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ACCURACY OF COMPLETE DENTURE BASES DUPLICATED BY MILLING AND 3D PRINTED CAD/CAM TECHNOLOGY USING SURFACE MATCHING DIGITAL METER

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ABSTRACT

Objective: The Objective of this study was to evaluate the accuracy of duplicating dentures made using milling and three-dimensional (3D) printed CAD/CAM (computer-aided manufacture) fabrication techniques. **Materials and Methods:** For this study, 20 mandibular complete denture (CD) bases were duplicated by two dissimilar kinds of acrylic denture base materials of different CAD/CAM manufacturing methods (pre-polymerized PMMA milling blocks and 3D printing photosensitive liquid resin) from ready-made **polymethyl methacrylate** (PMMA) acrylic mandibular CD (reference model). For accuracy evaluation, the linear and deviation measurements were carried out using digital metrology software. **Results:** The results of this study exposed that the milled duplicated denture showed a statistically significant higher linear accuracy and lower deviation in comparison with the 3D printed duplicated denture. **Conclusion:** The milling duplication techniques can be useful for producing duplicate CDs with a high degree of accuracy.

KEYWORDS: Accuracy, Duplication, CAD/CAM, 3D Printed

INTRODUCTION

A second denture meant to be a replica of the first is called a duplicate denture(1). Many patients with a complete denture (CD) ask their prosthodontist to make them duplicate dentures. These patients, especially when their own dentist cannot be reached, cannot bear the shame of being without a denture, even for a brief length of time, due to a denture fracture. Replacement dentures are generally similar to the patient's existing one(2). For senior people, getting used to replacement dentures can be a constant challenge, especially when significant adjustments are needed to the fitting as well as occlusal denture surfaces(1,3). The most challenging patients are those who have systemic diseases like Parkinson's, dementia, and physical frailty. A doctor must understand that the adaptability of elderly denture wearers is also influenced by their neuromuscular coordination, the health of the supporting tissues, and their desire to learn new abilities (4, 5).

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The duplicate denture approach entails a diversity of techniques intended to resemble full dentures[6]. There are several clinical and scientific techniques that, to varying degrees, can “copy” a prosthesis. It is simpler to choose which of the three denture surfaces to copy or modify based on the clinical situation if one thinks of a denture as having three surfaces: the occlusal, polished, and fit surfaces [7,8]. The traditional method often uses elastomeric or irreversible hydrocolloid impression materials to produce a mold that serves as the denture’s opposite or negative representation. However, the traditional approach requires a lot of work and takes a long time [1].

Given the increasing use of dental scanners technology and 3D printers in dental offices, the copying technique is well situated to treat older edentulous populations more precisely and effectively than conventional methods. The outcome is a high-quality prosthesis that may reduce the amount of time needed for adaptation and the frequency of adjustment appointments[9]. PMMA blocks that have already been pre-polymerized, software, and 5-axis milling, a new method for fabricating dentures have been developed with CAD/CAM. CAD/CAM sending impressions and interocclusal records to dental labs for commercial manufacturing of new final dentures using CAD/CAM technologies constitutes the CD prosthodontics [6].

However, the processing of dentures with different fabrication methods could result in distortion, which can range from 0.45% to 0.9% linear distortion [6, 10]. The diminished ability of the denture base to adjust to the mucosa is a consequence of this deformation. The deformation of dentures during production causes reduced retention, stability, and support. The patient is affected as a result of this decrease in retention, stability, and support, and the clinician’s time spent in the chair increases due to the necessary changes [6]. The degree and location of the dimensional change that takes place during denture production have both been evaluated using a variety of techniques. These have included variously complex 2-dimensional and 3-dimensional measures. Laser and contact scanners are now frequently used to measure the deformation of denture bases [6, 11]. These methods enable the overlaying and analysis of scanned files utilizing cutting-edge software [6].

Many studies had been carried out to evaluate the effect of construction techniques on different properties of the digitally fabricated acrylic denture base resin [11-13]. However, there were limited studies have been issued equating the processing distortion of conventional procedures with the CAD/CAM production methods. Therefore, the goal of this in-vitro study was to assess and compare the accuracy of replicated dentures constructed by using two different techniques; subtractive and additive techniques.

