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Storage time effect on marginal fit of full crown patterns made of wax, autopolymerized and light polymerized resin materials

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الهدف من هذه الدراسة تقييم التصاق حواف التاج الكامل والمصنعة قوالبه من ثلاث انواع مختلفة من المواد بعد تخزينه في درجة حرارة الغرفة لمدة تتراوح من ساعة إلى ٢٤ ساعة. تحت مقارنة الفجوات الحفافية لنماذج التيجان الكاملة المصنوعة من الشمع. تم صنع النماذج على أمثلة العمل الجبسية المصنوعة من طبعات أعطاها السيليكوني متعدد الفينيل وفقاً لتعليمات الجمعية الأمريكية لطب الأسنان لإعداد طبعات التيجان الكاملة المصنوعة من مادة الستانلس ستيل تم تخزين ثلاثين نموذجاً من كل مادة على المثال الموافق ضمن درجة حرارة الغرفة لفترة زمنية من ساعة واحدة إلى أربع وعشرين ساعة جرى بعد ذلك تقييم الفجوات الحفافية للنماذج على الأمثلة المعدنية الأساسية. أجرى بعد ذلك التحليل الإحصائي باستخدام تحليل أنوفا وأختبار t المزدوج وذلك بمستوى دلالة إحصائية ٠.٠٥. دلت النتائج على أن الانطاق الحفافي للتيجان المصنوعة من المواد المذكورة أعلاه كان الأفضل خلال الساعة الأولى مقارنة بـــأربعة وعشرين ساعة وعند الأخذ بعين الأعتبار حالتي التخزين فقد أبدت النماذج الشمعية الأنطباق الحفافي الأفضل ومن ثم الراتنبج ذو التصيب الضوئي والذاتي المبكر.

The purpose of this study was to evaluate the marginal fit of full crown patterns made from three materials after storing at ambient temperature for 1 hour and 24 hours. The marginal gaps of full crown patterns made from wax, autopolymerized and visible light cured acrylic resin materials were compared. The patterns were fabricated on stone (Vel Mix) working dies made from polyvinyl siloxane impressions of an American Dental Association full crown stainless steel die. Thirty patterns of each material were stored on their corresponding stone dies at room temperature after fabrication for 1 hour and 24 hours. The marginal gaps of patterns were evaluated on the metal master die. The data were subjected to one-way and two-way analysis of variance (ANOVA) and paired t-test. All the tests were conducted at 0.05 level of significance. The results indicated that patterns made from each of the three materials (wax, autopolymerizing and visible light-cured resins) had better marginal fit at 1 hour than at 24 hours after fabrication. Under the two storage conditions, the wax patterns showed the greatest marginal gap followed by visible light-cure resin and autopolymerizing acrylic resin.

INTRODUCTION

A cast dental restoration is fabricated by forming a pattern on a stone working die that can be removed and embedded in a refractory mold material from which it is eliminated by the use of heat and casted. Traditionally, wax has been used as a pattern material. [1] There is an increasing use of acrylic resin as pattern material such as autopolymerizing or visible light-cured VLC acrylic resin. [2] The accuracy of the pattern is of major importance for obtaining well-fitted cast restorations regardless of the pattern material used.

Desirable properties of wax include adequate strength, rigidity, ease of manipulation and absence of residue on burnout.[2] Thermoplastic characteristics of wax, however, can lead to distortion.[3] Shrinkage of wax patterns on the dies was found to create marginal gaps at shoulders and bevels.[4] This has been attributed to relaxation of elastic stress introduced during normal laboratory practice where the construction of patterns often involves re-melting part of it.[2] It has been reported that the maximum time a wax pattern can be stored at room temperature without noticeable distortion is approximately 45 minutes.[2]

Shrinkage was also reported to occur after removal of wax patterns from dies and this was attributed to relaxation of elastic stress in wax.[4,5] Iglesias *et al.*[6] examined the marginal gap of full crown wax patterns on a metal die 1 and 24 hours following fabrication on a stone working die. They found marginal discrepancy to range from 15 to 23 μm and the change at 24 hours was significantly larger than at 1 hour.

