Effect of storage time and framework design on the accuracy of maxillary cobalt-chromium cast removable partial dentures

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Abstract

Statement of Problem: Inaccuracies in the fit of palatal major connectors may be related to distortion of the wax pattern due to prolonged storage time and faulty major connector design. **Purpose:** This *in vitro* study was carried out to find out the effect of storage time and major connector design on the accuracy of cobalt-chromium cast removable partial dentures (RPDs). **Materials and Methods:** A brass metal die with a Kennedy Class III, modification 1, the partially edentulous arch was used as a master die. Thirty-six refractory casts were fabricated from the master die. The refractory casts were divided into three groups (Group I: Anterior-posterior palatal bar, Group II: Palatal strap and Group III: Palatal plate) based on the design of maxillary major connector and subdivided into four groups (sub Group A: 01 h, sub Group B: 03 h, Sub Group C: 06 h, and sub Group D: 24 h) based on the storage time. For each group, 12 frameworks were fabricated. The influence of wax pattern storage time and the accuracy of the fit palatal major connector designs on the master die were compared. Casting defects (nodules/incompleteness) of the frameworks were also evaluated before finishing and polishing. Repeated measures analysis of variance was used to analyze the data. **Results:** The gap discrepancy was least in sub Group A (01 h) followed by sub Group B (03 h) and C (06 h) and most in sub Group D (24 h). Statistically significant differences ($P < 0.05$ in all locations L1–L5) in the fit of the framework were related to the design of the major connector. The gap discrepancy was least in Group I (anterior-posterior palatal bar) followed by Group II (palatal strap) and most in Group II (palatal plate). **Conclusions:** It is recommended that the wax patterns for RPD to be invested immediately on completion of the wax procedure. The selection of a major connector design is crucial for an accurate fit of RPD.

Keywords: Design of major connector, storage time, wax pattern

Introduction

The treatment of choice for the partially edentulous patient, when all the factors are favorable, is normally a tooth supported fixed partial denture or implant supported the prosthesis. Some factors, however, militate against the use of tooth supported fixed partial denture and rule in favor of removable partial denture (RPD). These include the advanced age of the patient, greater length of the edentulous span, excessive bone loss, reduced periodontal support of remaining teeth, and absence of abutment teeth posterior to edentulous space. Cast RPDs are still a treatment option in such situations in spite of advancements in the field of dental implants.

The inability to accurately adapt the framework on the cast and in the patient's mouth has been attributed to several factors related to clinical and laboratory procedures. One among them is the extended storage of wax pattern before investing. In routine practice, the waxed RPD refractory cast is routinely sent back to the dentist for approval of the design. The dentist, in turn, authorizes the technician to cast the waxed framework. This procedure could vary in the time period from 01 h to 24 h depending on the workload of the dentist and the laboratory, the proximity of the dental office to the laboratory, and the appointment schedule for the patient. In many laboratories, the waxed patterns may be stored on the shelf under variable temperatures and humidity for extended periods of time. This additional storage time could increase the distortion of the wax and the refractory cast and may lead to inaccuracies in castings.[1]

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The accuracy of the framework is also related to the major connector designs. Anterior-posterior palatal bar, palatal strap, and palatal plate design are commonly used in Kennedy Class III modification situation since these designs provide excellent rigidity, support and patient tolerance. Although rigidity is considered as one of the important structural requirement for the selection of major connector design, the adequate scientific evidence is lacking regarding the accuracy of the framework in relation to the major connector design. Previous studies concentrated on rest seat adaptation,[2] sprue design, sprue position,[3] sprue size,[4] investment coating method,[5] various casting techniques,[6] and button versus buttonless castings systems.[7] The accuracy of the fit of the cast cobalt-chromium (Co-Cr) restoration is essential for its longevity because it allows for less accumulation of plaque and ensue easy insertion and removal with better mechanical and biological factors considering the patient health. Therefore, this study was undertaken to investigate the effect of storage time of wax pattern (01 h, 03 h, 06 h, and 24 h) and framework design (anterior-posterior palatal bar, palatal strap, and palatal plate) on the accuracy of fit of cast partial denture frameworks.