MATERIALS AND METHODS

The sample size was determined using data from an earlier study by Inokoshi et al. [15]. Using G* power version 3.0.10 with α error =0.05 and power = 80.0% and effect size =2.55. In this study, 20 mandibular CDs were duplicated from ready-made PMMA acrylic mandibular CDs which were used as a reference denture or study model by two diverse kinds of acrylic denture base materials (n=10) and divided into two groups according to the CAD/CAM manufacturing methods into group A; Pre-polymerized PMMA milling blocks (AvaDent, Global Dental Science Europe, Tilburg, The Netherlands) and group B; 3D printing photosensitive liquid resin (NextDent Base, NextDent, Zetterberg, Netherlands).

Study model’s preparation

A mandibular CD base constructed by compression molded technique was used as a reference CD base for comparison between two different CD bases constructed by using two digital different techniques. [16]

Using no. 6 and no. 8 round burs, three dimples (2mm X 2mm) were created on the fitting surface of the reference CD base at three specific locations [18] and represented by three reference marks as follows;

Point A: one anteriorly at the midline (between two central incisors), Point B: on the site of the premolar's areas on the right side, and Point C: on the site of the premolar's areas on the left side, **Figure 1.**

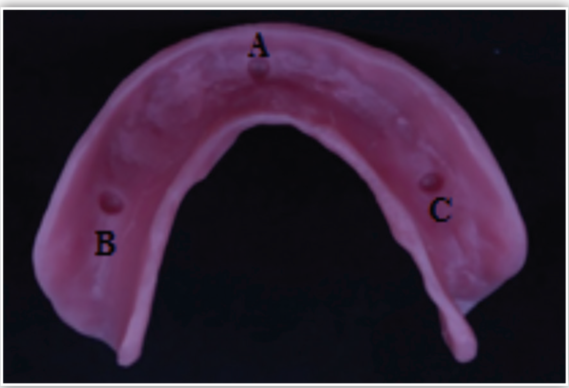

FIG (1) Mandibular CD with dimple preparation.

Denture Duplication

CAD/CAM milling copying method (Group A):

In this group, the reference mandibular CD was sprayed with DFS Telescan antiglare white spray (GmbH, Riedenburg, Germany) with a thickness of 7-10 microns. Then, the reference denture was scanned operating a lab scanner (DOF Swing Korea) with a scanner accuracy of 7-10 microns. The duplicated denture was then planned by means of CAD system software (3 Shape A/S, Copenhagen, Denmark). The definitive standard tessellation language (STL) design file was utilized for the duplicated dentures fabrication. The 5-axis milling machine (inLab MC X5, DENTSPLY, Sirona, USA) received the STL file. A PMMA block of 98.5 mm in diameter and 30 mm in the breadth was milled in misty condition with the minutest bur (Dentsply International Inc., York, Pa) size of 0.5mm, followed by 1, and 2.5 mm while connectors were set to 10. After the duplicated dentures were milled, they were detached from the discs by means of carbide burs [10, 14].

3-D printing duplicating method (Group B):

In this group, The STL file was transferred to the 3D printer (ANYCUBIC photon, M3 plus, Shenzhen Technology, Co, Limited) with a printing accuracy of 25 microns. Denture base resin was mixed for 1 hour by operating an LC-3D Mixer (NextDent, Netherlands) beforehand the printing course consistent with the manufacturers' instructions and pattern for the steady color of the resin. Using digital-light-processors (DLP) (Bio3D Inc., Korea), denture bases were set vertically (90° angle) with appropriate resin material at a rate of 10 to 30mm/h. The photopolymer materials were printed in a 3D pattern in succeeding ultra-thin deposits (25 microns) until the denture was finished, onto a construction tray. Ultraviolet (UV) light cured each photopolymer layer instantaneously after it was applied, creating models. Denture bases were taken off the platform after the printing process was finished, using an ultrasonic cleaner, and then post-cured in UV curing equipment (NextDent, Netherlands) for thirty minutes with a light power of 60 watts [10, 14].

The resulting mandibular dentures from both manufacturing methods were then finished consistently with the manufacturer's instructions.

Accuracy measurement:

The reference denture was scanned using a laboratory scanner (inEos X5 DENTSPLY). Each duplicated denture of each different technique utilizing two pieces of plasticine connected to the lower border of the denture was secured to the scanning table, and the scanning procedure was performed using the same laboratory scanner. For linear measurements, the STL file of individually duplicated dentures was overlaid on the reference denture file using metrology digital software (3D Systems, Geomagic Control-X), matching it with the corresponding dimple in each duplicated denture, However, for deviation measurements, the software's best-fit option was utilized for the measurement. A single researcher performed each measurement, had it repeated three times and then computed the averages. A distance of 0 to 0.05mm was used as the benchmark for our assessment of misfit, and a distance of 0.05 to 0.31 mm was used to establish a clinically acceptable fit [1,14,15]. Figure 2.

