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ORIGINAL ARTICLE

Fit accuracy of metal partial removable dental prosthesis frameworks fabricated by traditional or light curing modeling material technique: An in vitro study

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KEYWORDS

Accuracy;
Chrome cast framework;
Partial denture fit;
Light curing modeling material technique;
Gap measurement;
Cobalt–chromium

Abstract *Objective:* The aim of this study was to compare the fit accuracies of metal partial removable dental prosthesis (PRDP) frameworks fabricated by the traditional technique (TT) or the light-curing modeling material technique (LCMT).

Materials and methods: A metal model of a Kennedy class III modification 1 mandibular dental arch with two edentulous spaces of different spans, short and long, was used for the study. Thirty identical working casts were used to produce 15 PRDP frameworks each by TT and by LCMT. Every framework was transferred to a metal master cast to measure the gap between the metal base of the framework and the crest of the alveolar ridge of the cast. Gaps were measured at three points on each side by a USB digital intraoral camera at ×16.5 magnification. Images were transferred to a graphics editing program. A single examiner performed all measurements. The two-tailed *t*-test was performed at the 5% significance level.

Results: The mean gap value was significantly smaller in the LCMT group compared to the TT group. The mean value of the short edentulous span was significantly smaller than that of the long edentulous span in the LCMT group, whereas the opposite result was obtained in the TT group.

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Conclusion: Within the limitations of this study, it can be concluded that the fit of the LCMT-fabricated frameworks was better than the fit of the TT-fabricated frameworks. The framework fit can differ according to the span of the edentate ridge and the fabrication technique for the metal framework.

1. Introduction

Use of wax in dentistry dates back 200 years to the use of beeswax to take impressions of teeth. Resins have been used as patterns for dental restorations. Resins offer higher strength and lower flow than pattern waxes and non-residue burnout. Light-cured resins offer a greater working time to build the pattern compared to chemically cured resins (Craig and Wataha, 2004). The newer light-polymerized, dimethacrylate modeling resins can be manipulated with increased precision and stability after light polymerization. Advantages of these resins include low polymerization shrinkage, good dimensional stability, ease of use, less chair time, and absence of residue after burnout (Derleth et al., 1987). Unlike wax, curing the plastic pattern allows for removal of the framework from the master cast without distortion for subsequent casting procedures Potential causes of ill-fitting for cast frameworks may include dimensional changes in the investment materials, solidification shrinkage, and distortion of the wax pattern (Fenlon et al., 1993).

As much as 75% of removable partial dentures does not fit the mouth on the day of insertion. Improper fit may contribute to movement of the associated teeth and discomfort. Improper fit also may be the primary reason that many removable partial dentures are not worn (Phoenix et al., 2003). An ill-fitting prosthesis can exaggerate other problems caused by the prosthesis. Harmful effects, such as caries (especially root caries), periodontitis, oral candidiasis, denture stomatitis, and halitosis, can arise from the plaque that accumulates around a partial prosthesis. Plaque may serve as a reservoir for pathogens that cause pneumonia and other systemic diseases (Yang et al., 2014).

In one study, the authors compared the fit of a clasp assembly fabricated by the standardized conventional refractory wax up method or by a light-cured pattern. The clasp assembly fabricated by the light-cured pattern had better fit than the assembly fabricated by the conventional refractory wax up (Kumar et al., 2010). Another study described a new technique for fabricating a cast framework by using a light-polymerizing plastic pattern. This technique was proposed to minimize laboratory cost and time for partial denture construction. Although the accuracy of the framework was clinically acceptable, the dimensional stability of the denture required further assessment (Takaichi et al., 2011). The influence of the pattern material of conventional wax and light-polymerized patterns on the initial surface roughness and internal porosity of cobalt–chromium castings of partial removable dental prostheses (PRDPs) was investigated, but revealed no significant differences between the two pattern materials (Swelem et al., 2014).

The aim of this study was to compare the fit accuracies of metal PRDP frameworks fabricated by the traditional technique (TT) or the light-curing modeling material technique (LCMT). The null hypotheses were as follows: (a) There is no significant difference in accuracy between the TT- and LCMT-fabricated frameworks, and (b) The edentulous span has no effect on the framework fit for either technique.

2. Materials and methods

The research protocol was approved by the Ethics Committee of the Faculty of Dentistry of the Damascus University.