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Autopolymerizing resin as a pattern material was first described in the 1950's by Saunders.[7] It basically consists of polymethylmethacrylate and an initiator. The liquid consists of monomer and activator. Autopolymerizing resins offer strength, rigidity, and dimensional stability if immediate investment is not possible. It provides easy manipulation with rotary instruments with no fear of distortion.[2] However, a disadvantage of this material is its high polymerization shrinkage.[6] Mojon *et al.*[8] evaluated the polymerization shrinkage of autopolymerizing resin (Duralay®)* and found that the volumetric shrinkage at 17 minutes was 6.5% and 7.9 at 24 hours. They suggested that patterns may be built up incrementally to reduce contraction.

Cohen *et al.*[9] were the first to describe pattern fabrication from VLC resin. The VLC resin material is popular in dentistry and offer many benefits including faster and more complete curing, reduced porosity, adequate working time, ease of manipulation, and grinding without distortion, leaving no residue after burnout.[2]

In a study on vertical discrepancy of the margins of complete crowns, Tajan et al.[10] compared the efficacy of three autopolymerizing resin and three VLC resin pattern materials. They found that autopolymerizing resins recorded the least marginal discrepancy. However, other studies have shown that VLC resins produced better marginal fit compared with wax or autopolymerizing resin pattern materials.[6,11] According to Craig *et al.*[12] the average marginal discrepancies for full crown patterns fabricated with VLC resin (Triad®)**, autopolymerizing resin (Duralay®) and Type II inlay wax as 11 µm, 12 µm and 15 ìm, respectively. Koumjian and Holmes[13] found that autopolymerizing pattern resin (Duralay®) showed significantly less marginal discrepancy compared with wax and VLC resin (Triad®).

Various research reports have shown mixed results for marginal fit of autopolymerizing and light activated resin materials in the fabrication of patterns for cast restorations.[6,10,11,13] This investigation evaluated the marginal fit of full crown patterns made from three pattern materials after storing at room temperature for 1 hour and 24 hours.

MATERIALS AND METHODS

A Standard American Dental Association[14] full crown stainless steel die was used to fabricate a crown. Cross grooves at occlusal surface were made (Fig. 1). The master metal die was marked with 50 indentations using a fine pointed diamond bur to allow for orientation and to identify the gap during measurements. The indentations were made approximately 1m below the cervical preparation line. Groten *et al.*[15] have suggested that a minimum of 50 measurements along the margin of a crown yielded consistent estimate of the gap size. The metal die was attached to an acrylic resin plate that was keyed for accurate seating of an impression tray.

Thirty impression trays were fabricated in autopolymerizing acrylic resin*** with 2 mm thick wax spacers to include the key provided in the acrylic resin plate and were stored at room temperature for a minimum of 24 hours before use (Fig. 2).[16] The inner surface and periphery of each impression tray was coated with appropriate adhesive recommended by the manufacturer and permitted to dry for 15 minutes[17]. Light and heavy viscosity impression materials‡ were used to make thirty impressions of the master metal die (Fig. 3). The material for each impression was mixed

* Reliance Dental Mfg. Co., Worth, IL, USA
** Triad VLC, Dentsply, York Division, York, PA, USA

*** Fastray, Henry, J, Bosworth Co., IL, USA
President®.Coltene, AG, Alstatten, Switzerland

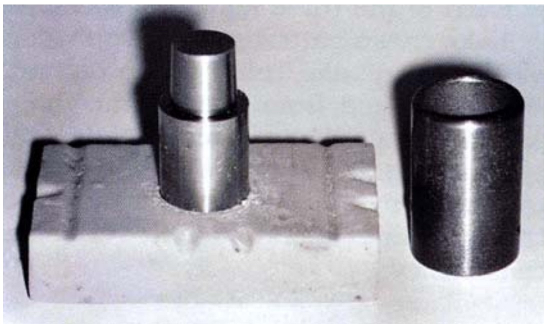

Fig. 1. ADA metal full crown with a metal tube.

