Original Article

Trueness of Stereolithographic Model Compared to Conventional Model Using CAD/CAM Prosthesis with Digital Photographs

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Abstract

Objective: Accuracy of the stereolithographic (SLA) model significantly influences their laboratory uses. The aim of this study was to compare the accuracy of SLA models created from digital impressions to conventional die stone models obtained from elastomeric impressions using full anatomic CAD/CAM fabricated fixed prosthesis.

Methods: A partially edentulous typodont model was prepared for this study with two-implant abutments as a reference model. Two impression techniques were used to fabricate study models. Group one (n=5), SLA models were created from digital impressions acquired by an intra-oral scanner. While in group two (n=5), die stone models obtained from vinyl polysiloxane impression materials (VPS). A full anatomic zirconia bridge was fabricated using CAD/CAM system and high-resolution digital photographs from the buccal surface were captured using a macro lens . The vertical distance between selected points was measured by three evaluators using a calibrated digital software program. The t-test with 95% confidence interval was used to evaluate the accuracy of the models.

Results: There was a strong agreement among observers with a statistically significant difference in the seating of prosthesis on the SLA model versus the conventional model, with a mean and standard deviation of -0.17±0.24 mm and 1.04±0.22 mm subsequently. Their results of the t-test were showed fewer errors in the SLA group.

Conclusions: CAD/CAM fabricated bridge was better seated on SLA models from digital impressions compared with die stone models from elastomeric impressions. Therefore, the trueness of 3D printed models was greater than conventional models compared to the reference model.

Keywords: *Stereolithographic model, Impression, CAD/CAM, Fixed prosthesis, Digital photograph.*

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Introduction

Facial digital technology in dentistry controls many fields. The digital impression and stereolithographic models generate new scope, and it is believed that it will solve the challenges and difficulties of conventional techniques. Conventional impression with elastomeric impression material and gypsum cast fabrication had been considered the gold standard in fixed prosthesis fabrication[1,2].

Improvements were made to the traditional impression materials to reduce tearing and improve quality. These materials include: non-elastic as waxes, gums, resins, plaster of Paris, zinc oxide eugenol, impression compound, and eugenol-free past and elastic which include hydrocolloids (Agar-Agar and Alginate) and synthetic elastomers as polysulphides, condensation-silicones, polyether and addition-silicon[3].

The traditional method of fabrication of dental prosthesis requires the use of gypsum products. According to the American Dental Association (ADA) Specification No. 25 the gypsum products are classified into five types, type I: plaster for impression, type II: plaster for model and laboratory, type III: low to moderate strength dental stone, type IV: dental stone high strength / low-expansion and type V: dental stone high strength / high-expansion[4].

The type IV gypsum product is the commonest die stone material, obtained from natural gypsum rock. It is workable, economical and involves the least equipment. The disadvantages are expansion upon setting, rough with the dehydrated surface, high viscosity leading to surface voids, and susceptibility to abrasion during the carving of wax pattern. Gypsum hardeners are added to increase abrasion resistance[5].

The accuracy of the impression depends on the impression material themselves[6-10]. types of tray[11-13], and impression techniques[14-16]. The accuracy of master casts dependent on numerous items, including the water/powder ratio, vacuum versus hand mixing, and the type of dental stone and its compatibility with impression materials. Each step in the process introduces potential human and material error[17-18].

The digital impression reduces patient and dentist discomfort, eliminating the problems relating to tray selection, it has unlimited storage time, indefinite reuse, thus saving time with no need for disinfection. Whereas; this technique requires a trained operator with good and up-to-date laboratory support[18].

Additive manufacturing methods deal with the sequential application of a thin layer of material to build the final geometry directly from the 3D data as opposed to the subtractive manufacturing method. Various additive manufacturing methods are available, which collectively termed rapid prototyping. Afterward, additive manufacturing transforms from rapid prototyping models to producing real parts for use as final products named rapid manufacturing[19,20].