2.1. Preparation of the metal master cast

A typodont model of the mandibular arch was prepared with the following specifications, and then duplicated into an aluminum metal master cast. Missing teeth were the second premolar and first molar on both sides and the second molar on the right side. Four rest seats were prepared adjacent to the edentulous spaces. The model was surveyed to ensure parallel guiding planes. The model was provided with a blockout relief, creating a ledge of 0.25-mm undercut gauge on the abutments, to delineate the positions of the retentive clasp tips. The alveolar ridges were smoothly planed. Three notches, serving as landmarks for measurement, were prepared on each side buccal to the alveolar ridge (Fig. 1).

2.2. Preparation of the stone casts

The metal master cast was duplicated by using additional silicone impression material (Ormaduplo 22, Major Prodotti Dentari S.P.A. Italy) and type IV stone (BegoStone Plus, BEGO Bremer Goldschlagerei Wilh. Herbst GmbH & Co., Germany) to make 30 stone master casts. The sample size was determined by using G*Power 3.1.7 (Franz Faul, Universitat Kiel, Germany). According to the calculations, the actual power of the study was 0.996 with 15 samples per group.

2.3. Selection of the framework design

The design selected for both techniques consisted of a lingual bar major connector, four simple circumferential clasps placed on the prepared abutments, metal bases fitted directly on the cast, and minor connectors joining the major connector to the other framework components. The design was standardized for all frameworks in both groups.

2.4. Preparation of the PRDP frameworks by the TT

Fifteen metal frameworks were fabricated by following the traditional steps of PRDP metal framework fabrication: duplication of the master cast, hardening of the refractory cast,

Figure 1 The metal master cast.

Figure 2 A TT framework on its corresponding stone cast.

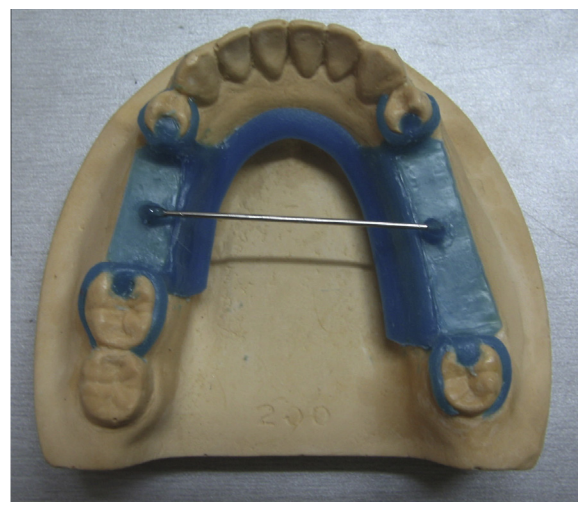

Figure 3 The plastic pattern supported using a 0.9 mm clasp wire.

beeswax dipping, adaptation of the prefabricated wax patterns (BEGO Bremer Goldschlagerei Wilh. Herbst GmbH & Co.), spruing, investing with phosphate-bonded refractory material (Cobavest, YETI Dentalprodukte, Germany), burnout, casting the cobalt–chromium alloy (Wironit, BEGO Bremer Goldschlagerei Wilh. Herbst GmbH & Co.) in a casting machine (Degussa TS-1, Degussa-Hüls, Germany), casting recovery, and fitting the framework to the stone cast by removing any metal nodule that may prevent fitting (Fig. 2). All the steps were standardized in all frameworks.

2.5. Preparation of the PRDP frameworks by the LCMT

LiWa® light-curing modeling material (LiWa; Willmann & Pein GmbH, Germany) was used for the LCMT. Fifteen metal frameworks were fabricated by following the steps of PRDP metal framework fabrication. A stone master cast was isolated by using LiWa Iso Step I + II. LiWa light-polymerizing plastic patterns were modeled directly on the master cast. Modeling of the light-curing material involves cold and hot modeling. In cold contouring, LiWa is shaped by kneading and contouring with the fingers in wet protective gloves or by using metal or rubber instruments. In hot contouring, the pattern can be built up gradually by using an electric wax knife (Liwaxer; Willmann & Pein GmbH). The pattern was sprayed with a cold spray to alter the consistency of LiWa from slightly viscous to sculptable. Plastic patterns were supported with 0.9-mm clasp wires connecting the right and left sides to minimize potential distortion of the plastic frameworks (Fig. 3). Light-curing was achieved by using a LaWa UV light-curing unit for 6 min. A LiWa finish varnish was used for conditioning the pattern surface, and then light-curing was repeated for 2 min. Spruing, investment, burnout, casting, and fitting the framework were performed similar to the TT procedures without using a refractory cast. All the steps were standardized in all frameworks.