Fig. 2. Impression tray in autopolymerizing acrylic resin.

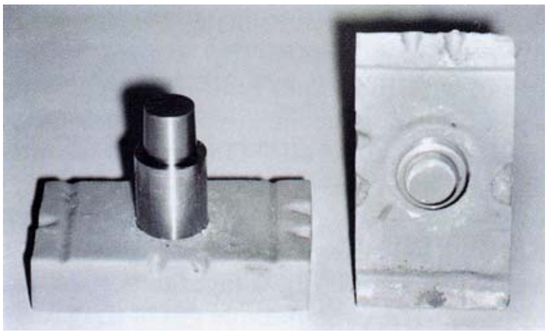

Fig. 3. Impression of master metal full crown die.

following manufacturer's instructions. The light viscosity impression material was syringed around the master metal die, and the heavy viscosity material was loaded into the tray.

The loaded tray was positioned on the master die such that the impression tray engaged the keys provided on the acrylic plate. The impression was allowed to set at double the manufacturer's recommended period of time at room temperature (25°C ± 1°C) and 50% ± 10% humidity. According to the American Dental Association Specification No.19,[14] manufacturers setting time can be doubled to compensate for polymerization at room temperature rather at mouth temperature (37°C). The impressions were separated and then aged by one hour bench set at room temperature before being poured in stone die.[18] The metal master die was cleaned with ethyl alcohol and distilled water and dried with paper towel before making each impression.

Fifty grams of stone die[‡‡] was weighed to the nearest 0.1 gram and 12 ml of water was measured to the nearest of 0.1 ml. The stone die was added to distilled water in a clean scratch free rubber-mixing bowl. The mix was allowed to soak and hand spatulated for 10 seconds with a round end steel blade spatula and spatulated in a mechanical vacuum spatulator[‡‡‡] for 20 seconds to obtain a creamy bubble free mix.

The impressions were poured under standardized vibration conditions using a mechanical vibrator[Π]. The frequency and amplitude of the instrument was set at 6000 cycles / minute and at step 3 (0.4 mm), respectively.[19]

In order to eliminate individual variability the same operator poured a total of 90 impressions to make 90 working stone dies. The working stone dies were removed from the impressions after 1 hour and were randomly assigned appropriate identification numbers and stored at room temperature. Working stone dies with surface voids were excluded and replaced.

‡‡Vel Mix, Kerr Manufacturing Co., Detroit, Michigan, USA
‡‡‡Va-u-Mixer, Whip-Mix Corp., Louisville, KY, USA
ΠVibromaster, Bego Bremer Gold Schagerel Wil GmbH & Co., Bremer, Germany

Preparation of Crown Patterns

To prepare crown patterns of standardized thickness from wax and autopolymerizing resin, a metal tube was used (Fig. 1). The working die and metal tube were attached to an acrylic resin plate that was keyed for accurate seating (Fig. 4). The open end of the metal tube was 1 mm above the occlusal surface of the working stone die. The space between the outer surface of the die and the inner surface of the metal tube was the same for all preparations. To develop crown patterns of standardized thickness in VLC resin, a vacuum-formed polypropylene matrix was made using autopolymerized resin full crown pattern (Fig. 5).

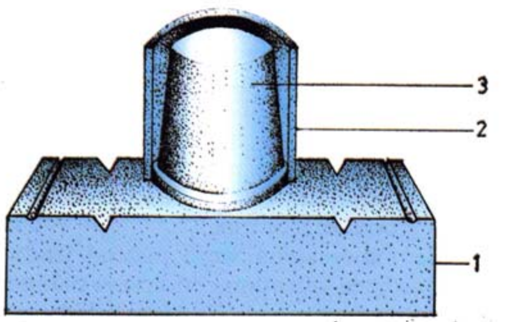

Fig. 4 Schematic view of metal tube keyed to acrylic resin base for the preparation of crown patterns. (1) acrylic resin base (2) metal tube and (3) working stone die keyed to resin base.