The first commercially available rapid prototyping technology was stereolithographic (SLA), which is characterized by application ultraviolet (UV) light to cure photosensitive liquid polymer resin on a layer basis after computer-aided design. A solid object is formed by subsequent curing of the layers and bonding them together by the self-adhesive feature of the material. The final object is further cured in an ultraviolet cabinet[21].

The aim of this study was to compare the trueness of the stereolithographic model and die stone model to a reference model using the seating of CAD/CAD fixed prosthesis with digital photographs. The null hypothesis was the accuracy of both models are similar.

Materials and methods

Preparation reference model

A partiality edentulous typodont model was selected for this study and two implants fixture were placed at teeth numbered 46 and 47. Implant abutment fixed into the implant to the simulated intraoral situation for abutment level impression, a soft tissue diode laser (iLase from BIOLASE, USA) was used to expose the margin of abutments. The prepared model was used as a reference model (Figure 1).

Figure 1: Occlusal and buccal view of reference model.

Manufacture of CAD/CAM prosthesis

The reference model was scanned by intraoral digital scanner TRIOS® 3 (3Shape, Copenhagen, Denmark). Full anatomic zirconia bridge was designed with a cement gap of 60 μm and fabricated using Computer-

Aided Design/Computer-Aided Manufacturing (CAD/CAM) system by 3 Shape Dental System (3Shape, Copenhagen, Denmark) as shown in Figure 2.

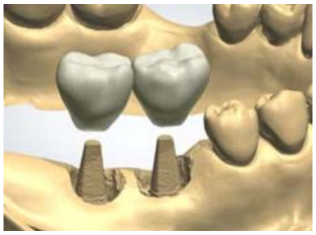

Figure 2: Design of full anatomic bridge.

The full anatomical bridge was milled by a five-axis computerized numerically controlled milling machine (Zirkonzahn GmbH, Gais, Italy) from a green-state zirconia block (ICE zircon, zirkonzahn GmbH, Gais, Italy) after machine calibration. The bridge was sintered in a furnace (Zirkonofen 600; Zirkonzahn GmbH) at 1500°C, then glazed and seated on the reference model.

Stereolithographic model construction

The stereolithographic model's group one (n=5) were fabricated from scans of a reference model, using TRIOS scanner (3Shape TRIOS® 3, Copenhagen, Denmark). The digital impressions were loaded into the 3Shape dental system using model builder module and virtual digital models were prepared as revealed in (Figure 3). The STL files of the designed models were 3D printed using PROJET MP 3500 printer, where resin models were manufactured using a stereolithographic technique, then cleaned and light-cured. All the models were fabricated in the same production center with the same printer setting.

Figure 3: Design of virtual model.

Conventional model construction

The conventional model group two (n=5) were constructed from Vinyl polysiloxane (VPS) impression material (Turboflex, R&S, Paris, France.), both putty and light consistencies were used in a single step two consistency technique. Disposable perforated plastic tray was loaded and positioned over the reference model. The tray was held in the same position for two minutes according to manufacture instruction while waiting for the final set of the impression material. A total of five impressions were made by the same procedure.

All impressions were poured after two hours using BonTop type IV extra hard stone by vacuum mixing machine according to the manufacturer's instructions, with a powder / liquid ratio of 100 g / 20 ml to obtain a creamy and homogeneous consistency. The anatomical portion of the models was poured using a low-speed vibrator. Once all the teeth had been sufficiently filled with the mixture, a larger increment of the mix was added until the entire impression was filled. Afterward, the impression was removed from the vibrator and left undisturbed to set. A separate mix was made to construct the model base, and the anatomical portion of the model was inverted onto the base, keeping the occlusal surface maintained in a parallel position to the countertop. The models were trimmed using a model trimmer after their separation from the impression tray, and the conventional stone models were prepared.

Evaluation of models accuracy

The deviation from the reference model defines the trueness of the method and evaluated by photographic assessment of prosthesis seated on the reference model compared to other groups. The flow-chart of the study design shown in Figure 4.

