two objects and the smallest sum of the squared absolute values of the distance between the measured points (best-fit method). This evaluation method uses the average of distances, thus revealing the degree of difference between two objects. The smaller the mean RMS value, the smaller the difference in shape between two objects. A color map shows the distribution of the distance between two objects. In this study, the average RMS value (mm) was significantly smaller for SM-PPD than AM-PPD, indicating that the machining accuracy of SM-PPD was excellent. Yoshidome *et al.* [9] used the conventional method (powder/liquid mold polymerization) and a CAD-CAM system (AM and RM) on a complete denture (CD) of the maxilla and compared the compatibility of the CD produced using RMS. Their findings revealed RMS values of 0.0028, 0.006621, and 0.01092 for SM-CD, AM-CD, and the conventional method, respectively, with SM-CD having the highest accuracy and the conventional method having the lowest accuracy. Consistent with previous studies, SM was more precise than AM as shown by the RMS value of the PPD with three missing teeth used in this study. The PPD color map results showed that the fit's overall accuracy was within an acceptable range for SM-PPD. Machining accuracy was only high when we observed negative deviations of the polished surface areas with missing teeth of the alveolar ridge on the mucosal surface and the anterior mandibular teeth.

For AM-PPD, the amount of yellow in the color map exceeded that of red for the anterior mandibular teeth of the mucosal and polished surfaces. Red indicates a positive deviation (+0.1 to +0.2 mm). In addition, negative deviations were found in areas with missing teeth or near the edges of the plate. Kalberer *et al.* [16] reported a color map comparison showing the accuracy of CDs of the maxilla made using AM and RM after being soaked in artificial saliva for 21 days and dried post-initial production. After production, CDs produced using SM were significantly superior to those produced using AM.

In addition, Yoshidome *et al.* [9] made CDs of the maxilla using AM and SM and compared the conformance accuracy of the mucosal surfaces using a color map. When SM was used, all mucosal surfaces were within the permissible accuracy range ($\pm$0.1 mm). In contrast, when AM was used, the anterior residual ridge and posterior denture base showed a slight positive deviation. All the borders showed a slight negative deviation. In addition, the type of missing-teeth model used in this study had different numbers of teeth missing on the left and right sides; nevertheless, negative deviations were observed on both sides of the color map, and no significant differences were observed. We observed material accumulation at the lingual flange of the anterior and left posterior regions in AM-PPDs. This phenomenon may be attributed to asymmetric polymerization shrinkage during the additive manufacturing process and differences in support placement. In addition, build orientation and gravity-induced deformation during photopolymerization may contribute to localized distortions in these regions.

As shown by the mean RMS value and color map results of this study and the findings of previous studies, the machining accuracy of SM was higher than that of AM. This is likely due to polymerization shrinkage. The degree of polymerization and curing depth of 3D printer materials produced by AM are affected by parameters such as light-curing unit properties [17], temperature and curing time [18], layer thickness [19], ethylene oxide units [20], and post-polymerization method [21–24]. In addition, it may be affected by excessive curing, leading to non-curing of the 3D printing process. Furthermore, it could impair the conversion of single-printed layers by causing heat generation during polymerization [25]. With SM, a ready-made PMMA disk is carved with no polymerization shrinkage of the disk [26, 27]. In a previous study that compared the mechanical properties of denture base resin materials fabricated by 3D printing, milling, and the conventional method, the flexural strength was reported as 96.08 $\pm$ 4.13 MPa, 89.62 $\pm$ 8.60 MPa, and 117.62 $\pm$ 9.81 MPa for the conventional method, milling, and 3D printing, respectively. Furthermore, the flexural modulus was 1.79 $\pm$ 0.14 GPa, 2.18 $\pm$ 0.14 GPa, and 4.06 $\pm$ 0.15 GPa for the conventional method, milling, and 3D printing, respectively [28]. These results suggest that denture base materials fabricated using 3D printing and milling exhibit comparable or even superior performance compared to those fabricated using conventional methods. Generally, in the SM, a prepolymerized disk is used, which does not undergo polymerization shrinkage, allowing for highly accurate machining. In contrast, AM involves a layer-by-layer photopolymerization process, where local polymerization shrinkage typically occurs in each layer. The accumulation of this localized shrinkage may have led to slight deviations in the final dimensional accuracy. Furthermore, this difference in accuracy could also be attributed to the modeling angles at the time of production [8, 9, 29, 30]. In a study conducted by Hada *et al.* [8], the CD of the maxilla was produced with modeling angles of 0°, 45° and 90° using AM, and their accuracy was compared. The accuracy of these dentures was dependent on the modeling angle. Yoshidome *et al.* [9] used AM to create eight CDs of the maxilla with eight different modeling angles and verified the accuracy and modeling angles of 45° and 225°, demonstrating excellent accuracy. Chaiamornsup *et al.* [30] designed a three-unit (left mandibular second premolar and the bridge of the second molar abutment tooth) fixed prosthesis using CAD software that utilized the DLP method and produced a casting pattern. During the design process, the modeling angles were set to 0°, 30° and 45°, and the effect of these different angles was compared. Excessive parts were observed for dentures with modeling angles of 30° and 45°, and an angle of 0° was recommended when manufacturing a three-unit fixed prosthesis by the DLP method.

