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To Evaluate And Compare The Marginal Fit And Internal Adaptation Of Cast Copings Fabricated With Pattern Wax And Autopolymerized Pattern Resin Materials Invested At Different Intervals Of Time- An In-Vitro Study

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Abstract
Introduction:
Precise marginal seating and internal fit of cast restorations are essential factors to fulfill the biological, physical and esthetic requirements of the restoration, taking this into consideration, the present study aimed to evaluate and compare the marginal fit and internal adaptation of cast copings fabricated with pattern wax and autopolymerized pattern resin materials invested at different intervals of time.
Materials And Methods: *A master metal Die was designed using CAD software and milled using Ni-Cr alloy. 3D printer was used to design a customized special tray for making impressions of master die. A total of 52 working dies were duplicated from the master metal die. The study included four groups; Group 1 included 13 samples fabricated using inlay wax by immediate investment. Group 2 included 13 copings fabricated using inlay wax by delayed investment (1 hr). Group 3 included 13 copings fabricated using pattern resins by immediate investment, and Group 4 includes pattern resins by delayed investment. The silicone replica technique has been used to measure marginal and internal fit in which a combination of light and heavy body silicone replica was used. These sections were visualized under a stereomicroscope.*
Results: *The marginal and internal fit of all groups was within the clinically < acceptable range (120μm). Cast copings obtained from immediately invested inlay wax patterns showed better marginal fit and internal adaptation among all the groups tested in this study. (Marginal gap - 35.84, axial wall -16.6 and occlusal -73.21).*
Conclusion:
Inlay wax when invested immediately showed less distortion with a clinically acceptable marginal and internal fit.
Keywords: *Marginal fit, Internal fit, Pattern resins, Inlay wax, Investment.*

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I. Introduction:

A fixed partial denture has always been considered as the golden standard for the replacement of missing teeth as it will improve the patient's comfort, masticatory ability, and patient's self-image. Precise marginal seating and internal fit of cast restorations are essential factors to fulfill biological, physical and aesthetic requirements of restorations.1 Accuracy in a fit of cast metal restoration has always remained as an essential factor in determining the success of the restoration.2 A well-fitting restoration needs to be accurate both along its internal surface and to its margins. The fit and detail of the cast restoration will depend to a great extent on the accuracy and fine detail of the pattern.3 Many factors affect the fit of dental castings, e.g., tooth preparation, impression materials, pattern material, die stone, investment, casting procedure, luting cement etc.4 Studies1,5 shows that soft tissue adjacent to the margin of the crown contains chronic inflammatory infiltrate. This infiltrates due to the accumulation of bacterial plaque at the microscopic opening of margins of the restoration. Poor internal adaptation of a coping can increase the thickness of the cement and thus influence the mechanical stability of dental restorations. This gap can be viewed as a physical roughness and may eventually lead to periodontal inflammation, caries, and loss of the restoration. Thus, minimizing the crown marginal and internal gap is an essential goal in prosthodontics.

Metal ceramics are still the most widely used materials for fabricating complete coverage crowns and partial fixed partial dentures.6Historically, the alloys of choice for metal-ceramic restorations have been based on gold. With the introduction of titanium, much importance was given to this material because of its biocompatibility, mechanical strength, satisfactory resistance, and cost similar to traditional gold alloys. However, later stages, use of economic alternatives such as base metal alloys were given much more emphasis due to economic constraints. The most commonly used base metals alloys are Nickle chromium (Ni-Cr) alloys and Cobalt-Chromium alloys (Cr-Co). Earlier, Nickel chromium alloys have been the most popular base metal alloys for metal-ceramic restorations, but concerns about the toxicity of nickel and beryllium limited the usage of this material and importance was given to cobalt-chromium (Co-Cr) alloys. The current trend is to replace nickel- chromium alloys with Co-Cr alloys, which are more biocompatible.5These alloys are corrosion resistant and stable in biologic environments.

Clearance is required between a fixed restoration and the prepared tooth to provide a space for the luting agent. Methods such as the provision of axial cement space, venting, and axial grooves have been used to reduce the hydraulic pressure between the cast restoration and cement and therefore improve seating, allow the escape of excess cement and decrease seating time.7 When compared to other methods, it is safer to use a die spacer because they provide internal relief close to the ideal. Also, its application technique does not cause any harm to the metal surface, as it is applied before casting. Besides, it promotes an internal relief for the luting agent, thus preventing the cement layer from interfering on the crown's complete seating and helps to compensate for the alloy's casting shrinkage by adding to the thermal expansion of the refractory material. 8The internal relief promoted by die spacers has been shown to reduce the intrapulpal tensions and the force required at the time of crown cementation. Thus ensuring a better marginal fit and enhancing restoration's retention; thus, paint-on die spacer before waxing has been used in fixed partial dentures for many years.