2.6. Measurement of fit accuracy

Each framework was transferred to the metal master cast and stabilized with a simple clamp. The gap between the metal saddle of the framework and the crest of the alveolar ridge of the metal cast was measured at three points on each side (Fig. 4). A USB digital intraoral camera (WTH, VIMICRO, China(with 480 k pixel resolution and a focus rate of 8–12 mm was used to capture images at ×16.5 magnification. A single examiner captured all images. While capturing the images, a determinant with two prominences specifically designed for this study was fixed to the camera by using a cyanoacrylate adhesive to secure a perpendicular fixed distance of 9.1 mm between the camera and the measured gap (Fig. 5).

Images were transferred to a graphics editing program (Adobe Photoshop CS5 ME version 12.0, Adobe Systems Inc., San Jose, CA, USA(and enlarged by 200%. The gap distance was measured by using the Marquee tool through the ‘‘Info’’ window (Fig. 6). A millimetric ruler with vertical and horizontal calibrations was positioned above the cast during capturing to be included in the image and used to detect the accuracy of the measurements. Each gap was measured only once at three points per side. A single investigator performed all measurements.

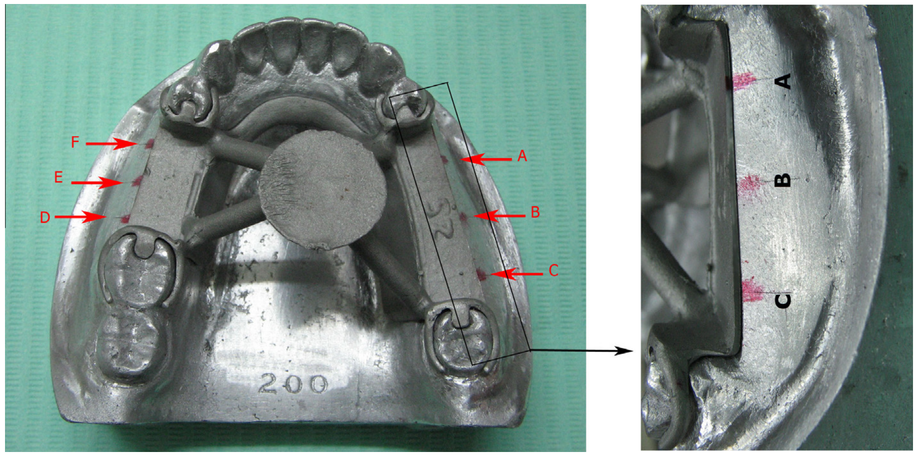

Figure 4 Framework on the metal cast with the three gap measurement sites at each side (arrows).

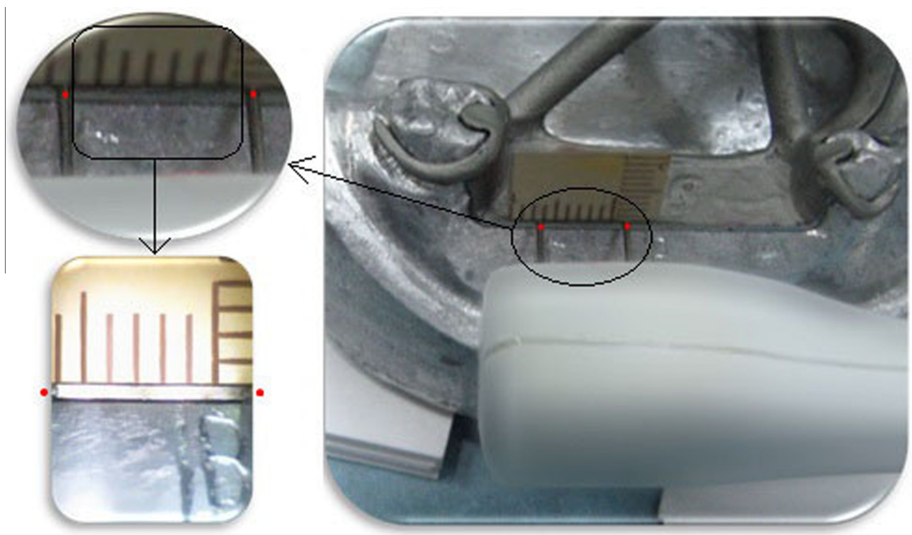

Figure 5 Special determinant secured to the camera to standardize the distance between the camera and measured gaps.

2.7. Statistical analysis

A total of 180 gap measurements were made, including 90 measurements of the short and long edentulous spans in the TT group (TT-S and TT-L) and 90 measurements of the short and long edentulous spans in the LCMT group (LCMT-S and LCMT-L). Means and standard deviations (SDs) of gap measurements were calculated for each group, as well as for the long and short edentulous spans within each group. A two-tailed *t*-test was conducted to compare between the two groups as a whole (TT and LCMT) and between the short and long edentulous spans within each group (TT-L and TT-S; LCMT-L and LCMT-S). All tests were performed by using SPSS version 12 (SPSS, Chicago, IL) at a significance level of 5%.

