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A Vitro Study of the Marginal Adaptation of Different Pattern Materials on Type IV Gypsum Dies

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Abstract

Introduction: The effectiveness of any cast restoration relies heavily on its proper fit over the underlying tooth structure, minimizing any discrepancies. Achieving accurate marginal fit of patterns before investing reduces the likelihood of marginal gaps in the casting. Various materials have been utilized for pattern fabrication, with inlay casting wax being the most common. Resin is also commonly used for its dimensional stability. In recent years, light-cured modeling paste has been introduced as an alternative to traditional waxes or acrylics due to its various advantages. However, various studies have indicated that different pattern materials may not consistently produce copings with satisfactory marginal accuracy on stone dies.

Objective: The study aims at evaluating and assessing the marginal adaptation of three different pattern with the objective of determining the pattern material with less discrepancy.

Methodology: A replica abutment resembling a prepared mandibular premolar was created. An impression of the prepared premolar was taken, and 30 type IV gypsum dies were produced. Patterns made of three different materials were fabricated after applying die spacer. The evaluation of marginal adaptation was conducted at 1, 6 and 24 hours using stereo microscope. All collected data was statistically analyzed using one-way ANOVA test.

Result: The findings indicated a significant statistical variance in the marginal adaptation among the three materials across all three-time intervals. Light-cured wax consistently demonstrated the highest accuracy, followed by thermoplastic resin and inlay casting wax.

Conclusion: The marginal adaptation of the three materials tested showed marginal gap within the range of 25–70 µm which is in clinically acceptable span.

Keywords: ANOVA Test, Scanning Electronic Microscopy, Digital Microscopes, Affordability, Accessibility,

Introduction

To ensure successful FDPs, precise adaptation is crucial for achieving proper mechanical retention, stability, durability and overall health of the adjacent tissues. Insufficient adaptation can lead to issues such as plaque accumulation, gingival inflammation, Microleakage of cement, tooth sensitivity, and cavities.

Pattern materials and casting materials are the main materials that affect the volume variations (expansion or contraction) and dimensional precision of investment castings. The pattern constitutes a key element of the investment casting process, as the ultimate quality of the cast product relies on its precision and quality. Several materials utilized in pattern making includes wood, plastic, wax, resin and green stick. Selecting the pattern material is a crucial aspect in investment casting, characterized by fundamental properties such as minimal ash content, excellent fluidity for precise replication of details, minimal contraction and expansion tendencies, compatibility with process materials, affordability, accessibility, ease of assembly and joining.

Resins are often utilized as casting pattern materials. Methacrylate resins that auto-polymerize have increased dimensional stability.

Type IV dental stone is widely used in the production of master casts and dies for FPDs. The choice for it is explained by its better mechanical qualities, which outperform those of other dental stones. These qualities include compressive strength, hardness and expansion characteristics.

The direct view technique gauges' space among the crown and die specifically at the margin, excluding internal measurements, by utilizing microscopes with varying magnifications. For assessing the marginal gap, Scanning Electronic Microscopy (SEM), digital microscopes, stereomicroscopes and travelling microscopes are employed. However, these methods yield restricted outcomes as they measure from distinct and distant points.

Marginal openings of 25–70 µm are generally considered clinically acceptable for complete coverage restorations on natural teeth. Nevertheless, in vitro studies have demonstrated that marginal openings of metal-ceramic crowns cemented on metal implant abutments are between 11 and 67.4 µm, while the marginal discrepancies of ceramic crowns cemented on implant abutments range from 65.9 to 168 µm.

Materials and Methods

Specimen Preparation: A zirconia abutment, simulating a prepared mandibular right first premolar, was milled. The abutment featured a height of 7 mm, and a consistent taper of 6°. A custom-made tray was fabricated and single step impression of the die was made. Dies were prepared and die hardener was applied. The die spacer was evenly coated on the axial surface within 0.5 mm above the margin. Each coat was allowed to dry before fabricating the wax pattern. Before making patterns, a thin layer of lubricant was applied to the gypsum dies, and the dies were allowed to dry.

All the samples were distributed randomly into three groups:

Table 1: Samples Group

Groups	Samples	No. of Samples
Group 1	Inlay wax	10
Group 2	Autopolymerising resin	10
Group 3	Light cure wax	10

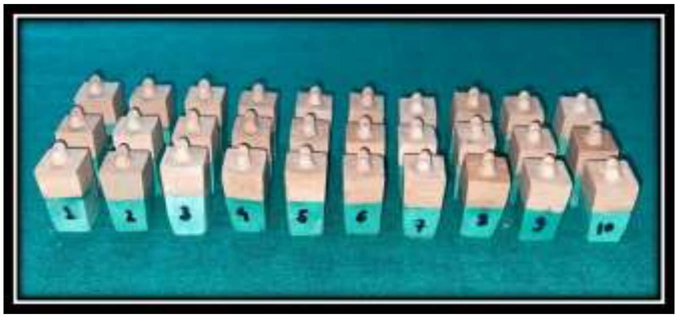

Figure 1: Die stone samples

Inlay Pattern Wax (Group 1)

Inlay wax medium was melted using a wax heater and sculpted with a wax carver over the die. The molten wax was allowed to cool to room temperature. Once the wax cooled down, the margins were redefined, and any excess wax was carved away. The margins were refined as needed.