Evaluation of the marginal adaptation can be done either quantitatively or qualitatively. Qualitative assessment is done by sense of touch and direct visualization, i.e., by use of an explorer, by using impression materials, or through radiological assessment. For the quantitative evaluation, employing a high magnification microscope would be the best choice to measure the gap space, which includes the use of Scanning electron microscopy (SEM),optical stereomicroscopy.8Impression techniques with impression material of low viscosity (replica technique) are popular methods for evaluating marginal discrepancies between the crown and the tooth. Compared to SEM, the replica technique's advantage reflects the fact that there is a small probability of damaging the sample and abutment in the process, which makes it a non-destructive methodology.9 Moreover, the majority of authors agree that, compared to other techniques, the replica technique offers more possibility for veritable and accurate results.

The ability to fabricate precisely fitting casting is the principle objective. Though there are many recent advances in investing materials, alloy composition, and casting techniques to improve the internal adaptation and marginal seating of cast restoration, the casting procedure is very technique sensitive, and discrepancies are very much common.1 The fabrication of the wax pattern is the most critical and labor-intensive step in conventional casting procedures. In this time-consuming task, the wax–up's quality is dependent on the skilled labor of the individual.

Wax has several inherent limitations, namely, delicacy, thermal sensitivity, elastic memory, and a high coefficient of thermal expansion and also affected by the storage time, making the procedure technique sensitive.10 Whereas resin patterns have less effect on storage time, rigid and can maintain the equal thickness of coping and easy to handle.

Keeping this in my mind, the present study was conducted to evaluate and compare the marginal fit and internal adaptation of copings fabricated by making patterns with inlay wax and pattern resin by conventional method and invested at different intervals of time.

The present study was mainly aimed at evaluating the comparing the marginal fit and internal adaptation of cast copings fabricated with pattern wax and autopolymerized pattern resin materials invested at different intervals of time.

The prime objectives of the present study were:
1. To evaluate the marginal fit and internal adaptation of cast copings produced by inlay wax pattern invested immediately and 1hour after fabrication.
2. To evaluate the marginal fit and internal adaptation of cast copings produced by autopolymerized pattern resin invested immediately and 1 hour after fabrication.
3. To compare the marginal fit and internal adaptation of cast copings produced by inlay wax pattern invested immediately and 1 hour after fabrication.
4. To compare the marginal fit and internal adaptation of cast copings produced by autopolymerized pattern resin invested immediately and 1 hour after fabrication.

II. Materials and Methods:

The present study was approved by institutional Review board of university affiliated college. Details of the methodology:

Metal master die fabrication

The first molar of the mandible was selected as the master die for the experiment. Molar tooth was prepared with a 1.0mm circumferential chamfer finish line, an occlusal height reduction of 1.5mm and 6 degree axial inclination was virtually designed and milled using Co-Cr alloy to simulate prepared natural tooth.

Impression making

A custom tray was fabricated using 3D Printing and designing. Double mix elastomeric impression technique was used for making impressions which were then poured in die stone. The procedure was repeated 52 times to obtain fifty two stone dies of same dimensions.

Study Groups

Fifty two stone dies/ working models were used for the fabrication of metal copings. Group A includes 13 copings fabricated using inlay wax by investing immediately. Group B includes 13 copings fabricated using inlay wax by delayed investment. Group C includes 13 copings fabricated using pattern resin by immediate investment. Group D includes 13 copings fabricated using pattern resin by delayed investment

Group –A&B

Conventional copings were prepared by lost-wax technique in a centrifugal induction casting machine (Bego, Bremen, Fornex T). Die spacer (DAV) of 24 microns thickness was applied to the 15 working dies. Die spacer was applied for a total of two coatings with uniform brush strokes in one direction, followed by which second coating was applied after 2 minutes in order to achieve uniform thickness of 24 micron thickness. For adequate marginal adaptation, a band of about 1 mm immediately adjacent to the preparation margin must be left unpainted.

Inlay casting wax was used to fabricate wax patterns on the dies. A uniform thickness of 0.5 mm was maintained throughout and measured with the help of wax gauge. Prefabricated wax sprues (MDM corporation)of thickness 2.5mm and 3.5mm were attached on top of each pattern at 45 degrees to the line angle where occlusal and the axial surface meets since this was the thickest portion of the pattern.These wax patterns were invested immediately for group A and invested after 30 min for group B after completion of pattern fabrication. A 6mm distance was provided from the top of the casting ring to the pattern. Surfactant (Debubbilizer, prime dental products. Pvt.ltd) was applied on the wax patterns before investing to decrease the water repellent effect of wax and decrease the surface tension and to ensure complete coverage of the intricate portion of the patterns with the investment material. This allowed smoother castings with reduced casting nodules and better fit of the casting on the die, it was then allowed to dry for 3 minutes. Casting ring was lined with 1mm of non- overlapping layer of moistened cellulose ring liner (Bego). The liner was placed in the ring and secured with sticky wax. This liner ring was then soaked in water for a minimum of one minute. It was then shaken off excess water. The wax patterns were invested using wirovest investment material which was vacuum mixed (Bego) with a recommended powder,liquid ratio (160gm of investment material to 24 ml of liquid). Wax patterns were carefully painted with the investment mixture. The casting ring lined with cellulose acetate liner was then filled with investment material under mechanical vibration and allowed to set for 1hour. Then wax burn-out procedure was carried out using Technico Muffle furnace till the temperature is about 760°C-800°C for

45 minutes. Followed by which casting procedure was done using Bego induction casting machine (Fornax, Germany), then Castings were divested, cleaned and air abraded with 110/150 micron alumina particles in a sandblasting unit (MINI SAB) at

0.4 mPa pressure. Sprues were removed using silicon carbide disks and copings were finished using rubber wheels.

