ABSTRACT

Background: Traditionally, inlay casting waxes have been used to fabricate patterns for castings. Newer resin pattern materials offer greater rigidity and strength, allowing easier laboratory and intraoral adjustment without the fear of pattern damage. They also claim to possess a greater dimensional stability when compared to inlay wax.

Aims: This study attempted to determine and compare the marginal accuracy of patterns fabricated from an inlay casting wax, an autopolymerized pattern resin and a light polymerized pattern resin on storage off the die for varying time intervals.

Materials and Methods: Ten patterns each were fabricated from an inlay casting wax (GC Corp., Tokyo, Japan), an autopolymerized resin pattern material (Pattern resin, GC Corp, Tokyo, Japan) and a light-cured resin pattern material (Palavit GLC, Hereaus Kulzer GmbH, Germany). The completed patterns were stored off the die at room temperature. Marginal gaps were evaluated by reseating the patterns on their respective dies and observing it under a stereomicroscope at 1, 12, and 24 h intervals after pattern fabrication.

Results: The results revealed that the inlay wax showed a significantly greater marginal discrepancy at the 12 and 24 h intervals. The autopolymerized resin showed an initial (at 1 h) marginal discrepancy slightly greater than inlay wax, but showed a significantly less marginal gap (as compared to inlay wax) at the other two time intervals. The light-cured resin proved to be significantly more dimensionally stable, and showed minimal change during the storage period.

Conclusion: The resin pattern materials studied, undergo a significantly less dimensional change than the inlay waxes on prolonged storage. They would possibly be a better alternative to inlay wax in situations requiring high precision or when delayed investment (more than 1 h) of patterns can be expected.

Key words: Dimensional accuracy, inlay wax, pattern distortion, resin pattern materials

The fabrication of acceptable patterns is an important variable that can affect the marginal fit throughout the casting procedure. Traditionally, patterns for dental castings have been formed from inlay casting wax. These materials combine familiarity and ease of manipulation with good replication of detail and cost effectiveness. However, waxes have two major defects: A high coefficient of thermal expansion and a tendency to warp or distort upon standing.

Wax patterns, regardless of the method of manipulation, develop a degree of internal strain during preparation. This strain tends to be relieved over time and the wax distorts. Distortion of wax is both time and temperature dependent and ideally wax patterns must be invested immediately after removal from the preparation.
These adverse properties of wax have long been recognized and therefore attempts have been made at finding alternative materials. Initially, chemically cured resins were formulated for use as pattern materials and more recently light cured resin pattern materials were introduced.

Autopolymerized methyl methacrylate resins were first described for pattern fabrication in the 1950s. They were said to offer improved dimensional stability if immediate investment was not possible and easy manipulation with rotary instruments without the fear of distorting the pattern.[4]

Command curing materials are popular in dentistry, and have superseded chemically activated materials in a variety of clinical and laboratory applications. They provide many benefits, including faster and more complete curing, reduced porosity as mixing is generally not required, almost instant finishing, adequate working time for complex procedures and material economy.[5]

Resin pattern materials used alone or in combination with wax, do simplify complex wax-up procedures. But, despite claims of superior dimensional stability and accuracy, doubts have been raised regarding the effects of polymerization shrinkage on the accuracy of these materials.

Taking into account the advantages as well as the reservations about the use of resin pattern materials, a study was designed to evaluate and compare the marginal accuracy of patterns fabricated from an auto-polymerized and a light-polymerized resin pattern material with that of an inlay casting wax at varying intervals of storage.

MATERIALS AND METHODS

Standardized dies were milled as per the design prescribed by the Accredited Standards Committee (MD 156). Three identical dies were milled along with their waxing sleeves and were used for pattern fabrication.

An oil based separating medium (True release die lubricant) was applied to the metal die so as to facilitate easy removal of the patterns. The waxing sleeve and the occlusal component were also coated on their internal surface with the separating medium and were then placed over the die.

Inlay wax (GC Corporation, Japan) was placed in an electrically controlled wax bath (NOVO) and kept at the recommended temperature of 100–150°C. This molten wax was flown into a preheated die–waxing sleeve assembly till slightly above the edge of the sleeve. This assembly was then allowed to cool to room temperature. Excess wax was carved away and margins redefined if necessary.