Thermoplastic resin pattern material (Group 2) -

Autopolymerised pattern resin was dispensed into two separate plastic mixing cups (as instructed by the manufacturer). The patterns were fabricated through incremental buildup using the brush-on technique. Afterward, the patterns were separated from the die and examined for any defects. The patterns were meticulously trimmed to precise dimensions.

Light-cured pattern material (Group 3)

LiWa II light cure modeling paste was applied in layers and polymerized incrementally, ensuring that the length and width of the pattern were consistently maintained. Once solidified, the patterns were placed in a light-curing chamber for curing cycle (as instructed by manufacturer). They were then carefully removed with minimal distortion and were trimmed to precise dimension.

The patterns were measured with a wax gauge to maintain a standard thickness. The margins were examined under optical stereo zoom microscope (model – CD 500A) using Capture Pro 4.6 software at 10x magnification, and all measurements were conducted by the same operator to maintain consistency. The average marginal discrepancy in microns was calculated. The mean value of measurements on midpoint of buccal surface of finish line for each of these time intervals was utilized for statistical analysis.

Figure 2: Fabricated patterns

Results

Descriptive statistical data of marginal adaptation of three different wax pattern of inlay wax, autopolymerising resin and light cure wax on stone dies were measured at three intervals of 1 hour, 6 hours and 24 hours.

Table 2: Marginal adaptation values of three pattern materials on stone dies after 1 Hour (µm)

Sn.	Inlay wax	Autopolymerising resin	Light cure wax
Mean	47.70	35.67	28.88
S.D.	1.463	2.194	2.084
SEM	0.4629	0.06938	0.6586

Minimum	44.6	32.6	24.2
Maximum	49.5	39.4	30.9

Table 2 showed, the maximum value of marginal adaptation of inlay wax at 1 hour was 49.5 µm and minimum value was 44.6 µm, with a standard deviation of 1.463 µm and mean of 47.70 µm.

Table 3: Marginal adaptation values of pattern materials on stone dies after 6 Hour (µm)

Sn.	Inlay wax	Autopolymerising resin	Light cure wax
Mean	51.57	37.88	29.44
S.D.	1.928	2.442	0.7723
SEM	0.6099	0.7723	0.6406
Minimum	49.2	34.1	25.1
Maximum	54.9	41.6	31.1

Table 3 showed, the maximum value of marginal adaptation of inlay wax at 6 hours was 54.9 µm and minimum value was 49.2 µm, with a standard deviation of 1.928 µm and mean of 51.57 µm.

Table 4: Marginal adaptation values of pattern materials on stone dies after 24 Hour (µm)

Sn.	Inlay wax	Autopolymerising resin	Light cure wax
Mean	55.65	39.44	29.79
S.D.	1.899	2.295	1.820
SEM	0.601	0.7257	0.5757
Minimum	53.6	36.4	26.3
Maximum	58.6	43.3	31.5

Table 4 showed, the maximum value of marginal adaptation of inlay wax at 24 hours was 58.6 µm and minimum value was 53.6 µm, with a standard deviation of 1.899 µm and mean of 55.65 µm. The maximum value of marginal adaptation of autopolymerising resin at 24 hours was 43.3 µm and minimum value was 36.4 µm, with a standard deviation of 2.295 µm and mean of 39.44 µm.

Table 5: Analysis of variance (ANOVA) at 1 Hour (µm)

Group	N	Mean	Std. Deviation	One way ANOVA“F” test	P value
Group 1: Inlay wax	10	47.740	1.4638	242.392	<0.0001**
Group 2: Autopolyme-rising resin	10	35.670	2.1940		
Group 3: Lightcure wax	10	28.880	2.0826		

One-way ANOVA test, the F value was 242.392 which signifies that there is highly significant difference (p value <0.0001) among the mean of marginal adaptation of wax patterns.

Table 6: Analysis of variance (ANOVA) at 6 Hour (μm)

Group	N	Mean	Std. Deviation	One-way ANOVA "F" test	P value
Group 1: Inlay wax	10	51.570	1.9288		
Group 2: Autopolymerising resin	10	37.880	2.4421		
Group 3: Light cure wax	10	29.440	2.0255		

One-way ANOVA, the F value was 271.415 which signifies that there is highly significant difference (p value <0.0001) among the mean of marginal adaptation of wax patterns among the study groups.