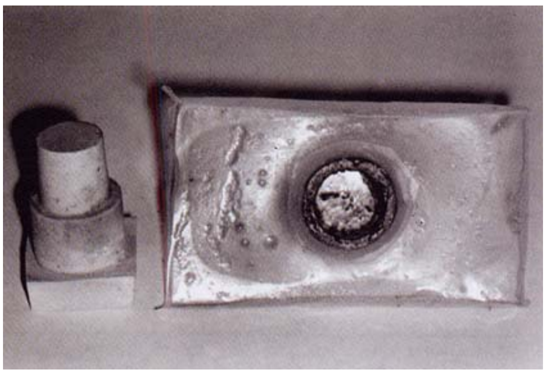

Fig. 5. Vacuum formed polypropylene matrix made over the autopolymerizing resin full crown.

Each of the three materials was used to make crown patterns on the individual working stone die. Thirty crown patterns were fabricated from each of the three-pattern materials to give a total of 90 patterns on 90 stone dies. This was performed by the same operator in order to achieve intra operator or intra examiner consistency.

Wax Crown Pattern

The working stone dies were first lubricated with die lubricant[ΠΠ] according to manufacturer's instructions. Wax patterns were fabricated following incremental technique. After application of each layer of inlay wax, it was allowed to solidify and checked for proper thickness using the warm metal tube. The wax margins were carefully cut back to finish line and were not re-melted before evaluation. The external margin of the crown pattern and the margin of the cervical preparation line of the master metal die made a butt joint and lied in the same vertical plane.

Patterns made out of autopolymerizing acrylic resin (Duralay®) were also fabricated in layers. The acrylic resin material was applied by wetting a fine brush with monomer followed by carrying some of the powder to produce a bead of acrylic material. The material was layered over the surface of the die and was allowed to polymerize. The pattern material thickness was verified using the metal tube each time a layer of acrylic was applied. The external margin of the crown pattern and the cervical preparation line made a butt joint and lied in the same vertical plane. This procedure was performed to maintain even thickness of the patterns and were seated over their corresponding working stone dies and stored at room temperature before evaluation. Triad ® VLC resin patterns

[ΠΠ]Die lub, JIM Ney Col, Bloomfield, CT, USA were fabricated using vacuum-formed polypropylene matrices. Each resin-filled matrix was adapted on its corresponding working stone die, which was lubricated with Triad Model release agent and photopolymerized for 4 minutes through the transparent matrix as recommended by the manufacturer.

The pattern was removed from the working stone die and all its surfaces were coated with Triad air barrier agent and were then placed in the Triad VLC curing unit for an additional 6 minutes to complete the photopolymerization process. The patterns were then seated over their corresponding working stone dies and stored at room temperature before evaluation.

Measurement of Marginal Discrepancy

Each pattern was removed from the stone die and repositioned on the master metal die using light finger pressure until resistance was met.[6,13] Grooves on the master metal die prevented rotation of the patterns and ensured correct seating. The vertical marginal discrepancy between the margin of the crown pattern and the cervical preparation line of the master metal die was measured using a traveling microscope[ΠΠΠΠ] with a low angle illumination light source.

The vertical marginal discrepancy refers to the marginal gap of Holmes *et al.*[20] and was defined as the shortest distance from the most external point at the crown pattern margin to the most external point at the cervical preparation line.

The external crown pattern margin and the margin of the cervical preparation line of the master metal die should be in the same plane while measuring the vertical discrepancy. A variation of tilt angles on the crown pattern margins may cause measurement error of up to 15%.[5] To overcome the parallax error when making measurements along the axis of the crown pattern and the margin of master metal die, an orientation jig was made in autopolymerizing acrylic resin (Fig. 6). To make the jig, an impression of the axial wall of the metal master die with the crown pattern was made in silicone. The impression was invested in gypsum and packed with autopolymerizing acrylic resin and retrieved after it had polymerized. The base of the jig was trimmed, until the crown pattern seated on the metal master die could be localized consistently, such that the two margins were in focus under the microscope.

