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Effect of Delayed Pouring of Condensation Silicone Impressions on the Dimensional Accuracy of Porcelain Fused to Metal Crown Frameworks: A Pilot Study

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Abstract

Background: Condensation silicone impression materials are widely used in prosthetic dentistry, particularly for the fabrication of single crowns, inlays, onlays, and fixed partial dentures. However, the influence of delayed pouring on the dimensional accuracy of porcelain-fused-to-metal (PFM) restorations remains unclear. **Aim:** To evaluate the effect of delayed pouring time on the dimensional accuracy of PFM metal substructures fabricated from a single condensation silicone impression.

Materials and Methods: A standardized full-arch condensation silicone impression was made and poured with Type IV dental stone at five time intervals: 30 minutes, 24, 48, 72, and 96 hours. The resulting casts were used to fabricate removable dies, wax patterns, and cast metal substructures. Mesiodistal, buccolingual, diagonal, and finish-line dimensions were measured using a dental caliper.

Results: Dimensional variations were observed among the metal substructures produced from casts poured at different time intervals. The greatest changes were noted at the finish-line region, with reductions in metal substructure dimensions observed after 24 and 48 hours of delayed pouring. Dimensional discrepancies were detected among the evaluated measurements which might be an indication that pouring time influenced the accuracy of the resulting restorations.

Conclusions: Delayed pouring of condensation silicone impressions resulted in dimensional alterations, particularly at the finish-line region. These changes may affect the accuracy of the fabricated PFM metal substructures and potentially compromise the marginal fit and clinical performance of the final restorations.

Keywords: Condensation silicone, delayed pouring, dimensional accuracy, metal substructure, marginal fit, PFM crowns.

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INTRODUCTION

In fixed prosthodontics, the long-term success of restorations is fundamentally dependent on their precision and marginal fit. Inadequate marginal adaptation has been associated with microleakage, secondary caries, periodontal inflammation, and eventual restoration failure[1]. Porcelain-fused-to-metal (PFM) crowns remain the most commonly utilized restorative option in dentistry[2] due to their favorable mechanical properties and clinically acceptable esthetic outcomes. Production of a successful PFM rely on several factors including a careful diagnosis and clinical management of the case, in addition to the selection of a good laboratory[3].The accuracy of the final prosthesis is largely influenced by the quality of the impression, which represents a critical step in the fabrication process. Elastomeric impression materials are widely used in dental practices due to their favorable properties [4]. Among the available and widely used elastomeric impression materials in dentistry is condensation silicone, owing to its ease of handling and excellent elastic recovery, in addition to its relatively good dimensional stability[5-7]. Condensation silicone is a type of polysiloxane consists of a base polymer which is polydimethylsiloxane with terminal hydroxyl groups. It is also consisting of crosslinking agents often alkoxysilane (tetraethyl orthosilicate) with fillers and catalyst (dibutyl-tin dilaurate). All these components help in controlling the setting reaction and the final properties of the material[8,9]. The ability to produce multiple casts from a developed impression for diagnostic, working, or backup purposes is clinically important[10,11]. However, the setting reaction of condensation silicone is distinguished by the release of a byproduct; mainly ethanol during the polymerization mechanism. Evaporation of this byproduct leads to changes in dimension particularly when molding is delayed and subsequently decrease in accuracy will occur[12].Dimensions of model from the second pour is affected by the continuing impression polymerization, as well as the distortion of the impression after removal of the first model[13]. For this reason, it is usually recommended to pour the condensation silicone immediately after taking the impression[14]. Furthermore, condensation silicone is known for its hydrophobic nature by means of low affinity for water and moisture. Oral environment is naturally moist due to the presence of blood and saliva; the hydrophobic nature makes this material difficult to flow on wet tooth surface or soft tissues. This may result in air bubbles or voids in the impression providing a less surface details and reduced accuracy. The presence of a catalyst in condensation silicone may possibly cause an allergic reaction which is another disadvantage for this material[15].

While all of the above-mentioned factors are true, many dental professionals in Libya continue to use condensation silicone (two step impression techniques) as an impression material mainly for crowns and bridges[16] regardless the low level of dimensional stability. This explains that the presence of the material that polymerizes by addition did not limit the use of condensation silicone on the market and at the dental practices. Similar behavior was also reported in Brazil[17] where nearly 78% of clinicians prefer to use condensation silicon over addition silicone at their practices.