3. Results

Means and SDs of the measured gaps of TT and LCMT are presented in Table 1. The mean gap value was smaller in the LCMT group compared to the TT group ($p = 0.02$). Table 2 shows the means and SDs of the measured gaps of the short and long edentulous spans for the TT and LCMT frameworks. The mean gap value was smaller for LCMT-S compared to LCMT-L ($p = 0.01$), and for TT-L compared to TT-S ($p = 0.003$).

4. Discussion

According to the results of the present study, both null hypotheses were rejected. LCMT-fabricated frameworks fit better than TT-fabricated frameworks, and the framework fit differed depending on the edentulous span.

A misfit in the saddle area was considered to be representative of misfit for the whole framework. Metal denture bases are well suited for attaining healed and ideally contoured residual edentulous ridges (Phoenix et al., 2003). Gaps between the metal saddle and the crest of the alveolar ridge of the metal cast were measured to determine the fit accuracy of the metal PRDP frameworks. Neither technique was able to achieve an optimal fit. One reason for the lack of fit is the high linear

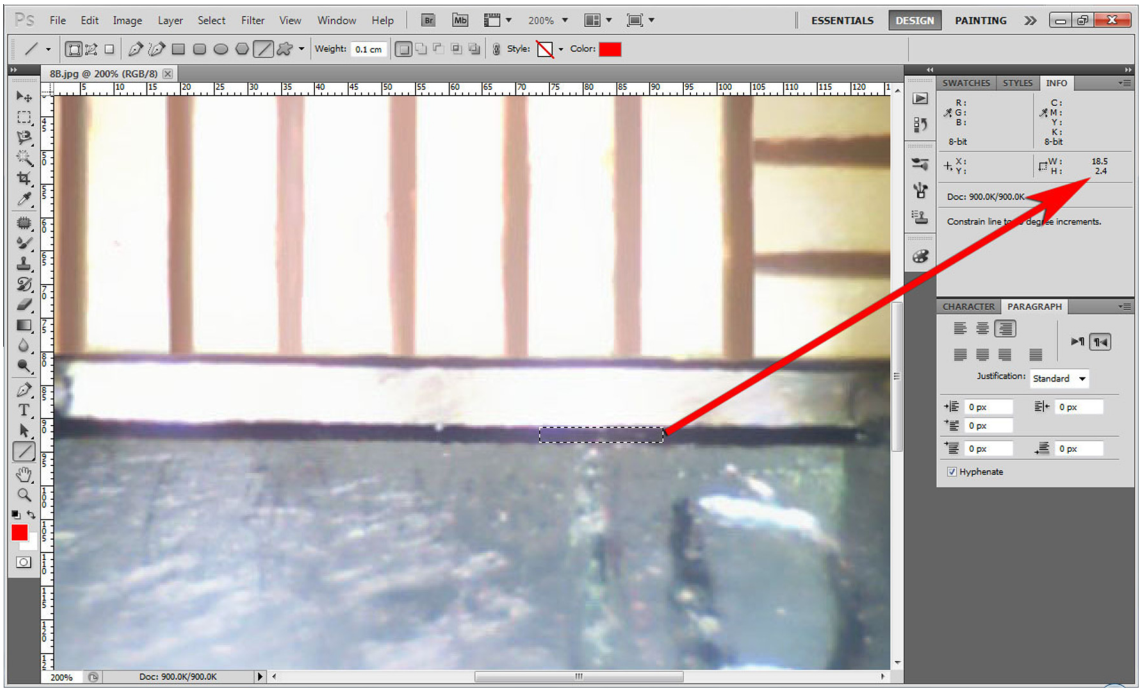

Figure 6 A Photoshop screen image showing the width of the measured gap (arrow); using the marquee tool and ''info'' window.

Table 1 Means, standard deviations, minimum and maximum values (micrometer) of measured gaps of TT and LCMT frameworks.

Group	Number of measured gaps	Mean	SD	Minimum	Maximum
TT	90	159.59	69.4	32	393
LCMT	90	135.47	68.96	32	300

Table 2 Means, standard deviations, minimum and maximum values (by micrometer) of measured gaps of short (S) and long (L) edentulous spans of TT and LCMT frameworks.