Materials and Methods

The maxillary part of Typodont (Columbia Dentoform® Model M-1560, Long Island, New York) was converted into a Kennedy Class III modification-1 edentulous situation by removing second premolars and first molars bilaterally. Typodont was surveyed, designed and necessary teeth preparations were carried out. This Typodont was converted into a metal dimade up of brass which served as the master die [Figure 1]. Master die was duplicated with reversible hydrocolloid material (Castogel, Bego, Germany) and 36 refractory casts were fabricated, 12 for each design with phosphate bonded investment material (Wirovest, Bego, Germany) following manufacturer's recommendations. Refractory casts were divided into three groups based on the design of maxillary major connector. Group I with anterior-posterior palatal bar design, Group II with palatal strap design and Group III with palatal plate design [Figure 2]. For each group, 12 frameworks were fabricated. The wax pattern for the framework was made from prefabricated wax forms to get a uniform thickness of various components. Groups I, II, and III were further divided into four sub groups based on the storage time of wax pattern before investing. These include (i) sub Group A: 01 h, (ii) sub Group B: 03 h, (iii) sub Group C: 06 h and (iv) sub Group D: 24 h, respectively. The storage temperature in the laboratory was maintained between 23°C and 25°C, with a low humidity of 20–30%. After the said storage periods, spruing, investing, and casting were carried out for each wax pattern and the casts were invested following standard protocols as recommended by the manufacturers. All the castings were examined visually under magnification by using hand–held magnifier lens (2.5 × Power MG82015-L, China) before finishing and polishing for any casting defect such as surface irregularities, nodules, porosities, or incompleteness. A number of defects in each casting and location of the defects were noted and tabulated. Sprues were cut-off with a high-speed grinder, finishing, and polishing carried out following manufacturers recommendations before evaluating fit on the master die.

Figure 1: Modified typodont converted to master die

Polyvinyl siloxane addition silicone (light body) material (Silagum®, DMG Chem-Pharm, Hamburg, Germany) was used to evaluate the fit of the framework on master die. For the application of uniform pressure, a custom made acrylic block was used. Over the acrylic block, the standardized pressure of 3 pounds/cm^3 was applied using a hydraulic pressure application clamp (Macro Dent, Pune, Maharashtra India). The thickness of an elastomeric material layer on the fitting surface of the metal framework was measured at each specific indexed grid point. The thickness at each point was measured and recorded to the nearest 0.01 mm