Although previous studies have hugely investigated the dimensional accuracy of condensation silicone at different pouring intervals, to the author's knowledge, no studies appear to have directly address the effect of delayed pouring of condensation silicone impressions on the dimensional accuracy and marginal fit of fabricated PFM metal crown frameworks. Therefore, this study will directly focus on the dimensional accuracy and marginal fit of PFM copings after delayed pouring of condensation silicone at time intervals of 30 mins, 24h, 48h, 72h and 96h.

MATERIALS AND METHODS

Study Design and Setting

This study was designed as an experimental pilot study to evaluate the effect of delayed pouring on the dimensional accuracy of porcelain-fused-to-metal (PFM) crowns obtained from silicone impressions. A condensation silicone impression putty and light (Oranwash L [hydrocompatible] and Indurent Gel catalyst; Zetaplus, Zhermack, Italy) was obtained from a patient undergoing routine dental treatment and served as the reference for subsequent laboratory procedures (Figure 1).

Figure 1*:* Condensation Silicone impression material used for this study as a reference.

Impression Disinfection and Cast Fabrication

The impression was rinsed with water and disinfected using a sodium hypochlorite solution for 3 minutes prior to pouring. Type IV dental stone was used to pour the impressions at five different time intervals: 30 minutes, 24, 48, 72, and 96 hours.

The stone was hand-mixed according to the manufacturer's instructions at a powder-to-water ratio of 100 g to 20 mL for 1 minute. The mixture was poured into the impression under constant vibration and allowed to set for 45 minutes, Figure 2 (a). After 1 hour, the casts were separated and trimmed to obtain a flat base, Figure 2 (b). Similar procedure was repeated across all-time intervals and eventually five models were produced from the same impression. Surface detail reproduction was evaluated visually.

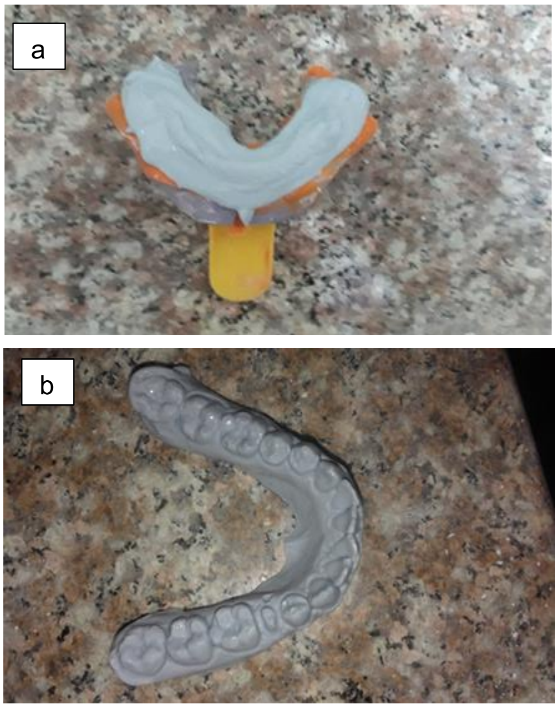

Figure 2 (a): Dental impression poured with type IV dental stone, **(b):** Master cast after trimming.

Master Die Fabrication

Five removable dies of a mandibular second premolar were fabricated using a conventional method, Figure 3 (a). Using a die saw, two parallel cuts were produced on the mesial and distal aspects of the prepared tooth Figure 3 (b), subsequently the die was carefully removed and trimmed. Oriented grooves were made to guarantee repositioning of the die precisely in the cast.

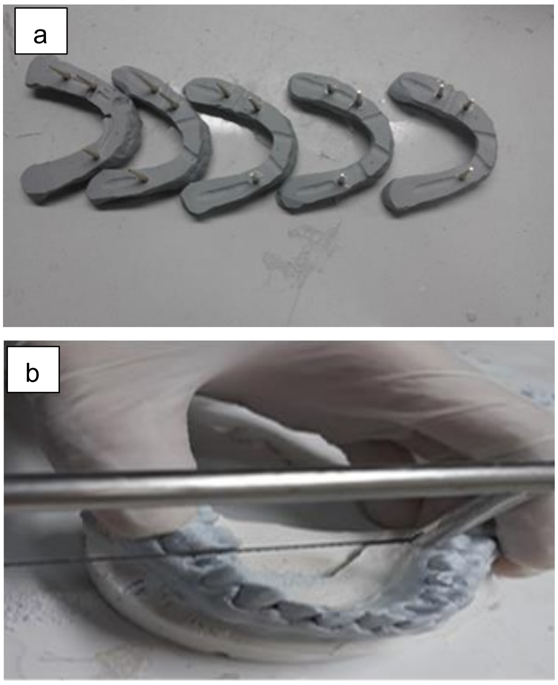

Figure 3 (a): Fabrication of removable dies of a mandibular second premolar, **(b):** a conventional die sectioning technique.