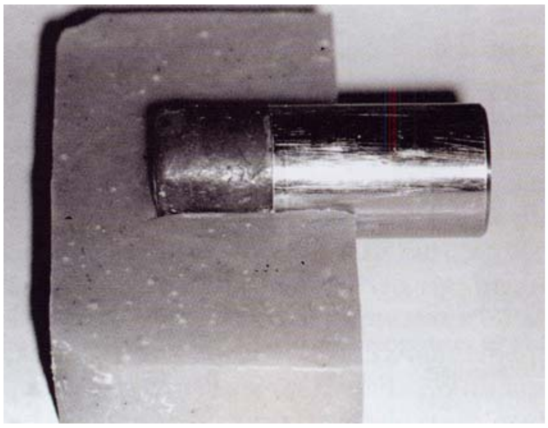

Fig. 6. Orientation jig carrying the full crown pattern seated on the metal master die.

For each crown pattern 50 vertical discrepancy gap measurements were made at the 50 reference locations marked on the master metal die. The measurements were added and divided by 50 to yield one value for each crown pattern. All measurements were made by one investigator.

Randomly selected test specimens were measured for vertical gap dimensional accuracy in order to find intra-examiner reliability. The value of Pearson and paired t test were found to be r=0.91 and t=0.8906 with a P value of 0.437 respectively, which showed a high degree of intra-examiner reliability

[ΠΠΠΠ]Titan, Measuring Microscope, Buffalo, USA of gap dimensional accuracy. The data were subjected to one-way and two-way analysis of variance (ANOVA) and paired t test. The tests were conducted at 0.05 level of significance.

RESULTS

The mean, minimum, maximum and SD of the vertical discrepancy of full crown patterns for the three materials at 1 hour and 24 hours after fabrication are listed in Table 1 and Figure 7.

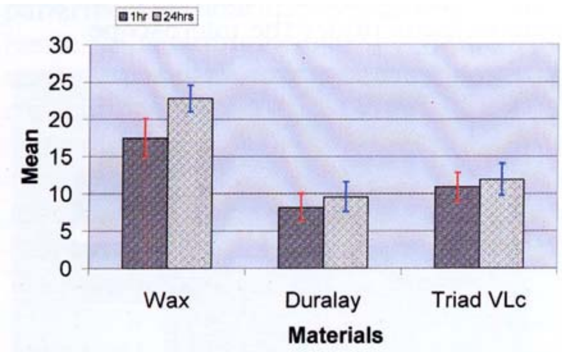

Fig. 7. The mean and standard deviation of marginal gaps for the three full crown pattern materials at 1 hour and 24 hours following fabrication (μm).

Two-way repeated measure design analysis of variance was conducted for storage times and pattern materials. Analysis of variance (ANOVA) showed statistically significant difference between the storage times ($P<0.0001$) and materials ($P<0.0001$). Since there was an interaction effect, the data were further analyzed using paired t test for each storage time for each pattern material. The paired t test showed statistically significant difference between storage times ($P<0.0001$) for each material (Table 1). The mean value for wax pattern marginal discrepancy at 1 hour was 17.50 μm and 22.77 μm at 24 hours respectively, indicating a considerable increase in marginal gap as a result of time factor.

Table 1. Mean, minimum, maximum and SD of the vertical marginal discrepancy (μm) of full crown patterns for each of the three pattern materials measured between 1 and 24 hours after fabrication with p. values.

MATERIALS	1 HOUR				24 HOURS				T value	*P* value*
	Min	Max	Range	Mean** (SD)	Min	Max	Range	Mean** (SD)		
Wax	13	22	9	17.50^{a} (2.56)	18	25	7	22.77^{a} (1.77)	-11.100	<0.0001
Duralay	6	12	6	8.13^{b} (1.85)	7	13	6	9.53^{b} (2.01)	-8.266	<0.0001
Triad VLC	7	14	7	10.83^{c} (1.97)	8	15	7	11.87^{c} (2.15)	-6.998	<0.0001

* P value compares the mean at 1 hour and 24 hours
** Different alphabets in superscript indicate statistically significant difference column wise

ANOVA showed statistically significant difference ($P<0.0001$) in the mean values of marginal gaps between Duralay® and Triad® VLC at 1 hour and 24 hours, respectively after fabrication. All the three materials were statistically significantly different from each other at 1 hour and 24 hours ($P<0.0001$). However, Duralay® was significantly more accurate than Triad® VLC.