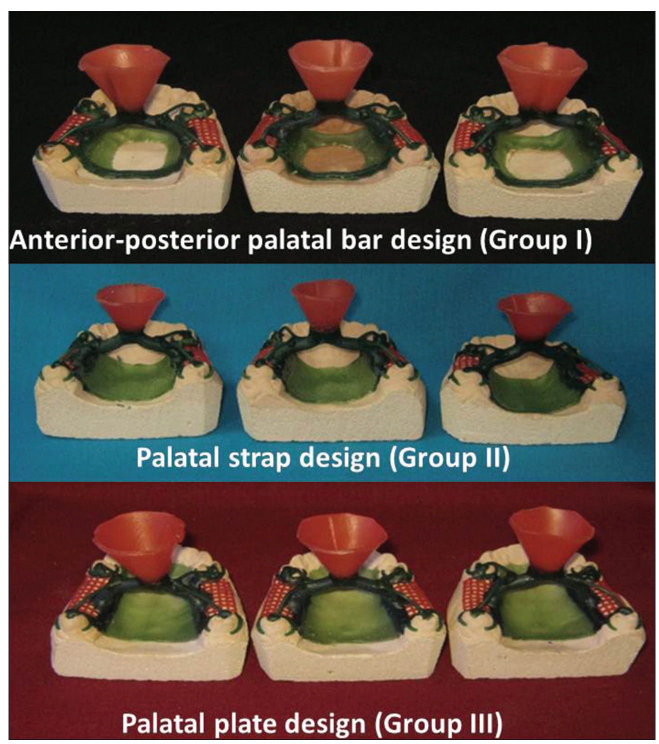

Figure 2: Wax up for three groups

with a digital Vernier Caliper Micrometer Guage (model 102-217, Mitutoyo Corporation. Tokyo, Japan). The measured indexed grid points [Figure 3] were located as follows: points L1 and L2, 0.5 cm medial to the internal finish lines from the midpoint of the of saddle on the major connector for all three groups, point L3, 1.2 cm posterior to the apex of interdental papilla between the central incisors on the midline at the midpoint of the anterior-posterior palatal bar (Group I), the palatal strap (Group II) and modified palatal plate (Group III), and lower point L4, 1.2 cm anterior to the posterior border of master die on the midline at the midpoint of the anterior-posterior palatal bar (Group I), the palatal strap (Group II) and modified palatal plate (Group III). An additional point (L5) was located in the palatal strap (Group II) and modified palatal plate (Group III), at the center of the major connector which is about 2.5 cm anterior to the posterior border of the master die on the midline. This point was not used for the anterior-posterior palatal bar group because of the connector's open window design. Initially, thickness of the framework was measured at specific locations i.e. (A). Then the thickness of framework with the light body adhered was measured at corresponding specific locations i.e. (B). Then the thickness of the elastomeric material at each indexed grid point i.e. (C) was calculated by subtracting the mean thickness of the metal framework at the corresponding indexed locations. The thickness of the elastomeric material or gap discrepancy between the master die and framework (C) = thickness of metal and elastomeric material (B) – thickness of metal framework alone (A).

Mean values and standard deviations were used to describe the measured discrepancies between the fitting surface of the major connectors and the metal die for each experimental condition. Repeated measures analysis of variance (ANOVA) was used to analyze the data, with the distance between the fitting surface of the connectors and the metal die (distortion) as the outcome variable, measurement location as the within subject factor, and time and connector type as between subject factors. For statistical analysis, the statistical software "SPSS-Version 17, IBM India" was used.

Results

Samples in Groups I II, and III exhibited gap discrepancies between the fitting surfaces of the major connectors and the master die at all locations (L1, L2, L3, L4, and L5) as evidenced by the thickness of elastomeric impression material at these points. The data observed with Group III is reflected in Table 1 and the same was observed in other groups. It has been found there was a gradual increase in mean values of gap discrepancies with an increase in storage time period of wax pattern irrespective of major connector designs in all the specific locations L1–L5. When with in-subject effects were tested, the location had a significant effect on the measured distortions ($P < 0.05$). Mean values of gap discrepancy at the L4 and L5 locations were significantly higher than those at the lateral L1 and L2 sections.

In one-way ANOVA analysis, it has been observed that there was gradual increase in mean gap discrepancies values for each major connector design for any given storage time of the wax pattern for each location such as L1–L5. Multiple comparisons analysis between all the locations L1–L5, statistically significant deterioration of fit of the palatal major connector designs occurred at the each locations L1– L5 ($P < 0.05$ for all the locations L1– L5) as the storage time of the wax patterns on refractory casts increased from 01 h to 24 h. For all the major connector designs, the highest inaccuracies in fit were revealed in sub Group D (wax pattern stored for 24 h) for Group I (anterior-posterior palatal bar) at the location L4 with mean gap discrepancies was

Table 1: Gap discrepancy at different locations for Group III

Sample notation	L_1 (in mm)	L_2 (in mm)	L_3 (in mm)	L_4 (in mm)	L_5 (in mm)
Group- III (Palatal plate) Sub group –B (03 hr)					
G-III B1	0.4	0.41	0.42	0.43	0.44
G-III B2	0.39	0.38	0.4	0.41	0.43
G-III B3	0.42	0.43	0.42	0.42	0.44
Group- III (Palatal plate) Sub group –C (06 hr)					
G-III C1	0.52	0.49	0.52	0.5	0.53
G-III C2	0.51	0.48	0.51	0.53	0.54
G-III C3	0.5	0.51	0.52	0.54	0.55
Group- III (Palatal plate) Sub group –D (24 hr)					
G-III D1	0.62	0.62	0.63	0.64	0.65
G-III D2	0.65	0.63	0.66	0.67	0.68
G-III D3	0.64	0.63	0.64	0.65	0.66