Wax Pattern Fabrication and Investing

A full-contour wax-up was fabricated for each die to produce the final morphology of the crown, Figure 4 (a). The wax patterns were sprued (Figure 4 (a)) and invested using a phosphate-bonded investment material (Rebivest Investment, Turkey). After setting, the invested ring was placed in a burnout furnace ((Ivoclar Vivadent, Germany) and heated gradually to 800 °C to ensure complete wax elimination.

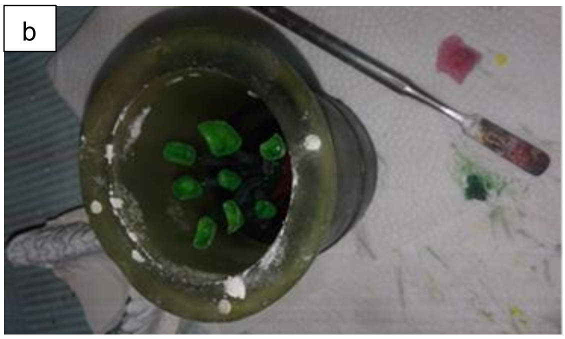

Figure 4: (a): Full contour wax-up of the die, **(b):** Sprued wax patterns prepared for investing.

Casting Procedure

Following burnout, a non-precious nickel–chromium alloy (NoBel; Kuwotech Co., Ltd., Gwangju, Korea) was used to fabricate the metal frameworks. Casting was performed using a centrifugal casting machine (Zhermach SpA, Badia Polesina, Italy). The castings were then divested and finished using carbide and round burs, Figure 5 (a, b), followed by ultrasonic cleaning for 30 minutes.

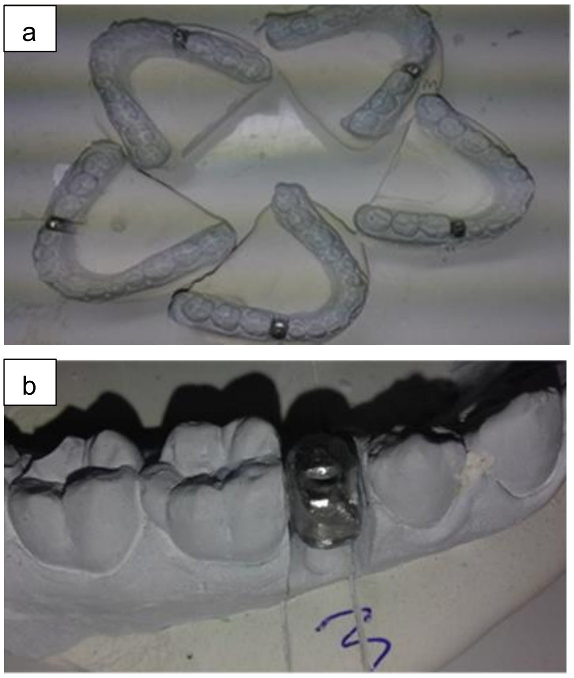

Figure 5 (a): Five Metal frameworks after being divested and finished, **(b):** Finished metal framework placed on the cast after ultrasonic cleaning.

Dimensional Measurements

The dimensions of the metal frameworks were measured using a digital caliper accurate to 0.01 mm. Two measurements were recorded for each specimen, and the mean value was calculated. The following dimensions were assessed:

- Mesiodistal
- Buccolingual
- Diagonal (mesiobuccal–distolingual and distobuccal–mesiolingual)

Porcelain Application and Firing

Opaque porcelain paste was prepared by mixing powder with distilled water (Ivoclar Vivadent, Germany) and applied using a No. 6 sable hair brush. Two layers were applied and fired at 930 °C for 15 minutes in a porcelain furnace (Ivoclar Vivadent, Germany). Dentin (body) porcelain was then condensed onto the metal frameworks and fired at 890 °C for 15 minutes.

The fabricated porcelain-fused-to-metal (PFM) crowns were evaluated for marginal fit, and clinically acceptable adaptation was achieved.