Group –C & D

Conventional copings were prepared by brush bead technique in a centrifugal induction casting machine (Bego, Bremen, Fornex T). Die spacer (DAV) of 24 microns thickness was applied to the 15 working dies. Die spacer was applied for a total of two coatings with uniform brush strokes in one direction, followed by which second coating was applied after 2 minutes in order to achieve uniform thickness of 24 micron thickness. For adequate marginal adaptation, a band of about 1 mmimmediately adjacent to the preparation margin must be left unpainted. GC resin patters material was used to fabricate resin patterns on the dies. A uniform thickness of 0.5 mm was maintained throughout and measured with the help of wax gauge. Prefabricated wax sprues (MDM corporation)of thickness 2.5mm and 3.5mm will be attached on top of each pattern at 45 degrees to the line angle where occlusal and the axial surface meets since this was the thickest portion of the pattern.These patterns were invested immediately for group C and invested after 30 min for group D after completion of pattern fabrication. A 6mm distance was provided from the top of the casting ring to the pattern. Surfactant (Debubbilizer, prime dental products. Pvt.ltd) was applied on the resin patterns before investing to decrease the water repellent effect and decrease the surface tension and to ensure complete coverage of the intricate portion of the patterns with the investment material. This allowed smoother castings with reduced casting nodules and better fit of the casting on the die, it was then allowed to dry for 3 minutes. Casting ring was lined with 1mm of non-overlapping layer of moistened cellulose ring liner (Bego). The liner was placed in the ring and secured with sticky wax. This liner ring was then soaked in water for a minimum of one minute. It was then shaken off excess water.

These resin patterns were invested using Wirovest investment material which was vacuum mixed (Bego) with a recommended powder, liquid ratio (160gm of investment material to 24 ml of liquid). Resin patterns were carefully painted with the investment mixture. The casting ring lined with cellulose acetate liner was then filled with investment material under mechanical vibration and allowed to set for 1hour. Then burn-out procedure was carried out using Technico Muffle furnace till the temperature is about 760°C-800°C for 45 minutes. Followed by which casting procedure was done using Bego induction casting machine (Fornax, Germany), then Castings were divested, cleaned and air abraded with 110/150 micron alumina particles in a sandblasting unit (MINI SAB) at 0.4 mPa pressure. Sprues were removed using silicon carbide disks and copings were finished using rubber wheels.

Marginal and internal fit evaluation

This experiment used a non-destructive silicone replica technique to measure the marginal and internal gaps in the Co-Cr copings. For all 45 metal copings in three different groups, a quarter of the interior was filled with light body silicone and the coping was immediately place on the master metal die. Uniform pressure of 50 N was placed and maintained for5 minutes until the soft silicone hardened. The metal copings were then removed from the master die with light body silicone film firmly attached to them. The assembly (coping and silicone film) was then reinforced and stabilized by filling its inner side with heavy body silicone impression material. This resulted in a combination of light and heavy body silicone replica ready to section for measurement of the thickness of the light body silicone impression material that will determine marginal and internal gap. Using a blade, the silicone replica was divided into 2 sections along the buccal/lingual direction to examine at 5 circumferential sites on the sliced specimen to evaluate marginal gap, adaptation to axial wall and occlusal surface.

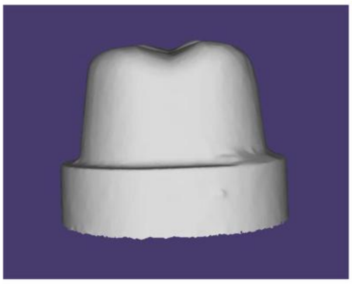

Figure 1: Designing Master metal die Using EXO CAD Software

Figure 2: CoLiDo 2.0 plus 3D printer used for fabricating of special tray to duplicate master die

Figure 3: 52 Stone die/Working model

Figure 4: Metal Copings fabricated using inlay wax and auto polymerized pattern resins

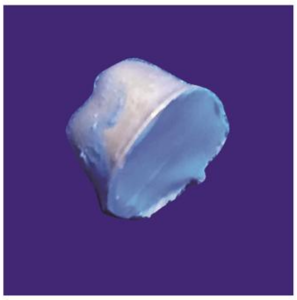

Figure 5: Coping stabilized with heavy body impression material

Figure 6: Light body re-inforced with heavy body material

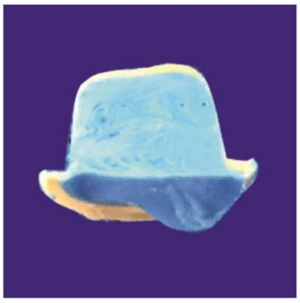

Figure 7: Sectioned sample to be viewed under stereomicroscope

Figure 8: Specimen visualized under Stereomicroscope ×100

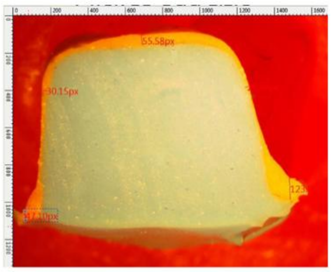

Figure 9: Measurements done using Micaps Software

Figure: Depicting the Entire Protocol Followed

Statistical Analysis:

The collected data was obtained in mean values, which was analyzed and compared with 1- way analysis of variance (ANOVA) and the data will be reported using SPSS software.