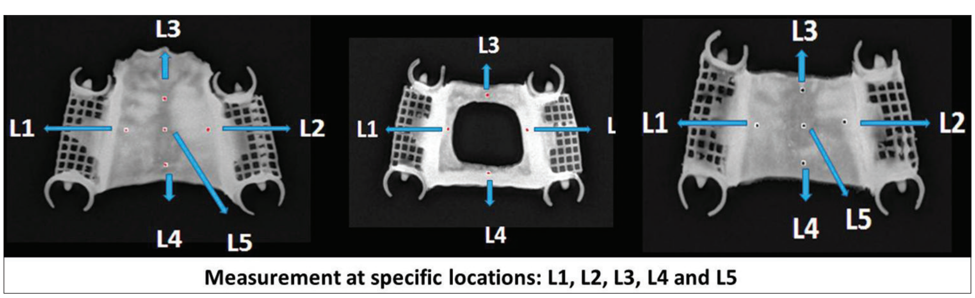

Figure 3: Measurement at specific locations

0.44 ± 0.01 mm and for Groups II and III at the location (L5) of the connectors with mean gap discrepancies 0.66 ± 0.01 mm for the palatal strap design and 0.66 ± 0.01 mm for the palatal plate design. Wax patterns in sub Groups A (stored for 01 h) revealed better fit than those stored for 03 h, 06 h, and 24 h at all locations for all the connectors designs. The least gap discrepancies were recorded at locations L1 (lateral section) for this sub Group A with mean values of 0.19 ± 0.03 mm for the anterior-posterior palatal bar designs, 0.20 ± 0.04 mm for palatal strap design and 0.34 ± 0.02 mm at location L1 (lateral section) for the palatal plate connector. Discrepancies in the fit increased toward the center of the palate at location L5 followed by L4 (lower middle section) as compared with the lateral sections L1 and L2, in all the Groups I II and III.

Discussion

Clinical experience with cast Co-Cr alloy partial dentures have shown that a framework rarely get adapted to the oral cavity accurately without the need for some adjustment, despite the fact that some adjustments has already been performed in the laboratory to fit the framework to the master cast.[8] This problem is related to the dimensional inaccuracies that occur during various stages (clinical and laboratory) of framework construction. The framework that appeared to have a good fit may have been distorted when seated on the cast or in the mouth. Such distortion is possible because of the flexibility of framework, including the major connector design. Distortion of the wax pattern used for the fabrication of cast RPD framework is another factor which often leads to inaccuracy of the fit of completed castings. Wax has been used as a common pattern material for cast RPD frameworks. Of all dental materials, waxes have the highest coefficient of thermal expansion, which may be a major contributing factor to the inaccuracy of the final restoration when it is not controlled. On cooling, wax contracts. Inlay waxes and other pattern waxes can have a linear thermal expansion of up to 0.6% when heated from 25°C to 37°C. This constitutes solidification shrinkage plus contraction on cooling to room temperature.[1]

Conditions may arise in dental laboratories that could lead to a delay in the casting of the wax pattern of a partial denture framework. This leads to the additional storage time of wax pattern and could increase the distortion of the wax and the refractory cast. The accuracy of the framework is also related to the major connector designs. Other factors that influenced their accuracy included the mold temperature, sprue size, position, and dimension of the wax patterns. Although there are enough studies regarding the accuracy of fit related to fixed partial dentures, studies related to RPDs are limited.[9,10] After an extensive search of the literature related to cast RPDs, it was found that studies related to the storage of the wax pattern and the major connector design on the accuracy of fit were lacking. Therefore, this study was taken up with the objectives to evaluate the casting defects and accuracy of fit of frameworks of frameworks fabricated from wax patterns of various maxillary major connector designs (anterior-posterior palatal bar, palatal strap, and palatal plate) stored at different time periods (1 h, 3 h, 06 h, and 24 h).