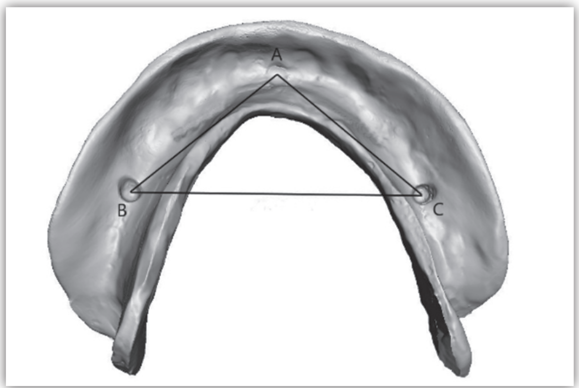

FIG (2) The measurement of fit accuracy throughout the whole duplicated denture, a representative sample.

Statistical analysis

With the help of SPSS® statistics Version 20, data were gathered, tabulated, and statistically examined. The normality of the distribution was examined using the one-way Shapiro-Wilk test. A mean and standard deviation were used to describe the numerical data. ANOVA compares more than two groups for quantitative variables with normally distributed. Tukey's Post-hoc HSD test was used for multiple comparisons among the groups. An Independent t-test was used to compare two different groups. The significance threshold was established at $p \geq 0.05$. Every test was two-tailed.

RESULTS

The results of the Shapiro-Wilk test for the evaluation of the normality of the distribution for linear measurement showed normal distribution (p-value >0.05) for all studied measurements variable. The one-way ANOVA test's statistical results revealed a statistically significant difference between the different linear measurements of the two tested groups. However, the inter-group comparison revealed a non-significant difference between the milled duplicated denture and the reference model for all different linear measurements. (Table 1) The independent t-test's statistical results revealed a statistically significant difference between the deviation measurement of the duplicated dentures from the reference denture. (Table 2) The results indicated that the duplicated denture manufactured by milling had significantly better linear accuracy and a significantly lower overall deviation when compared with the 3D-printed duplicated denture.

TABLE (1) Comparison of the mean values and standard deviations for linear measurements in mm:

Variable	AvaDent	NextDent	Reference model	p-value
AB Line	$33.05{\pm}0.02^{A}$	$32.69{\pm}0.03^{B}$	$33.07{\pm}0.01^{A}$	<0.00*
AC Line	$31.98{\pm}0.01^{A}$	$30.80{\pm}0.35^{B}$	$32.03{\pm}0.07^{A}$	<0.00*
BC Line	$47.07{\pm}0.14^{A}$	$46.06{\pm}0.14^{B}$	$47.03{\pm}0.07^{A}$	<0.00*

**Significant statistical difference (p-value ≥0.05)*

; Different uppercase litters in the same raw mean are statistically significant.

TABLE (2) Comparison of the mean values and standard deviations for deviation measurements in mm:

Variable	AvaDent	NextDent	p-value
Overall deviation	0.148±0.004	0.227±0.004	0.000*

**Significant statistical difference (p-value ≥0.05)*

DISCUSSION

Clinicians can recreate (duplicate) a medically effective CD using conventional or digital means[1,19]. However, the traditional approach requires a lot of work and takes a long time [1]. Therefore, in this present study, the recent advanced CAD/CAM processing techniques were selected to examine the accuracy of CAD/CAM milling versus 3D printing in denture duplication.

In the conventional duplicating technique, a mold that serves as the CD's negative representation is made using irreversible hydrocolloid or elastomeric impression materials. However, the entire duplicate process must be finished quickly using an irreversible hydrocolloid impression medium to prevent distortion [1]. To prevent the bias of mold deformation, elastomeric impression material was used in this investigation rather than hydrocolloid impression. Moreover, denture flasks or stock trays are frequently familiar hold and maintaining the impression materials in the conventional duplicating approach [1, 7, 21]. However, this study's flask was chosen to support and confine the elastomeric impression material to prevent distortion.

In order to duplicate a denture traditionally, an impression is taken or a flashing-and-investing procedure is used, and then the resin is repositioned using heat- or self-curing [22]. However, in this present study, the auto-polymerized resin was selected instead of the heat-cured resin because of its simplicity and relatively good accuracy for the fabrication of CDs [19]. The reference mandibular master CD was used in the present study because it had insignificant undercuts and was cordial enough to be optically scanned. Nevertheless, optical scanning might not be viable for CDs with substantial undercuts and extensive denture extensions[1,23]. In addition, a digital lab scanner was used for scanning the master cast instead of the intra-oral scanner in this study because the intra-oral scanner cannot capture the necessary extensions of the soft tissues desirable for a removable prosthesis without the traditional border molding [24].