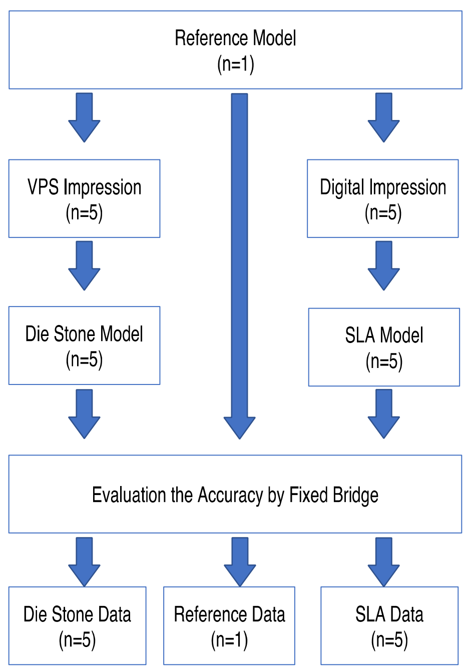

Figure 4: Flow-chart of the study design.

In order to minimize any potential distortions of the photographs, a digital camera (Canon, EOS 550D, Tokyo, Japan) with Canon marco lens EF 100 mm was mounted on a stable tripod 150 mm away from the model, 1:1 high-resolution digital photographs were taken in sequence with no change in the inclinations of the camera[22].

The method of measurement was standardized by using computer-aided design software AutoCAD 2019 that architects and engineers rely on precise measure 2D images. The calibrated images were imported into software as layers and superimposed over each other's; a horizontal line was drawn and used as a reference line in the software. All measurements were taken in millimeter perpendicular from the two points on the buccal surface of the prosthesis to this reference line and evaluated by three observers.

The restoration was seated with normal thumb pressure without any adjacent on all models and measurements were recorded in the same procedure.

The trueness of the model was defined as a deviation of the method and evaluated by comparing the reference data to data achieved from both SLA and die stone models.

Statistical analysis

The data were tabulated and statistically analyzed using descriptive statistics and t-test to compare between the groups. statistical software package (SPSS for Windows v.16; SPSS Inc) was used to analyse the data and p value ≤ 0.05 was considered as statistically significant.

Results

The assessment of consistency and reproducibility of dimensional measurements made by three observers measuring the distances between the selected points was assessed by a descriptive statistic using the intraclass correlation coefficient (ICC) at 95% confidence interval as shown in Table 1. The result revealed a strong agreement between observers in all measurements within groups and teeth (ICC more than 0.90).

Table 2 shows the descriptive statistics values for the differences of the mean, minimum and maximum differences between the two groups and the reference model with the standard deviation. Less values revealed closer matching with the reference model. Individual tooth measurement at 46 and 47 indicated local trueness while both group measurements indicated general trueness of the model with less mean and standard deviation in SLA group of -0.17±0.23 mm compared with 1.03±0.22 mm for conventional group.

The result of the t-test showed that there was a statistical significant difference between the two groups, with fewer errors in the SLA group than the conventional method (Table 3).

Table 1: Results of intraclass correlation coefficient revealed strong agreement between observers in all measurements.

	n	ICC	95% Confidence Interval		p value
			Lower bound	Upper bound	
All measurements	20	0.996	0.992	0.998	< 0.0001
Method					
SLA	10	0.979	0.939	0.994	< 0.0001
Conventional	10	0.98	0.943	0.994	< 0.0001
Tooth					
#46	10	0.992	0.980	0.998	< 0.0001
#47	10	0.998	0.993	1	< 0.0001

Table 2: The mean, minimum, maximum values of differences and standard deviation between the two groups and the reference model.

Tooth no.	Group	n	Minimum	Maximum	Mean	SD
46	SLA	5	-0.313	0.127	-0.140	0.166
	Conventional	5	0.757	1.220	1.033	0.184
47	SLA	5	-0.757	-0.003	-0.207	0.311
	Conventional	5	0.62	1.393	1.045	0.285
Both	SLA	10	-0.757	0.127	-0.173	0.237
	Conventional	10	0.62	1.393	1.039	0.226

Table 3: T -test to compare the distances between the two groups showed significant difference between the two methods, with less error in the SLA group.