RESULTS

Metal Frameworks Dimensions Results

Table 1 represents the mean dimensions for mesiodistal, buccolingual and diagonal tooth aspects recorded at different time intervals. The results clearly demonstrated that pouring time influenced the dimensional measurements of the fabricated metal frameworks. The mean mesiodistal dimension was gradually decreased from 5.8 mm in the immediate pour to 5.4 mm at 24 hours and reached the lowest value of 4.8 mm at 48 hours. However, a slight increase in mean dimension to 5.1 and 5.5 mm was noticed with delayed pouring times at 72 and 96 hours, respectively. In contrast, the buccolingual mean dimensions showed an increase from 6.6 mm to 7.4 mm at the 24 hours of pouring and remained relatively stable between 7.4-7.5 mm at the subsequent pouring intervals. Similarly, the diagonal dimension revealed an increase from 4.2 mm at the immediate pour to 5 mm after 24 hours and remained constant up to 96 hours.

Table 1: Metal substructure mean dimensions at different pouring time interval.

Pouring Time (hrs)	Mesiodistal (mm)	Buccolingual (mm)	Diagonal (mm)
***Immediate Pour**	5.8	6.6	4.2
24h	5.4	7.4	5.0
48h	4.8	7.5	5.0
72h	5.1	7.4	5.0
96h	5.5	7.5	5.0

**immediate Pour = within 30mins*

Finish Line Measurement Results

The effect of different pouring times on the finish line measurements for the mandibular second premolar before preparation, after preparation and for the fabricated metal substructure are presented in Figure 6. It can be seen that the finish line before preparation showed slight variation in the dimension ranging between 7.2 and 7.7 mm. A reduction in the finish line dimension was noticed at 48 hours, followed by an increase at 72 and 96 hours respectively. Surprisingly, after preparation, the finish line appeared to be relatively constant (6 mm) throughout all time points, indicating that the dimensions of the prepared tooth were standardized and unaffected by delayed pouring time. On the other hand, the finish lines measurements for the metal substructure demonstrated a great variability across different time points. The highest value approximately 8.0-8.1 mm was recorded at 30 minutes, 72 and 96 hours, whereas lower value of 7.0 mm was seen at 24 and 48 hours. All fabricated metal substructures exhibited acceptable adaptation. The measured depth values for all metal substructures remains relatively stable and recorded to be 0.098 m.

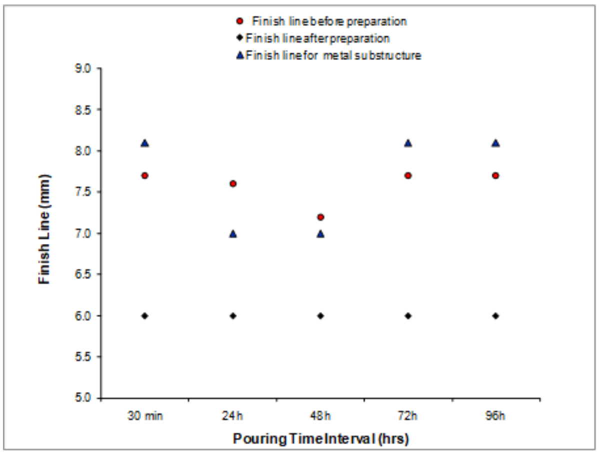

Figure 6: Finish line results for the mandibular second premolar before and after preparation and for the metal substructure as a function of pouring time.

DISCUSSION

Marginal fitness is considered one of the most important clinical factors affecting the survival rate of dental restorations, at both the biological and aesthetic levels. In traditional porcelain-fused-to-metal (PFM) crowns, structural strength is provided by the metal substructure, while porcelain offers the required esthetics. The present pilot study was conducted to evaluate the effect of delayed pours on the dimensional accuracy of PFM produced from elastomeric impression (condensation silicone) at different time pouring intervals: immediate pour (within 30 minutes), 24, 48, 72, and 96 hours respectively. The findings demonstrated noticeable dimensional variation in the tooth aspects; mesiodistal, buccoloingual and diagonal across the time points. Immediate pouring produced the highest mesiodistal mean dimension (5.8 mm), while delayed pouring, particularly at 48 hours, resulted in a reduction of this value to 4.8 mm. On the contrary, the buccolingual and diagonal dimensions increased with delayed pouring times and remained relatively constant after 24 hours. These results emphasized that storage time before pouring may significantly deteriorate the dimensional stability of impression material, which may in turn, influences the accuracy of the fabricated metal frameworks. The dimensional changes observed in this study may be associated with the inherent properties of condensation silicone, since it is known for the release of by-product, especially alcohol during polymerization mechanism. This loss by-product causes a shrinkage of the impression material on storage. The rise in dimension seen in the buccolingual and diagonal aspects with prolonged pouring time may be an indication to non-uniform distortions occur in different directions and that storage time and polymerization stresses as well as the material thickness may be responsible for such variations in certain dimensions. Controlled amount of impression volume is required since a large amount of impression does not necessarily indicate better impression. Naumovski and Kapushevska [24] reported that better results are usually achieved when the silicone impression layer is of moderate thickness and distributed evenly, this will cover the impression surface, penetrating into the undermined areas and adheres well to the tray after the polymerization.