Statistical analysis of data has shown that there was significant increase in mean values of gap discrepancy with respect to increase in storage time of wax pattern irrespective of major connector designs in all the locations ($P < 0.05$) and this was more at L5 in case of palatal strap and palatal plate design and L4 in case of anterior-posterior palatal bar design [Table 1]. The mean gap discrepancies in locations L1 were least followed by L2 (midpoints in the lateral straps and lateral sides) in all connector designs, and these mean gap discrepancies were significantly less than those measured at the middle locations L3 (upper middle) and L4 (lower middle) of the connectors. These findings are in agreement with the results of the study conducted by Diwan *et al*. They also observed that the fit of frameworks deteriorated markedly as the storage time increased from 24 h to 1 week.[1]

The storage time of the wax pattern on the refractory cast before casting had a significant effect on the resulting distortion in the fit of the cast major connectors. In the palatal plate design, most of the distortion occurred in the first 01 h (sub Group A) and increased slowly thereafter in sub Groups B (03 h), C (06 h), and D (24 h). The anterior-posterior palatal bar design showed much less distortion within 01 h (sub Group A), but distortion occurred later at a comparatively higher rate (sub Groups B, C, and D) [Figure 4]. Connector design had a significant effect on the amount of distortion between the fitting surface and the master cast ($P < 0.05$ in all the location L1–L5). The palatal plate design showed more distortion than the anterior-posterior palate bar design.

The amount of internal stresses induced in the wax patterns with the palatal plate (closed) design was significantly greater than those in the palatal strap and anterior-posterior palatal bar designs as evidenced by the greater gap discrepancy. This was most likely the result of differences in their manipulative abilities and the area of coverage by wax. For the connectors, finger pressure was used to mold or adapt the wax sheets to the surface of the refractory casts, particularly at the

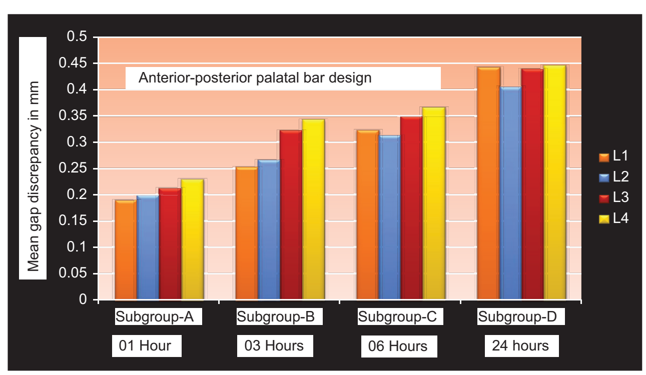

Figure 4: Gap discrepancy at all locations with AP bar design

center of the palate. Thus, more compression was applied at this section in contrast to other designs. The latter variable, in addition to the increased area of coverage by wax in the palatal plate design, would have increased the induced stresses in that group of wax patterns, with a resultant contraction that was increased by aging. The palatal sections of the plate, compressed to fit the curved palate, would attempt to straighten out as the wax cooled to room temperature. It would be logical to assume that the observed distortions in the fit of castings were not solely attributed to changes in the casting wax alone. Instead, the distortions resulted from a combination of dimensional changes in the wax and the refractory casts. The same was observed by Eliopoulos *et al*. their study.[11]

Earnshaw reported that phosphate-bonded investments removed from the mold 1 h after mixing and freely exposed to air demonstrated a decrease in setting expansion.[12] Slight shrinkage occurred when the specimens were allowed to stand overnight. This shrinkage was attributed to drying and the cessation of crystallization. Wirovest® investment material, which was used in this study, is a phosphate-bonded material. High setting expansion rates have been reported for phosphate-bonded materials, particularly when mixed with a silica sol (special liquid) more than with water. The setting expansion was found to be sensitive to factors such as mixing speed, water or liquid powder ratio, the presence of extra water from the duplicating gel, and age of the material.[13] The materials are also characterized by their high thermal expansions in comparison to gypsum-bonded investments.[13,14] It would be reasonable to assume that storing the waxed refractory casts for long periods would have resulted in some shrinkage. Despite its high thermal expansion, the investment material when heated exhibited an insufficient shrinkage compensation that further increased the inaccuracy of the final castings. The behavior of the wax patterns for all the connector designs validates these assumptions, and the same observation was found in a study conducted by Diwan *et al*.[15] The other factors that could possibly affect the fit of the partial denture frameworks, such as spruing techniques and type of alloy, were controlled in this study. Careful polishing of the metal framework was performed according to guidelines by Stern *et al*. to avoid the effect of metal loss on the contact between the tooth and framework.[2] Casting defects which were evaluated by visual examination under magnification in this study were basically external defects such as distortion in the form of nodules and incomplete casting. These findings are in agreement with explanation given by Rudd and Rudd in their review article.[16]

In this study, only some of the major connector designs were evaluated. It is unreasonable to expect similar results with various other brands of materials and equipment used in the casting procedure. The objective of this study was only to evaluate the effect of three wax pattern framework designs (anterior-posterior palatal bar, palatal strap, and palatal plate) and storage time (1 h, 3 h, 06 h, and 24 h) on the accuracy of fit of removable Co-Cr cast partial denture frameworks. The other factors such as dimensional changes and effect of different materials were not investigated. Further research can be taken up to overcome these limitations.