The autopolymerized resin pattern material (Pattern Resin, GC Corporation, Japan) was dispensed in two separate plastic mixing cups (provided by manufacturer), one containing the powder (polymer) and the liquid (monomer) in the other. The patterns were then fabricated by incremental build up using the brush on technique.

After setting, the die with the pattern was removed from the waxing sleeve. The pattern was then separated from the die and inspected for deficiencies. Excess resin in the form of fins was removed using a carbide bur and a slow speed hand piece.

The light cured resin patterns were fabricated from Palavit GLC ( Heraeus Kulzer GmbH, Germany). The low viscosity light cured resin pattern material (K-I) was adapted onto the margin of the die. The die was then placed in a Light curing unit (Dentacolor unit- Heraeus Kulzer GmbH, Germany) and cured for 90 sec. After retrieval, care was taken not to touch the polymerized resin surface as it would result in removal of the dispersion film formed. This film is essential for the bonding of the subsequent increment to the first. In the case this layer was lost, a thin film of Palavit GLC liquid was painted onto the surface. Increments (2 mm thick) of high viscosity resin pattern material (K-II) were then adapted to the die and shaped. Each increment was polymerized in the light curing unit for 90 s.

After the final increment, the pattern was cured again for 180 s. No adjustments of the patterns were generally required as each increment was sculpted accurately prior to polymerization. When required, trimming was done with a carbide bur on a slow speed hand piece. Any additions to adjusted surfaces were made after painting on the Palavit GLC liquid.

Ten patterns from each of the three materials were fabricated on the metal dies. On completion, the patterns were visually inspected with a magnifying lens to ensure proper marginal adaptation.

The patterns were then separated from their dies and stored in a container at room temperature. At intervals of 1, 12, and 24 h, the patterns were re-seated by the same operator onto their respective dies, using gentle finger pressure. The margins were then observed under the stereomicroscope, and the marginal gaps were measured at all three time intervals. Mean value of measurements at the gingival margin at each of the time intervals were used for the statistical analysis.

The marginal discrepancy between the metal die and the patterns were measured using a stereomicroscope (Olympus SZH 10). A 0.75 apochromatic objective was used to capture images through a CCD camera (Axio Cam HR). Measurements of the marginal gaps were made using an Image Analyzer Software (Axio Vision 3.0.6.38, Service pack 4, Carl Zeiss Vision GmbH Germany).
RESULTS

The marginal gaps of the patterns were measured at 1, 12, and 24 h after fabrication. The mean marginal gaps at these time intervals for the three materials is presented in Table 1.

A repeated-measure analysis of variance (ANOVA) by Greenhouse-Geisser method was carried out to test the significance in difference of marginal gaps among three pattern materials at three time intervals [Table 2]. The ANOVA table reveals that there is a significant difference between marginal gaps of the three materials at the three time intervals.

A multiple comparison using Bonferroni’s test was carried to verify the significance of difference in marginal gaps between any pair of pattern material [Table 3]. The test revealed there was significant difference between all the pairs of patterns materials.

DISCUSSION

The procedure for fabrication of cast restorations is complex, involving various stages, each of which may affect the dimensions and therefore the accuracy of fit of the castings. Marginal adaptation is considered to be a primary and significant factor in the prevention of secondary caries and is an important indicator of the overall acceptability of the cast restoration.[6,7]

Great improvements in impression materials, die materials, and casting techniques have enabled the production of more accurate castings. Yet, very little progress has been made towards the formulation of a pattern material that overcomes the disadvantages of inlay casting wax.

Table 1: Descriptive statistics (marginal accuracy of patterns on storage)

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>S. D.</th>
<th>Number of samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Margin 1 h</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inlay wax</td>
<td>12.90</td>
<td>1.04</td>
<td>10</td>
</tr>
<tr>
<td>Autopolymerized resin</td>
<td>13.26</td>
<td>1.56</td>
<td>10</td>
</tr>
<tr>
<td>Light-cured resin</td>
<td>10.34</td>
<td>1.19</td>
<td>10</td>
</tr>
<tr>
<td>Margin 12 h</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inlay wax</td>
<td>18.94</td>
<td>3.86</td>
<td>10</td>
</tr>
<tr>
<td>Autopolymerized resin</td>
<td>14.81</td>
<td>1.51</td>
<td>10</td>
</tr>
<tr>
<td>Light-cured resin</td>
<td>10.69</td>
<td>1.25</td>
<td>10</td>
</tr>
<tr>
<td>Margin 24 h</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inlay wax</td>
<td>21.92</td>
<td>3.23</td>
<td>10</td>
</tr>
<tr>
<td>Autopolymerized resin</td>
<td>16.01</td>
<td>1.93</td>
<td>10</td>
</tr>
<tr>
<td>Light-cured resin</td>
<td>11.01</td>
<td>1.22</td>
<td>10</td>
</tr>
</tbody>
</table>