III. Results:

Table 1: Descriptive Statistics

Group	n	Occlusal (Mean±SD)	Margin (Mean±SD)	Axial (Mean±SD)
Inlay wax immediate investment (Group 1)	13	73.21±22.02	35.84±16.52	16.6±7.55
Inlay wax delayed investment (Group 2)	13	91.76±28.3	58.07±26.33	33.92±10.71
Resin immediate investment (Group 3)	13	76.4±25.46	39.07±30.72	20.35±21.2
Resin delayed investment (Group 4)	13	79.2±35.81	40.03±40.38	21.03±17.18

Table 2: Region wise comparison of distance between alloy and stone in the four study groups

Region	Grou p	Mean±SD	Betwee n group sum of squares	Within group sum of squares	d f	Mean square	F valu e	P value
Occlus al	Grou p 1	73.21±22.0 2	13265.8 9	65352.9	3	4821.9 6	3.54	0.02*
	Grou p 2	91.76±28.3						
	Grou p 3	76.4±25.46						
	Grou p 4	79.2±35.81						
Margin	Grou p 1	35.84±16.5 2	9051.54	31632.9 4	3	3140.1 8	3.21	0.021 *
	Grou p 2	58.07±26.3 3						
	Grou p 3	39.07±30.7 2						
	Grou p 4	40.03±40.3 8						
Axial	Grou p 1	16.6±7.55	789.3	4764.88	3	291.76	2.84	0.048 *
	Grou p 2	33.92±10.7 1						
	Grou p 3	20.35±21.2						
	Grou p 4	21.03±17.1 8						

Table 3: Multiple pairwise comparison of the distance between alloy and stone at the occlusal region

Reference group	Comparison group	Mean difference	P value	95% Confidence interval
Group 1	Group 2	-18.55	0.043*	-46.94 – -2.31
Group 1	Group 3	-3.19	0.73	-10.24 – 5.69
Group 1	Group 4	-5.99	0.41	-27.3 – 18.62
Group 2	Group 3	15.36	0.062	-0.69 – 36.34
Group 2	Group 4	12.56	0.08	-2.95 – 28.1
Group 3	Group 4	-2.8	0.89	-26.78 – 21.33

Table 4: Multiple pairwise comparison of the distance between alloy and stone at Marginregion

Reference group	Comparison group	Mean difference	P value	95% Confidence interval
Group 1	Group 2	-22.23	0.026*	-65.29 – -3.16
Group 1	Group 3	-3.23	0.78	-28.3 – 20.83
Group 1	Group 4	-4.16	0.54	-11.25 – 7.88
Group 2	Group 3	19	0.04*	4.06 – 37.06
Group 2	Group 4	18.04	0.052	-0.32 – 33.16
Group 3	Group 4	-0.96	0.994	-24.02 – 27.41

Table 5: Multiple pairwise comparison of the distance between alloy and stone at Axial region

Reference group	Comparison group	Mean difference	P value	95% Confidence interval
Group 1	Group 2	-17.32	0.043*	-32.68 – -2.77
Group 1	Group 3	-3.75	0.61	-28.89 – 24.02
Group 1	Group 4	-4.43	0.57	-42.1 – 36.08
Group 2	Group 3	7.57	0.38	-4.66 – 19.25
Group 2	Group 4	6.89	0.49	-13.87 – 27.03
Group 3	Group 4	-0.68	0.996	-24.67 – 26.28

IV. Discussion:

A cast metal restoration with accurate and precise fit is considered to be the primary requisite in determining the success of the restoration. Restoration needs to be accurate along its margins and internal surface.2 The marginal gap is defined as the quantitative space or discrepancy between the crown and the prepared tooth surface.9 The fit and detail of the cast restoration will depend to a great extent on the accuracy and fine detail of the pattern.3

Many factors affect the fit of dental castings, e.g., tooth preparation, impression materials, pattern material, die stone, investment, casting procedure, luting cement etc.4

The internal adaptation should be uniform to avoid compromising either the retention or the resistance of the crown and should also provide an appropriate luting space.9 If too much space is lost as a result of large occlusal discrepancies, the intercuspal clearance available for veneering is reduced and also leads to open margins. Open marginal configurations encourage microleakage of bacteria and their by-products due to the dissolution of the luting agents. This can cause severe effects on the health of pulpal tissues. The relationship between margin adaptation andperiodontal health has been confirmed in experimental animals and humans.

A casting cannot be more accurate than the wax pattern from which it is made thus a flawless wax pattern should be accurately formed to have a precise casting.31

It is difficult to use a single correct technique since many variables and environmental conditions are involved during the conventional lost wax procedure.