The current results come in agreement with the findings by Singh et al. [18] who assessed the precision of condensational and additional silicone for the duplicating master dies. In their study, grooves were made on mesial, distal, lingual and buccal surfaces of an acrylic model of mandibular first molar. They reported significant marginal discrepancies between the model and duplicated master die fabricated from condensation silicone impression material. In contrast, Hafezeqoran et al.[19] compared the dimensional accuracy of casts obtained from two elastomeric impression materials at different pouring times of cast preparation i.e.1h, 24h, and 14 days and different impression techniques using a metal model. In their study, different pouring times showed no effect on the dimensional accuracy of die height and internal vertex distance of dies made from condensation silicone. It is worth mentioning that Hafezeqoran [19]investigation did not encountered the complicated factors such as wax patterns and metal casting which what the current study worked on. This might explain the similarity in the dimensional accuracy results they achieved at different time points. Khan et al [20] reported that condensation silicone showed the best results of dimensional accuracy (0.44%) only at the first half an hour of pouring when compared with the dimension of master die, while significant decreased in dimension was observed after 24 h, 1 week and 15 days' duration, therefore concluded that this material should be poured immediately, or within 30 minutes from taking the impression. A similar result was also achieved by Shetty et al[21]. and Sebastian et al[22] who reported a dimensional instability of condensation silicone on repeated pour and suggested that the time span between pours should not exceed 30 minutes even when putty wash technique is used. The slight stabilization seen after 72 and 96 hours may be an indication for completion of polymerization contraction within the early storage time. Fonte-Boa JC[17] study the dimensional stability and gas chromatography of different types of condensation silicone materials at six time intervals (immediately after setting, 30 minutes, 2 hours, 24 hours, 3 days, and 7 days after the setting). They found that all materials studied can have their molds stored for up to 30 minutes before casting the models. From 30 min to 2 h storage, all materials contracted. Whereas at 24 h, significant statistical differences were observed between the first time pour and all other storage times for all materials studied. Therefore, emphasized that the safest time to cast models using condensation silicone continues to be up to 30 min maximum. From the gas chromatography results they reported a release in ethanol from condensation silicone material even after clinical setting. A comparative in vitro study carried out by Rigzin Motup et al [23]reported that a condensation silicone exhibited the greatest dimensional change among the elastomeric materials due to the release by product and that the progressive contractions occurred particularly when pouring is delayed.

The results of finish line dimensions after tooth preparation remained relatively constant throughout all pouring intervals, indicating successful standardization of the tooth preparation procedure. However, the finish line measurements for metal substructure exhibited slight variation, especially at 24 and 48 hours. This illustrates that delayed pouring adversely affects the dimensional precision of the fabricated restorations. Similarly, Brăilă EB et al [25] discovered the linear dimensional variations of two elastomers within 24 hours from the first manipulation of the material to the time of casting the models and reported a significant difference between the values obtained and that of control model. These findings highlight the importance of pouring condensation silicone impression materials immediately or as early as possible to minimize dimensional inaccuracy, particularly in fixed prosthodontic restorations where high precision is required and even minor dimensional change can compromise the marginal adaptation.

CONCLUSION

Condensation silicone impression material demonstrated dimensional changes at all investigated pouring intervals, with greater variation observed following delayed pouring. Although most dimensional alterations remained within clinically acceptable limits, these changes reflect the inherent characteristics of condensation silicone associated with polymerization shrinkage and release of volatile by-products. The findings indicate that the highest dimensional accuracy was achieved within 30 minutes after impression making. Delayed pouring resulted in a measurable variation at the finish-line region, which may affect the accuracy of the metal substructure and subsequently compromise the marginal fit of porcelain fused to metal restorations. Since even small discrepancies at the restoration margin can influence clinical performance, careful selection of the pouring time is essential to optimize marginal adaptation and ensure accurate restoration fabrication.

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