Subgroup	Number of measured gaps	Mean	SD	Minimum	Maximum
TT-S	45	181.11	71.9	32	393
TT-L	45	138.07	60.3	32	270
LCMT-S	45	117.02	64.35	32	276
LCMT-L	45	153.91	69.15	48	300

solidification shrinkage of cobalt–chromium-based alloys (~2.3%) (Anusavice et al., 2012). Moreover, the PRDP framework is a complex casting because it is usually fabricated from a high-fusing base metal alloy, which results in higher shrinkage than gold alloys (Gowri et al., 2010; Kumar et al., 2010). Hence, it is not surprising that we had difficulty achieving the desired fit.

Gowri et al. (2010) studied the effect of anchorage on the accuracy of the palatal major connector of PRDP frameworks. Gap values between the major connector and metal cast were significantly different between the experimental group (0.16–0.43 mm) and the control group (0.44–0.65 mm). These authors did not discuss the clinical consequences of these high palatal gap values, but concluded that precision of fit of dental castings may be difficult to achieve. Gebelein et al. (2003) studied the dimensional changes of one-piece frameworks supported on telescopic crowns. The metal frameworks underwent significant dimensional changes during fabrication and tended to contract toward the geometric center. The resulting geometric contraction between the telescopic crowns would appear to exceed the physiological tooth mobility and, therefore, affect the desired passive fit outcomes.

The fit of the cobalt–chromium PRDP may be compromised by errors in wax blocking out and duplication, variability in expansion of the refractory material, and the techniques used for fitting and polishing the metal frameworks (Brudvik and Reimers, 1992). In the TT, the agar impression material that is normally used for the duplication process undergoes dimensional changes of syneresis and imbibition, which may eventually adversely affect the reproduction of the refractory cast (Kumar et al., 2010). Therefore, it is reasonable to have a more accurate fit with LCMT because there is no duplication of the master cast, and the light-curing modeling material is adapted directly to the desired position on the master cast.

Kumar et al. (2010) studied the accuracy of fit of cast clasps designed with conventional wax and light-cured patterns. Castings made by the light-cured patterns had significantly better fits compared to the castings made by the conventional wax patterns. Although our findings could not be compared directly with this study due to the different specimen designs, the results are in general agreement.

In the LCMT group, the fit of the short edentulous span was better than the fit of the long edentulous span ($p = 0.01$). This result can be explained by the proportional casting distortion of the metal geometry (Gebelein et al., 2003). However, the fit of the short edentulous span in the TT group was worse than that of the long edentulous span ($p = 0.003$). Akeel (2009) fabricated PRDP frameworks by the TT and studied the effect of the edentulous span on the fit of occlusal rests to the working cast. The fit of the bounded saddle PRDP framework occlusal rests was worse on abutments adjacent to long edentate ridges compared to those adjacent to short edentate ridges. Moreover, approximately one-fifth of all rests did not contact the rest seat at any point. The disagreement of our results with those of Akeel could be due to the difference in the position of measuring misfit. No contact or poor fit between rests and rest seats does not necessarily mean misfit at the adjacent metal base.

Phillips (1991) suggested that dimensional changes of castings may vary between different areas of the casting, and that these changes occur more often vertically than horizontally. Another study found that spaces were significantly greater between palatal aspects of abutment teeth and palatal reciprocal arms, and between buccal aspects of occlusal rests and rest seats. Excessive contraction toward the palate center was found. Expansion of the refractory investment may not have compensated adequately for solidification and cooling contraction of the cobalt–chromium alloy. Although dimensional changes in investment and casting are by volume, no evidence of anisotropic expansion of castings in a vertical direction was found (Fenlon et al., 1993). The abovementioned studies can explain the difference between the results of the present study and those of Akeel.

Despite careful attention during the laboratory phases of the PRDP service, some discrepancies in the fit of the framework will occur. Improvements in materials and techniques have reduced the number and size of these discrepancies, but have not eliminated them. It is hoped that discrepancies can be kept to a minimum, but these discrepancies must be corrected if the practitioner is to provide the patient with appropriate care (Phoenix et al., 2003). Laboratory and chair-side fittings of the framework are vital steps for achieving an acceptable clinical fit.

One limitation of this study was that we evaluated fit accuracy through metal base adaptation. Further investigation is needed to study the fit accuracy of all framework components to detect the exact position of the interference. In addition, an in vivo study of the "gaps" should be made, to detect whether these gaps were in the clinically acceptable range.

5. Conclusions

Within the limitations of this study, it can be concluded that the fit of the LCMT-fabricated frameworks was better than that of the TT-fabricated frameworks. Framework fit can differ according to the span of the edentate ridge and the fabrication technique of the framework.

Conflict of interest

The authors have no known conflicts of interest associated with the products used in this study and there has been no financial support for this work that could have influenced its outcome.

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