A study conducted by Holmes32 gave in detail description of the fit of the restoration. He stated that the internal gap as the perpendicular distance from the axial wall of the preparation to the internal surface of the casting and the same measurement when measured along the margins is termed as the marginal gap. The vertical marginal misfit measured parallel to the path of the draw of casting is called the vertical marginal discrepancy. The horizontal marginal misfit measured perpendicular to the path of the draw of casting is called horizontal marginal discrepancy. An overextended margin is defined as the perpendicular distance from the marginal gap to the cavosurface angle of the tooth. The absolute marginal discrepancy isdefined as the angular combination of the marginal gap and the extended error.

For the feasibility of studies, these terminologies were given less preference, and simple variables like marginal and internal gap were selected and evaluated.9

The most commonly used base metals alloys are Nickle chromium (Ni-Cr) alloys and Cobalt-Chromium alloys (Cr-Co). Earlier, Nickel chromium alloys have been the most popular base metal alloys for metal-ceramic restorations. Still, concerns about the toxicity of nickel and beryllium limited the usage of this material, and importance was given to cobalt-chromium (Co-Cr) alloys. The current trend is to replace nickel-chromium alloys with Co-Cr alloys, which are more biocompatible.5 The present study uses Co- Cr alloy.

Holmes et.al33 stated that the clinical acceptance of fixed partial dentures and cast metal restorations were not extensively studied during the early 1990s. Still, later on, several studies were conducted to determine the clinical acceptance range for marginal and internal discrepancies.Fusayama et al. investigated seating discrepancies and found cement lines with shoulder preparations of 44 to 48 µm. Wanserski et al.reported a maximum mean fabrication discrepancy for metal or porcelain shoulder margins of 37 µm, which agrees closely with the findings of others.

A clinical study was conducted by McLean and Vonfraunhofer 34 on 1000 restorations for a period of five years and derived at a conclusion that 120µm was considered as the maximum acceptable, marginal opening. Beyond this value, the fit of the crown was considered unacceptable. Theoretically, limits of marginal fit should have a zero discrepancy at the cavosurface margin between the prepared tooth surface and the intaglio surface of the metal restoration. But considering practical aspects, obtaining a perfect result closer to zero discrepancies is questionable.

Bryne G stated that 39 µm as the maximum acceptable, marginal discrepancy along the accessible surfaces of the casting and the value at gingival margins could be greater because of difficulty to access these regions.35

American Dental Association (ADA) suggested that marginal discrepancy ranging from 25-40µm is the clinically acceptable range for fixd restorations.36 The present study was conducted using the reference range proposed by McLean and Von Fraunhofer, which is 120µm.

However, when describing a reference range for the internal gap, there were several misconceptions in defining the exact range. No clinical studies reported the range except a study conducted by Quante et al. and Ucer et al. wherein the acceptable range of internal discrepancy can lie within 60- 250µm.37 Below these values, the internal fit was considered highly acceptable. The present study used this range (60-250 µm) as a reference in determining the internal fit.

Christensen reported that marginal discrepancies of 39µm or more, in visually accessible surfaces, are unacceptable.38

Obtaining precise marginal and internal fit is directly related to the fabrication technique employed. Despite several advances in investing materials, alloy composition, casting machines, and procedures, casting procedure as a whole is always considered to be technique sensitive, and discrepancies occur.1,In this study 2 different pattern materials are used for comparison for marginal fit and internal adaptation they were inlay wax and auto polymerized pattern resins.

These samples were further compared by different time intervals of investment, i.e., immediate investment and invested after 1hr (delayed investment).

Wax products used in dentistry are classified as pattern, processing, and impression waxes. Pattern waxes include inlay wax, casting wax for RPD framework patterns, and baseplate wax.39 Inlay waxes are of two types- type I and type II. Type I inlay waxes are used for direct wax pattern fabrication inside the oral cavity, and Type II inlay waxes are used for indirect pattern fabrication in the laboratory.

A regular or soft type of wax is typically used for indirect work at room temperature or in cold weather. A harder or medium type with a low flow property is indicated for use in warmer climates. The higher flow of softer waxes produce larger restoration than harder waxes because the softer waxes expand more as the investment heats up during setting and they offer less resistance to the expanding investment during setting.3Distortion of a wax pattern results from physical deformation (during molding, carving, or removal) release of stress "trapped" during previous cooling, occluded air in the pattern, excessive storage time, and extreme temperature changes during storage. After cooling it contracts and after attaining equilibrium, it reaches a state of dimensional stability. To avoid distortion, the wax pattern is to remain seated on the die for several hours to prevent distortion and ensure that equilibrium conditions are established.40,41

As the investment hardens, some distortion of the wax pattern occurs around it. The hygroscopic expansions setting reaction of the investment may produce a nonuniform expansion of the walls of the pattern. This type of distortion occurs in part from the nonuniform outward movement of the proximal walls. The gingival margins are forced apart by the mold expansion, whereas the solid occlusal bar of wax resists expansion during the early stages of setting.40,41