Chen et al.[1] discovered that the amount of time spent on trimming, finishing, and labor overall in the groups using DLP printers was much lower than that in the groups using SLA printers, therefore, the DLP 3D printer was chosen in the current study instead of the SLA 3D-printer for printing the duplicated dentures because it is a fast and more accurate printer.[25] The printed denture bases were rinsed in 99% Isopropyl ethyl alcohol for 5 minutes to remove any uncured resin material; however, the increased rinsing time could result in the fissuring of the printed object [26, 27]. Then the printed dentures were dried and placed in a UV- light curing unit for 30 minutes to obtain the full conversion of polymer[26,27]. In this present study, scanning the reference denture was carried out by laboratory scanner. Other studies using as an intraoral scanner as an alternative option for a CBCT scanner because it is not accessible. Furthermore, this technique's viability and precision have already been looked into in earlier research. [19, 21]

In this current investigation, a 5-axis CAD/CAM milling method was selected for dentures duplication across the use of PMMA blocks and computer software. This is because the 5-axis machines are appropriate for generating complex structures such as denture bases, frameworks, and implant-retained prostheses in the subtractive manufacturing [29].

In this current investigation linear distortion was chosen as measurable for the accuracy of the duplicated dentures produced by different processing techniques because, during processing, dentures can have linear deformation of up to 0.9%, or 0.45%, in some cases. Reduced adaptation of the denture base to the mucosa is a result of this deformation(6). Linear measurements between points, however, do not take into consideration how manufacturing deformation affects the intricate 3D structure of a denture base. So, the method's clinical applicability is called into question (30). In this study laboratory scanner was used to measure the deviation of duplicated denture bases this is because this method enables the overlaying and analysis of scanned files utilizing cutting-edge software. Moreover, previous studies have shown that these evaluation techniques are valid (1,6,30). In contrast to linear or cross-sectional measurements, which only provide restricted information, the 3D AutoCAD software technique produced a more accurate picture of the overall deformation over the full fitting surface of the denture bases, hence it was selected as a test technique in this present study (30).

The findings of this study revealed that using the linear measurement assessment method and a statistical difference, the CAD-CAM milled group's dimensional accuracy was statistically higher than that of the 3D-printed group. This outcome was supported by the results of previous investigations by Lee et al.(10) and Helal et al. (31). This mismatch can be attributable to internal tensions created after polymerization as well as shrinkage during polymerization. This is because while industrially pre-polymerized PMMA pucks of the final dimensions are subtracted during the milling process, photopolymerized 3D printing is influenced by the polymerization shrinkage(31). Moreover, the statistically significantly different findings in this investigation between the linear measures between the CAD/CAM milled dentures and the 3D-printed resin could be due to the resin pattern's chosen build angle (90˚) and thick support, which may have had an impact on the resin pattern's dimensional accuracy and ultimately on the accuracy as a whole as reported by Negm et al.(17) and Alharbi et al. (32).

In addition, the statistically significantly different findings in this investigation between the linear measures between the CAD/CAM milled dentures and the 3D-printed resin could be due to its high precision, the CAD/CAM milling machine with five axes of machining was used in this work, whereas 3D printing was carried out using a DLP 3D printer with a 100-m layer and just three axes of machining. As a result, the CAD/CAM milled dentures had greater dimensional precision than the 3D-printed dentures (31, 33). Additionally, since 3D-printed dentures are not fully polymerized until the final light-polymerization step, polymerization shrinkage is theoretically conceivable during the rapid prototyping phase. When removing the partially polymerized dentures from the construct platform or throughout the isopropyl alcohol wash and polymerization procedure, the prosthesis may distort (31, 33). However, because of the intricacy of the printing practice and hysterical recoveries of duplicated faults, it is presently uncertain precisely which processing problems occur (31). The absence of oral condition simulations, longstanding storage in water, and the absence of thermocycling cogitated the main limitations of the present study.

CONCLUSIONS

The milling duplication techniques can be useful for producing duplicate CDs with a high degree of accuracy. Digital duplication procedures differed from one denture to the next. However, in a therapeutic situation, the difference might not even be noticeable.

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