	Mean difference (SLA-Conv)	Std. error difference	95% confidence interval of the difference		t	p value
			Lower	Upper		
All teeth	-1.213	0.104	-1.431	-0.995	-11.688	<0.0001
46	-1.173	0.111	-1.429	-0.918	-10.589	<0.0001
47	-1.252	0.189	-1.687	-0.817	-6.636	<0.0001

Discussion

One of the important factors in fabricating indirect fixed dental prosthesis is the production of an accurate model either from conventional or digital impression systems. Die stone model made from impressions using elastomeric impression materials have been used for fabrication of prosthesis for many years(23,24). However, these models are susceptible to the risk of loss, damage, and wear(25).

The stereolithography printing method used in this study, because it is the commonly used method in dentistry in terms of printing accuracy, speed, cost and quality(26), computer-aided design/computer-aided manufacturing (CAD/CAM) technology provides new changes in dentistry, offering superior experience and excellence(19,27). The 3D virtual model can be manufactured as a physical model through 3D printing technology(28,29). SLA technology forms each layer by irradiating a UV laser to the photopolymer along the contour of the object. After the layer is polymerized, the platform moves vertically by the layer thickness, and the laser cures the new layer(23), by repeating this process, a 3D object is created(30).

According to engineering science and metrology, the term ISO 5725 'trueness' is similar to accuracy that was defined as 'the ability of a measurement to match the actual value(31). Trueness describes the deviation of a measurement from the actual dimensions of the measured object. The high level of trueness indicates a result that is near or equals to the exact dimensions of the measured object(24).

The typodont model was used in this study because of its durability, material stability, as well as providing the same conditions(32). However, the structure, texture, and other properties are different from natural teeth and failed to reproduce clinical situations(33). Previous studies evaluating the accuracy of dental models manufactured by subtractive manufacturing or additive manufacturing have mainly been limited to diagnostic models in the field of orthodontics(34-36). In the field of prosthodontics, it has been limited to single tooth(37). Therefore, in this study measurements were taken from two-point on fixed bridge for teeth numbers 46 and 47 to provide data about local and general trueness of the models.

Previous studies have shown that the accuracy of dental models has measured by linear distance measurements(38). Therefore, the present study used such an analysis to evaluate the accuracy of the model. However, this method is limited because of the lack of measuring points and the inability to measure repeatable measuring points(Error! Bookmark not defined.). In addition, the drawback is that a clear reference marker with a specific shape for the measurement is needed, and it is impossible to represent 3D changes of the model(38). Three evaluators were taken the measurements in all groups to minimize the bias and the effect of previously mentioned points.

The small deviation from reference model in 3D printed model in this study may be due to the cleaning and post-curing which were used to increase the mechanical properties of the printed model which was in agreement with previous study revealed that the less-cured photopolymer material may remain on the printed model surface due to carelessness of the operator during the cleaning process. Shrinkage or warpage may occur because of additional polymerization processes[23].

In this study, die stone models showed lesser trueness than stereolithographic models, the low accuracy of die stone models may be related to cumulative errors at each stage of the convectional workflow, such as selection of perforated plastic tray, manipulation of materials and thumb pressure errors, this result was in disagreement with previous study which concluded that stone models are accurate as 3D printed models[39]. This study was in agreement with the a study that revealed that the water requirement of high strength stone affects the final product and the un-reacted water at the end of chemical reaction weakens the stone product and decreases the accuracy[23].

The present study did not consider factors such as x–y resolution, exposure time, manufacturing environments and used printing materials that can affect the accuracy of 3D printers[26]. The type and performance of the digital scanners and dental 3D printers used may also influence the results of this study[24,32]. Therefore, further research recommended being conducted considering more varied environments, factors and clinical situations.

Conclusions

Within the limitations of this in vitro study, results showed that CAD/CAM fabricated bridge was better seated on SLA models from digital impressions compared with die stone models from elastomeric impressions. This finding of higher trueness indicates that the accuracy of the SLA model is closer or equivalent to the reference model when compared to gypsum models.

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