Though inlay waxes possess desirable properties such as ease of manipulation, predictable coefficient of thermal expansion, and absence of residue on burnout; their thermoplastic characteristics can lead to distortion resulting from thermal changes and release of internal stresses.[4,8]

The amount of contraction which inlay waxes undergo from mouth temperature to room temperature is important when the direct technique is used to form a wax pattern. Phillips[8] stated that the average linear coefficient of thermal expansion over such a temperature range was $350 \times 10^{-6}/K$ and therefore the average contraction in this range was 0.35 percent. Many other authors have quoted figures for wax shrinkage over this temperature range and these have varied from 0.3% to 2.3%.[8,9]

Distortion of wax patterns always accompanies stress relief, and this process is accelerated by increased temperature. It is an important factor which must be considered in any technique which involves delayed investment after removal from preparation/die, or, heating the wax pattern before investing or complete setting of investment.[7]

Factors which influence wax pattern distortion have been thoroughly investigated by a number of workers. Phillips and Biggs[7] found that most of the distortion occurred during the first two to three hours of storage off the preparation and in some patterns in the first 30 min. Distortion was more pronounced as the storage temperature was increased and also in patterns which had been formed from moulded wax at nonuniform temperatures and which had been subjected to patching and pooling during formation.[7]

The longer the wax pattern is allowed to remain off the preparation before being invested, the greater is the release of residual stress. Since higher temperatures raise the flow and lower the yield point of wax, the release of stress is accelerated by increases in either storage temperature or investing temperature. A low-storage temperature is hence recommended to minimize distortion. It is also recommended that ideally patterns should be invested immediately after removal from the preparation.[7]

The correct method to manipulate wax during indirect pattern making is controversial. It has been advocated[10] that molten wax be poured into the mould and allowed to solidify without pressure. Phillips and Biggs[8] have reported that poured wax patterns (molten wax) showed less distortion.
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Table 3: Multiple comparison (Bonferroni’s test)

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean difference (I-J)</th>
<th>Standard error</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlay wax</td>
<td>Ap resin</td>
<td>3.23</td>
<td>0.87</td>
</tr>
<tr>
<td>Lc resin</td>
<td>-7.24</td>
<td>0.87</td>
<td>0.0001</td>
</tr>
<tr>
<td>Autopolymerized pattern resin</td>
<td>Wax</td>
<td>-3.23</td>
<td>0.87</td>
</tr>
<tr>
<td>Lc resin</td>
<td>-4.01</td>
<td>0.87</td>
<td>0.0001</td>
</tr>
<tr>
<td>Light-cured pattern resin</td>
<td>Ap resin</td>
<td>-4.01</td>
<td>0.87</td>
</tr>
</tbody>
</table>

Complete polymerization is important for light activated pattern materials since the presence of unpolymerized or partially polymerized inclusions may allow plastic deformation of the pattern as it is handled, resulting in impaired fit of the subsequent casting.\(^6,\(^13\)

Rueggeberg et al.,\(^14\) found that important limiting factors in photopolymerization include the intensity of the incident light, the duration of exposure, material color, and the nature and volume of filler. The light-cured pattern resin used in this study was composed of a high molecular weight methacrylic ester with initiator and stabilizer complexes. It also contained organic fillers and pigments (blue).

In their study Whitworth et al.,\(^6\) found that the light cured resin pattern materials cure in a manner similar to composite resins. Their study showed that the cure depths of light cured resin pattern materials was in the range of 3.5–6.7 mm after visible light activation for 30 s. The light cured resin patterns in the present study were fabricated in an incremental manner (increments not more than 2 mm thick). Each increment was cured for 90 s in a light curing unit (Dentacolor, Heraeus Kulzer Gmbh, Germany).