The configuration of the pattern, the type of wax, and the thickness influence the distortion that occurs. As the investment sets and setting expansion occurs, it eventually gains sufficient strength to produce a dimensional change in the mold cavity and wax pattern. If the pattern has thin wall, the effective setting expansion is somewhat greater than that of a pattern with thicker walls because the investment can move the thinner wall more readily. Also, softer the wax, the greater is the effective setting expansion, because the softer wax is more readily moved by the expanding investment. If a wax softer than a type II inlay wax is used, the setting expansion may cause excessive distortion of the pattern.40,41

Problems associated with conventional casting procedure arise due to distortion of wax patterns, setting expansion of investment, casting shrinkage of alloys, insufficient metal flow, and die spacer application.2 Wax alone has several disadvantages because of its properties such as elastic memory and high coefficient of thermal expansion. Moreover attaining a precise fit of cast metal restorations is directly related to the experience and skill of a technician.10

Few studies 1,23,28,42,43,44,45 were conducted comparing all three groups, and the obtained results were conflicting with a lot of variations. Most of these earlier studies differed in several aspects, such as the type of alloy used, sample size, measurement technique employed, coping or fixed partial denture fabrication, die spacer thickness used, clinically acceptable range values. Considering all these aspects, the present study was conducted tocompare all four groups with the efficient material, reliable measurement technique, most clinically acceptable range in determining marginal and internal fit, and uniform die spacer thickness, proper designing of coping.

Effect of storage time:11

As the storage time was increased, the distortion became progressively worse. Although most of the distortion occurred during the first six hours, continued changes were noted up to 24 hours. The results of the study suggested that the higher the temperature at which the wax was manipulated, the fewer were the internal strains, and the less was the resulting distortion upon storage. Since the flow of wax decreases and the yield point increases as the temperature are lowered, it is possible that the patterns might be stored more safely at low temperatures, and the strain would be more slowly released.

Most of the distortion occurs during the first 2 or 3 hours of storage off the preparation and is often evident in some types of preparations within 30 minutes. It was also found that the higher the temperature of the wax during manipulation, the less the distortion and internal strain upon storage, to prevent distortion of wax patterns the pattern must be invested immediately as soon as after removal from the die.11Under varying thermal conditions, wax patterns were not constant in their dimensions and were observed that the wax molded into the cavity exhibit some amount shrinkage during solidification.46

Distortion of the wax pattern is accelerated by increasing the temperature and is always accompanies with stress relief. It can also due to molded wax at nonuniform temperatures and which has been subjected to pooling during formation and patching.47

The longer the wax off from die, the more is the release of internal stresses.since higher temperature increase the flow and decreases the yield point of the wax, the investing temperature or storage temperature can increase the release of stresses. So it is better to store the patterns at low temperatures to minimize the distortion.17

Ideally, the pattern should invest immediately as soon as after removal from the preparation.47

Shaikh et al. concluded that inlay wax can still be the pattern material of choice to produce a casting with minimal marginal and internal discrepancy which is user-friendly and cost-effective.4

If the wax is correctly manipulated, the resulting pattern shows less distortion. They concluded that the wax patterns had been unreasonably accused of being a vital cause of dimensional changes and that Inlay waxes were comparatively stable materials if invested immediately and was not mistreated during pattern fabrication .46,48 This could be due to the elastic memory of the Inlay wax which shows a tendency to return to its original form after being worked or changed in shape as shown by Smyd.46

Auto polymerized patter 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.48

Auto polymerized resin pattern materials used alone or in combination with wax to simplify complex wax-up procedures .17

Generally, two methods for Autopolymerized resins are used, namely, the conventional mixing technique (standard liquid: powder ratio) and the brush on technique. Shirato reported the L/P ratio of both methods for autopolymerized resins (brush-on technique: 0.31- 0.38 L/P, mixing technique: 0.5 L/P). The brush –on technique was developed by Nealon. A bead of slurry resin attached to the end of the brush is placed in

incremental manner on the die to reduce polymerization shrinkage. The procedure is repeated at 10 -15-second intervals. The brush –on technique indicated significantly more dimensional accuracy than the conventional mixing technique as it compensated for the shrinkage and had a lesser powder to liquid ratio.35

Since the auto polymerizing resin with a brush on technique had better results, it was decided to use the GC Autopolymerising resin in this study.

A more recent study using a strain gauge technique found that GC Pattern Resin produced less microstrain. Cerqueira stated that GC reports polymerization shrinkage of 0.36% after 30 minutes and 0.37% after 24 hours but does not specify the method used to determine the shrinkage. In their study shrinkage was determined immediately after setting, which was 20 minutes for the auto polymerizing material .19

Phillips and biggs stated that most of the distortion will occur during first 2-3 hrs storages off the preparation and in some patterns it is 30 min.11

Autopolymerization reduces the amount of time available for manipulation, but the rigidity and hardness of the polymerized resin allow for shaping to

Beperformed with abrasive instruments, but the main disadvantage of acrylic resin is its high polymerization shrinkage .12

Resins are alternative materials that are used as pattern materials for casting. Auto polymerizing methyl methacrylate resins have offered enhanced dimensional stability even if investing immediately was not possible. They allow easy manipulation with rotary instruments without fear of distorting the pattern.49The disadvantage of pattern resin is its polymerization shrinkage which is much more than inlay pattern wax and eventually leads to discrepancies in the castings Phillips and biggs11 and have shown that this distortion is evident just 30 minutes after the preparation of wax pattern, and hence should be stored at low temperatures to reduce the degree of distortion or the patterns should be invested immediately to minimize the distortion.17