Conclusions

The accuracy of fit of frameworks deteriorated markedly as the storage time increased from 03 h to 24 h. Minimum inaccuracies were seen with 01 h storage time and the greatest inaccuracies in fit were observed with 24 h storage time. The resulting discrepancies in fit were possibly the result of a combination of dimensional changes in the casting wax and the refractory casts. The design of the major connector had an influence on the fit of the framework. More gap discrepancies were evident with a palatal plate and palatal strap compared to an anterior-posterior palatal bar design. A number of casting defects (Nodules/Incompleteness) observed less in the frameworks fabricated from the wax pattern which were invested in 01 h or less. It is recommended that the wax patterns for RPDs be invested immediately on completion of the wax procedure. For best results, the wax patterns should be started and completed in 1 h or less.

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Conflicts of interest

There are no conflicts of interest.

References

1. Diwan R, Talic Y, Omar N, Sadig W. Pattern waxes and inaccuracies in fixed and removable partial denture castings. J Prosthet Dent 1997;77:553-5.
2. Stern MA, Brudvik JS, Frank RP. Clinical evaluation of removable partial denture rest seat adaptation. J Prosthet Dent 1985;53:658-62.
3. Chan D, Guillory V, Blackman R, Chung KH. The effects of sprue design on the roughness and porosity of titanium castings. J Prosthet Dent 1997;78:400-4.
4. Custer F, Diemer R. Porosities in dental gold castings. Effects of sprue size, investment manipulation, venting, and casting pressure. J Mo Dent Assoc 1967;47:10-5.
5. Koike M, Hummel SK, Ball JD, Okabe T. Fabrication of titanium removable dental prosthesis frameworks with a 2-step investment coating method. J Prosthet Dent 2012;107:393-9.
6. Shanley JJ, Ancowitz SJ, Fenster RK, Pelleu GB Jr. A comparative study of the centrifugal and vacuum-pressure techniques of casting removable partial denture frameworks. J Prosthet Dent 1981;45:18-23.
7. Mohammed H, Hassaballa MA, Talic YF. Button versus buttonless castings for removable partial denture frameworks. J Prosthet Dent 1994;72:433-44.
8. Gay WD. Laboratory procedures for fitting removable partial denture frameworks. J Prosthet Dent 1978;40:227-9.
9. Davis DR. Limiting wax pattern distortion caused by setting expansion. J Prosthet Dent 1987;58:229-34.

10. Ito M, Yamagishi T, Oshida Y, Munoz CA. Effect of selected physical properties of waxes on investments and casting shrinkage. J Prosthet Dent 1996;75:211-6.
11. Eliopoulos D, Zinelis S, Papadopoulos T. The effect of investment material type on the contamination zone and mechanical properties of commercially pure titanium castings. J Prosthet Dent 2005;94:539-48.
12. Earnshaw R. Cobalt-chromium alloys in dentistry. Br Dent J 1956;101:67-75.
13. Eerikäinen E, Rantanen T. Inaccuracies and defects in frameworks for removable partial dentures. J Oral Rehabil 1986;13:347-53.
14. Lacy AM, Fukui H, Jendresen MD. Three factors affecting investment setting expansion and casting size. J Prosthet Dent 1983;49:52-8.
15. Diwan R, Talic Y, Omar N, Sadiq W. The effect of storage time of removable partial denture wax pattern on the accuracy of fit of the cast framework. J Prosthet Dent 1997;77:375-81.
16. Rudd RW, Rudd KD. A review of 243 possible errors during the fabrication of a removable partial denture: Part I, II and III. J Prosthet Dent 2001;86:251-88.