DISCUSSION

The marginal fit is important to long-term success of cast restorations. This demands the highest technical standards at each stage of laboratory procedures.

In this study, the marginal gaps were measured on the master metal die 1 hour and 24 hours after its fabrication on the stone working die made from addition silicone impression. Examining the marginal fit of patterns on the master die before investing allows evaluation of pattern material at this stage of fabrication. The crown patterns were placed with finger pressure by one investigator instead of using a jig capable of exerting a standard load for specific period of time as this procedure simulated laboratory conditions. The finger pressure is subjective and greater pressure might have resulted in improved adaptation of the wax pattern.[5]

The polymerization shrinkage of impression material and the expansion of the stone die are also associated factors that affect the marginal fidelity. However, no attempt was made to investigate these factors in this study. The bulk of the material in the fabrication of crown patterns was standardized. In this study, the crown wax pattern were examined after 1 hour because according to Phillips[2] the minimum time that wax patterns can be stored at room temperature without noticeable distortion of the casting is approximately 45 minutes. During the formation of wax crown pattern shrinkage may be restricted by the friction between the pattern and the die, which results in residual stress in the pattern. The stresses are released after removal of the wax pattern from the die, allowing further shrinkage.[4]

In this investigation, the marginal discrepancies of wax pattern at 1 hour and 24 hours were 17.50 µm and 22.77 µm, respectively. The greater marginal gap at 24 hours after fabrication could be attributed to the effect of thermal change over a period of time and release of internal stress. The results of this study are in close agreement with those of Iglesias *et al*[6] who found 15 µm for one hour and 19 µm at 24 hours. The tolerance limits of marginal discrepancy of pattern are not known. However, remargination of wax pattern was found to improve the adaptation to the dies, especially if carried out after the pattern was removed and replaced on the die.[4]

The effect of continued polymerization of autopolymerizing resin (Duralay®) was investigated by comparing the crown patterns on the master die 1 hour after fabrication with the fit after storage for 24 hours. The autopolymerizing resin crown patterns were evaluated after 1 hour because according to Mojan *et al.*[8] most of the changes (80%) occur before 17 minutes. The mean marginal gap distance at 1 hour was 8.13 µm and 9.53 µm at 24 hours. A similar trend of marginal gap discrepancy was observed for VLC pattern material at 1 hour and 24 hours after fabrication (Table 1). However, the marginal gap for autopolymerizing resin was significantly less compared with VLC for both 1 hour and 24 hours of storage. Koumjian and Holmes[13] evaluated the marginal accuracy of seven commercially available autopolymerizing resins including Duralay® and Triad® VLC under conditions: immediately after fabrication, after storage of 1 week in air, and after storage of 1 week in water. They reported that all materials showed evidence of continued polymerization shrinkage after storage in air for 1 week.

The observations of this study indicated that wax crown patterns had the greater mean marginal gap than did VLC patterns, or autopolymerizing resin patterns and the mean marginal gap for VLC patterns was greater than the mean for the autopolymerizing patterns. The results of this study are in agreement with those of Tjan *et al.*[10] and, Koumjian and Holmes.[13] In contrast, Ogle *et al.*[11] and Iglesias *et al.*[6] have reported that Triad® VLC patterns showed better marginal fit compared with autopolymerizing resin patterns. This could be due to manipulative differences and variations in the thickness of patterns materials.

CONCLUSIONS

Within the limitations of this study, the following conclusions were made.

1. All pattern materials showed evidence of continued shrinkage after storage of full crown patterns at room temperature for 1 hour and 24 hours.

2. Under the two storage conditions, the wax material had the greatest marginal gap and autopolymerizing resin (Duralay®) the least with visible light-cured acrylic resin (Triad®) between.

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