A study conducted by shillingberg showed that autopolymerizing resin pattern material undergoes a polymerization shrinkage of 1-7 % on storage for 24 hrs.50

Inlay wax shows the highest marginal discrepancy at 12 hrs & 24 hrs, and auto polymerized resin pattern shows a marginal gap at a storage time of 1 hr, which is more when compared to inlay wax. For auto polymerized resins

the maximum shrinkage is known to occur in 1-2 hrs after curing, and on storage beyond this time, an evident decrease in shrinkage of pattern material and shows a little change over 24 hrs.17

Earlier studies show that shrinkage of autopolymerized resins are more when they are fabricated with bulk technique.so, in the present study incremental technique was used to fabricate patterns as this technique shows less shrinkage.17

It is also possible that a thermal contraction differential between a coping and the casting investment during solidification and subsequent cooling of an alloy casting with poor resistance to plastic flow at intermediate temperatures can cause coping distortion. It is not known whether the grinding of copings causes an increase in the marginal discrepancy because of generalized distortion or marginal distortion of the copings. An increase in marginal gap width or height could result from an inward radial displacement of the axial wall, which will produce a tighter fit and incomplete seating. An outward and upward displacement of the marginal area alone can cause a similar change in the gap width or height. In any event, incomplete seating of the crowns occurs due to an inward radial displacement of the internal surface of the casting. Whether thisdiscrepancy is of sufficient magnitude to affect the ultimate clinical success of metal-ceramic crowns is subject to speculation.tis can be reduced by applying die spacer.51

In the past, many researchers believed that better adaptation was attained with a frictional fit between the coping and the tooth surface. Emphasis was not given on providing a sufficient amount of space for the luting agent. Later on, as the research progressed, many researchers believed that a perfect fit could not be obtained if there is a lack of space for the luting agent, which will be provided by applying die spacer. One of the major advantages of using the die spacer is it reduces the stresses generated during cementation and therefore enhances the fit of the restoration.

One of the studies by Carrieria N et al. stated that the lowest marginal discrepancy was seen when two layers of die spacer were used when compared to a single layer of spacer application and when the spacer was not applied. 52

In a study conducted by Oliveria A 14 stated that best marginal and internal adaptation to cast metal crowns was attained when the die spacer covered the entire preparation except 0.5mm short of the finish line Hollenback7 stated that an ideal spacer thickness of 25µm, which simulates the film

thickness of type I Zinc phosphate cement, was considered to be standardized value to accommodate the adequate amount of cement. The present study used a die spacer thickness of 25 µm. Die spacer thickness was normalized in all four groups so that there will not be any disparity in the final result.

The internal relief promoted by die spacers has been shown to reduce the intrapulpal tensions and the force required at the moment of crown cementation thus ensuring a better marginal fit and enhancing restoration's retention thus, paint-on die spacer before waxing has been used in fixed partial dentures for many years.15

John A Sorenson53 was the earliest researcher to describe a standardized method for determining marginal and internal fit. Measurements were done with the help of plastic overlays and glass square cross-sections. These Cross-sections were then photographed and measured with the help of Olympus stereomicroscope.

Several studies, 7,9,20,53,54 conducted in the past, used various methods for measuring marginal and internal fit. The direct measuring method in which the gap was measured directly with the help of a microscope after the prosthesis was placed on the tooth model followed by sectioning it. A

Siliconereplica technique in which the thickness of the light body silicone present between the prosthesis and the prepared tooth model was measured with the help of a microscope.54 A qualitative technique, such as visual examination, was not considered a reliable method because they are mostly subjective and depends on the skill of the observer and his or her tactile sensation.

Scanning Electron Microscopy (SEM) and Optical Stereomicroscopy are techniques, which were used for measuring the marginal and internal gap. A recently introduced technique named X-ray microcomputed tomography (Micro CT) in which the inner surface of the dental prosthesis was scanned and measured. These techniques were accurate, but high costs limit their usage.9

The present study uses Stereomicroscope (Magnus MSZ Series) to measure the marginal and internal gaps and the data obtained were recorded in microns.

Several studies were conducted previously using the silicone replica technique. This technique was described in detail by Molin and Karlson 55 In this technique, the intaglio surface of copings was filled with light body polyvinyl siloxane addition silicone impression material and placed on the

die with the uniform pressure of 50 N. After a complete set of the material, copings were removed from the die with light body film firmly adhered to the intaglio surface of the coping. The assembly (coping and the silicone film) was reinforced and stabilized by filling its inner side with heavy body silicone impression material. Measuring the thickness of the light body silicone impression material will determine the marginal and internal gap.55

Compared to other techniques, there are fewer chances of damage to the sample and abutment thus making it a non-destructive methodology with enhanced precision.9

Laurant M 16 evaluated the efficacy of silicone replica. Two brands of silicone were tested to determine the most appropriate one in simulating the cementing technique. The study revealed that both types equally simulated the cementation technique. Moreover, the silicone method was considered valid in whatever region measurements were done (cervical, axial, and occlusal).