AM modeling angles may affect not only accuracy but also mechanical strength [9]. These reports also suggested that polymerization shrinkage and expansion may have inferior machining accuracy due to molding angle anisotropy. A suitable modeling angle may exist for manufacturing equipment using AM. In the present study, the machining accuracy of the AM-PPD was found to be low. Hence, verifying the appropriate modeling angles for production when using AM is necessary.

In the present study, a priori power analysis was not conducted when determining the sample size, which may have limited the statistical power of the findings. Future studies should consider using a larger sample size to enhance the robustness of the results. Limitation of the study was that this study was an *in vitro* investigation using a static jaw model, which did not replicate dynamic oral conditions such as the presence of saliva, fluctuations in temperature, or variations in mucosal pressure. These limitations may affect the accuracy of the fit when applied in actual clinical situations. Therefore, caution should be exercised when extrapolating these results to clinical practice. Future studies should explore these variables under *in vivo* conditions to enhance clinical relevance and validity.

Generally, PPDs are manufactured using the brush-on technique with immediate polymerization resin. They require impression recording and model-making. PPD quality can depend on the proficiency of the surgeon or technician, and errors can occur during the various technical processes. While the fabrication of pediatric dentures using CAD-CAM involves challenges such as the initial cost of equipment and the adoption of a digital workflow, it is expected to offer future advantages including greater efficiency in remanufacturing, reduced inventory requirements, and easier adjustment. CAD-CAM technology simplifies technical operations, standardizes production, and could be used for many patients if complete digitalization is achieved. Recording impressions may not be necessary. The high accuracy of SM-PPD enhances functional performance and patient comfort by facilitating efficient mastication and minimizing mucosal irritation. Accurate denture adaptation plays a critical role in pediatric patients undergoing craniofacial growth by supporting normal maxillofacial development. Furthermore, the high accuracy of fabrication reduces the need for post-insertion adjustments, thereby decreasing the frequency of follow-up visits, which is beneficial for patients and their caregivers. However, even if the denture has high processing accuracy, cooperation of children in wearing the denture and maintaining it (cleaning and remaking in case of breakage) are major issues in actual clinical practice. Using a CAD-CAM system is advantageous because remanufacturing can be done quickly. However, the understanding and cooperation of the parents are essential.

Material aging in AM-PPD and SM-PPD, as well as the repair methods for damaged PPDs in pediatric dentistry will be examined in future studies. In addition, we aim to design artificial teeth based on the PPD on CAD software for real-world clinical application and manufacture the PPDs so that they can be widely used.

5. Clinical relevance

The RMS values obtained in this study (SM: 0.06389 mm, AM: 0.09840 mm) are within the permissible range for conformance accuracy (±0.1 mm). Over-adaptation in denture bases can cause discomfort or tissue damage in pediatric patients. In contrast, slight under-adaptation can often be clinically acceptable and corrected using chairside adjustments or tissue conditioners.

6. Conclusions

1. No significant difference exists in the mucosal surface fitting of PPDs fabricated using conventional methods and CAD-CAM systems, suggesting that the introduction of digital technology into pediatric dentistry is realistic.

2. When comparing the AM and SM methods, SM had significantly higher precision than AM and should be considered a preferred method in future pediatric dental workflows.

3. The PPDs fabricated using the CAD-CAM system have good machining accuracy and are expected to be applied in pediatric dentistry.

ABBREVIATIONS

AM, additive manufacturing; CAD-CAM, computer-aided design-computer aided manufacturing; CD, complete denture; DLP, digital light processing; PMMA, poly methul meth acrylate; PPD, pediatric partial denture; SD, standard deviation; SM, subtracting manufacturing; STL, Standard Tessellation Language; RMS, root mean square; SLA, stereolithography; VAT, vat photopolymerization; 3D, three-dimensional.

AVAILABILITY OF DATA AND MATERIALS

The data analyzed in this study are available upon request. Please write to the corresponding author.

AUTHOR CONTRIBUTIONS

KK and KW—conceptualization; data curation; visualization; project administration. KK and YT—methodology; software. KK, YN, KW and YT—validation. KK, YN and YT—formal analysis; investigation. KK, YN, KW and HT—resources. KK, KW and HT—writing original draft preparation. KK, KW, YT, TI and HT—writing review and editing. KW, TI and HT—supervision. KK—funding acquisition. All authors have read and agreed to the published version of the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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