Table 7: Analysis of variance (ANOVA) at 24 Hour (μm)

Group	N	Mean	Std. Deviation	One-way ANOVA "F" test	P value
Group 1: Inlay wax	10	55.650	1.8993	242.392	<0.0001
Group 2: Autopolymerising resin	10	39.440	2.2950		
Group 3: Lightcure wax	10	29.790	1.8205		

One-way ANOVA test, the F value 242.392 which was highly significant (p value <0.0001) among the mean of marginal adaptation of wax patterns among the study groups.

Discussion

The precision of a cast restoration's fit and details is heavily reliant on the accuracy of the fabricated pattern.[7] This investigation aimed to evaluate and contrast the marginal adaption of patterns made from three different materials: thermoplastic resin, light-cured modeling paste, and inlay casting wax, at three different time interval: 1, 6 & 24 hours.

The composition of inlay wax is composed of 60% mineral paraffin, 25% plant carnauba, 10% mineral ceresin, and 5% animal beeswax.[8] Autopolymerising resin composed of methyl-methacrylate polymer powder that makes up the powder, and ethyl methacrylate (5%–10%), ethylene dimethacrylate (2%–5%), and methylmethacrylate monomer (80–90%) makes up the liquid.[7] Light-activated pattern material description of direct pattern manufacturing was first published by Cohen et al. in 1991. In order to achieve a favourable colour contrast with die materials, UDMA resins were developed, impregnated with blue dyes. The structural integrity of the material is enhanced by the addition of natural, non-glassy additives that burn out of the investment mould without leaving behind residue.

For assessing the marginal gap, Scanning Electronic While the comparison was made between inlay wax and autopolymersing resin & light cure wax and inlay wax it was observed that inlay wax had a highly significant difference with light cure wax as compared to autopoymerising resin at 1 hour. There could be a number of causes for the variations in the marginal adaption of inlay wax pattern. The two main flaws with waxes are their high coefficient of heat expansion and their propensity to twist or deform when left to stand.[7] The high coefficient of thermal expansion of inlay wax was one of their most noticeable thermal properties. Phillips and Biggs have demonstrated that distortion becomes noticeable within just 30 minutes after the wax pattern was prepared. Therefore, it was recommended to store the wax patterns at low temperatures to decrease the extent of distortion, or alternatively, invest the patterns promptly to minimize distortion.[11]

The high coefficient of thermal expansion of inlay wax was one of their most noticeable thermal properties. Wax may expand by up to 0.7% when the temperature rises by 20˚C (36˚F), while it may shrink by up to 0.35% when the temperature drops from 37˚ to 25˚C (99˚ to 77˚F). Within this temperature spectrum, the linear coefficient of thermal expansion is around 350 × 10−6/˚C on average.[12]

Autopolymerizing resins provide strength, rigidity, and dimensional stability. Nevertheless, this material's propensity for polymerization shrinkage is a disadvantage.[13] In a study conducted by Shillingberg, it was revealed that autopolymerizing resin pattern material experiences a polymerization shrinkage ranging from 1% to 7% when stored for 24 hours.[11] hence the marginal discrepancy of resin was noted. Autopolymerizing pattern resin showed a considerably reduced marginal discrepancy than wax and VLC triad resin, according to a study by Komajian and Holmes[14].

Light penetration of a high enough intensity to start polymerization is necessary for the formation of light-cured materials. The light's intensity is important at the material specimen's surface, but beyond that, it is attenuated by absorption and scattering, which limits the depths of cure that may be reached. For light-activated pattern materials, thorough polymerization is essential because the presence of unpolymerized or partially polymerized inclusions may cause plastic distortion of the pattern during handling, compromising the fit of the ensuing casting.[7]

The crown pattern fabrication materials available do not meet all the requirements, as each has its own advantages and disadvantages; however, they remain popular choices. Both the approach and the operator's skill level have a major impact on the application's success. After carefully examining all of the study's components and comparing the findings to previous research, it is possible to draw the conclusion that light-curing.

The limitations of this study is that the findings in this study are applicable solely to the specific pattern materials and its individual techniques employed to fabricate the patterns. Only the marginal discrepancy of patterns on the dies was considered at one point, and the marginal discrepancy of the final castings was not taken into account in the current study. The future studies should be conducted with increased sample size and should be assessed at various points.

Conclusion

Within the limitation of this study, following conclusions were made:

1. All the pattern materials exhibited marginal discrepancies at 1 hour, 6 hours, and 24 hours.
2. Patterns created with light-cured modelling material had the least mean marginal adaption discrepancy.
3. For patterns created using inlay wax, the mean marginal adaption discrepancy was the highest.
4. Statistically significant difference was found in determining the marginal adaptation amongs all determined groups that is: Group 3 > Group 2 > Group 1

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