In one of the studies by Rahme YH et al. 55 compared the film thickness of light body polyvinyl siloxane addition silicone impression material using the replica technique and the film thickness of the cement resulting from the cementation of copings. The study revealed that the film thickness of

silicone impression material was similar to the thickness of glass ionomer cement. Thus, light body silicone impression material used in this study did not interfere with the placement of crowns. Moreover, the replica technique was considered to be a reliable technique in reproducing film thickness. Considering these facts, the present study was conducted using the non- destructive silicone replica proposed by Molin and karlson 55 to determine the marginal and internal gap.

The number and site of measurements used to determine the marginal and internal gap in the sectioned samples also varied among studies. Measurement location varied, ranging from 4 to more than 100 sites for measurement Cooney JP56 have measured the sectioned samples at four regions to determine the marginal and internal gap. Groten M57 evaluated the marginal fit of copy milled all-ceramic crowns. The study utilized measuring four regions to determine the marginal gap with the help of scanning electron microscopy. Tamac E 58 measured 13 points on the sectioned sample and reported the result by taking the mean of measured values. Gunsoy. S42 evaluated 17 reference points on the sectioned samples with the help of a stereomicroscope. Quante K 59 has stated that analyzing 10 points on the sectioned samples is sufficient to determine

marginal and internal discrepancies. The present study was conducted similarly to the study proposed by Lougren N 45 by measuring 15 points to evaluate the marginal gap, adaptation to the axial wall, and occlusal surface. Kim D 44 reported marginal and internal discrepancies by analyzing 8 points on sectioned silicone replicas. Kim ki 60 determined the fit of the copings by analyzing 40,000 points on a computer-aided design reference cast. This technique, though considered to be a reliable one, the results were difficult to interpret. The present study measures five regions to determine the marginal and internal gap.

The results of the present study of (Group 1), i.e., patterns with inlay wax and immediate investment were Mean marginal gap 35.84± SD 16.52, adaptation to axial wall 16.6± SD 7.55 and occlusal surface 73.21± SD22.02. (Group 2) i.e., patterns with inlay wax and delayed investment were Mean marginal gap 58.07± SD 26.33 adaptation to axial wall 33.92± SD 10.71 and occlusal surface 91.76± SD 28.3. (Group 3) i.e. patterns with auto polymerized pattern resins and immediate investment were Mean marginal gap 39.07± SD 30.72 adaptation to axial wall 20.35± SD 21.2 and occlusal surface 76.4± SD 25.46 (Group 4) i.e patterns with auto polymerized pattern resins and delayed investment were Mean marginal

gap 40.03± SD 40.38 adaptation to axial wall 21.03± SD 17.18 and occlusal surface 79.2± SD 35.81 All the groups in this study obtained a clinically acceptable range (120µm) for the marginal gap as stated by McLean and von Fraunhofer 34 and clinically acceptable range for internal gap stated by Quante et.al and Ucer.37

Among all the study groups, the lowest mean values were recorded in the axial region, followed by marginal and occlusal regions. It was observed that the highest mean values were recorded at the occlusal region in the Inlay wax delayed investment group, and this difference was statistically significant. At the margin and axial regions, the Inlay wax immediate investment group demonstrated the lowest mean values.

Among the above description inlay wax, immediate investment gives better results when compared to inlay wax delayed investment, and auto polymerized pattern resins immediate investment and auto polymerized pattern resins delayed investment group.

Though wax has its disadvantages like elastic memory, high coefficient of thermal expansion still it can be the pattern of material if it can invest as soon as completion of pattern fabrication and also economical.

If the fabricated patterns have to delay for the investment more than an hour, then autopolymerized pattern resin is the best material to choose even though it has a polymerization shrinkage, but after 2 hr, the shrinkage pattern will decrease and shows a little change over 24 hrs.

Limitations of the present study includes:

Samples were not subjected to thermocycling. All samples were evaluated under ideal situations, which may not reflect daily clinical situations, Metal dies were used for measuring marginal and internal fit, but the use of human teeth might have simulated an ideal condition. Present was conducted on copings; results might have differed if a fixed partial denture was evaluated.Manipulation temperatures of inlay wax may vary from coping to coping according to that shrinkage patterns can also differ leads to minor errors. Future studies have to concentrate on eliminating these factors.

V. Conclusion:

Within the limitations of the present study it can be concluded that, Copings produced by inlay wax patterns invested immediately showed good marginal fit and internal adaptation than the patterns that were invested 1 hr later.Copings produced by auto polymerized patterns invested immediately showed good marginal fit and internal adaptation than the patterns that were invested 1 hr later.Comparison among the two tested materials inlay wax immediate investment samples showed better marginal fit and internal adaptation than the immediately invested auto polymerized pattern resins. Comparison among the two tested materials auto polymerized patterns invested immediately samples showed better marginal fit and internal adaptation than auto polymerized pattern resins invested after 1 hr.So, if the pattern has to invest immediately inlay wax is the best choice, and if it has to delay the investment, then resin patterns gives the best results.

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