An acceptable pattern can be fabricated by the controlled manipulation and understanding of the dimensional changes of wax and pattern resins. But, the distortion caused by prolonged storage before investing has shown to affect marginal integrity.\(^11,\(^12\)

As discussed earlier, it has been proven by earlier studies that inlay wax undergoes dimensional changes when stored off the preparation/die. Resin pattern materials, irrespective of their mode of activation show some degree of polymerization shrinkage which could lead to a compromise in the dimensional stability of patterns fabricated from these materials.

Studies conducted by Shillinburg et al.,\(^15\) Pagiano et al.,\(^16\) and Cahi et al.,\(^13\) have shown that autopolymerized resin pattern materials undergo a polymerization shrinkage of 1%–7% on storage for 24 h.

Whitworth et al.,\(^6\) found that polymerization shrinkage of light activated pattern materials was in the range of 0.45%–1.89%. These values were obtained after monitoring light-cured resin patterns for 1 h.

The present study evaluated the marginal fit of patterns fabricated from an inlay wax, an autopolymerized resin and a light-cured resin pattern material on storage off the die for varying time intervals. In order to simulate a situation warranting delayed investment after direct pattern fabrication, the patterns were stored off the metal dies at room temperature.

Measurements of the marginal gaps at 1, 12, and 24 h after pattern fabrication revealed that the marginal gaps of

than moulded patterns and that the higher the temperature at which the wax is manipulated, the fewer are the internal strains developed and the less is the resulting distortion upon storage. In the present study, the wax patterns were fabricated by pouring molten inlay casting wax into a warm die and waxing sleeve assembly.

Based on their studies on the distortion of wax patterns, Meiners and Kunzemann,\(^9\) and Jorgensen and Ono\(^4\) concluded that because of the inherent property of distortion, inlay wax was an inadequate material for pattern production in techniques requiring high precision. Hence in the present study, two resin pattern materials (one autopolymerized and the other light polymerized) were evaluated and compared inlay wax.

The autopolymerized resin pattern material (Pattern resin, GC Corp, Japan) is available as a powder + liquid system. The powder is composed of prepolymerized methyl-methacrylate polymer powder. While the liquid is composed of methyl-methacrylate monomer (80–90%), ethyl methacrylate (5%–10%), ethylene dimethacrylate (2%–5%).

Autopolymerized resin patterns can be fabricated either by the bulk technique i.e. mixing the monomer and polymer (in the recommended powder-liquid ratio) to form a workable dough which is then adapted to the die or by the incremental technique in which small additions of the mix are applied to the die, thus building up the pattern in increments.\(^5\)

Earlier studies have shown that the polymerization shrinkage of autopolymerized resin is much greater with the bulk technique. Hence, it was decided to fabricate the autopolymerized resin patterns for the present study using the incremental technique.\(^11,\(^12\)

Patterns were also fabricated using a light cured resin pattern material (Palavit GLC, Heraeus Kulzer Gmbh, Germany). This is a single component photocuring resin that is available in two different viscosities, i.e., the low viscosity K I and high viscosity K II pastes.

The light-cured materials rely on the entry of light of sufficient intensity to initiate polymerization. Light intensity is significant at the surface of a material specimen, but at deeper levels it is attenuated by absorption and scatter, which limits the depths of cure that can be achieved.
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Patterns fabricated from all three materials increased with time [Figure 1].

Inlay wax showed the highest marginal gaps at 12 and 24 h of storage.

The autopolymerized resin patterns demonstrated a marginal gap at 1 h which was found to be greater than that of inlay wax and the light-cured resin. This could be the result of polymerization shrinkage of the autocured resin. The maximum polymerization shrinkage is known to occur in the first 1–2 h after curing of an autopolymerized resin. On storage beyond this time, the polymerization shrinkage decreases as evident in the pattern showing little change over 24 h.

The light-cured resin was found to be significantly more accurate at all time intervals and the resin pattern showed minimal change in the marginal gap on storage for 24 h. Hence, it proved to be more dimensionally stable than the other two pattern materials.

CONCLUSION

Of the three pattern materials analyzed, the light-cured resin proved to be most dimensionally stable on storage, followed by the autopolymerized resin. Though the autopolymerized resin showed an initial (at one hour) gap slightly greater than the inlay wax, the difference was not statistically significant.

As evidenced in this study, these resin pattern materials undergo a significantly less dimensional change than the inlay waxes on prolonged storage. Hence, it is advisable to use them in preference to inlay wax in situations requiring high precision or when delayed investment (more than 1 h) of patterns can be expected.

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