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RESEARCH ARTICLE

AN IN VITRO COMPARISON OF OVERALL FIT OF COBALT-CHROMIUM COPINGS CASTED CONVENTIONALLY FROM INLAY CASTING WAX, PATTERN RESIN & 3D PRINTED RESIN; EVALUATED BEFORE & AFTER CERAMIC FIRING CYCLES

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Overall Fit, Cobalt-Chromium Copings, Inlay Casting Wax, Pattern Resin, 3D Printed Resin

Abstract

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Aim: To compare the overall fit of cobalt-chromium copings casted conventionally from inlay casting wax, auto polymerizing pattern resin & 3D printed resin; evaluated before & after ceramic firing cycles.

Method: A stainless-steel master die assembly was fabricated which was used to fabricate the working models. 60 working dies (Group A Inlay Casting Wax n=20, Group B Pattern Resin n=20, Group C 3D Printed Resin n=20) simulating full crown preparations werestudied. The stainless-steel master die was duplicated using polyvinyl siloxane (PVS) elastomeric impression and poured in gypsum type IV die stone. Dieswere scanned using a digital scanner. 60 cobalt-chromium (Co-Cr) metal copings were fabricated using three different techniques: inlay casting wax, autopolymerising pattern resin& 3D printed resin. Each die was fired with conventional PFM ceramic. A standardized weightwas used to exert uniform pressure on the elastomeric impression material while recording the intaglio surface of the crowns (copings) fabricated before and after ceramic firings. It was thenscanned aiding in STL File. The STL files were later overlapped and evaluated on their respective working die STL file using the software. The overall fit was measured by colour surface mapping software viz before & after ceramic firing cycles.

Results: The copings obtained by 3D printed resin technique revealed the best overall fit before and after ceramic firing cycles amongst the three fabrication techniques.

Conclusion: 3D printed resin technique had the best overall fit before and after ceramic firing cycles followed by inlay casting wax technique and pattern resin technique.

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Introduction:-

Fixed prosthodontics is the branch of prosthodontics concerned with the replacement and/or restoration of the teeth by artificial substitutes that cannot be removed from the mouth by the patient.[1] Fixed dental prostheses range from the restoration of single tooth to complete mouth rehabilitation restoring function, patient comfort, masticatory ability, maintaining the health and integrity of the dental arches and in many instances elevates the patient's self-esteem by improving the aesthetics. The pursuit of this success involves an intricate procedure called dental castings which has been an integral part of prosthodontics for more than a century. Accuracy in fitting of cast metal restoration has always remained as one of the primary factors in determining success of the restoration. A precise fitting restoration needs to be accurate both along its margins as well as with regard to its internal surface, the long-term success of restoration is significantly influenced by the right marginal and internal fit. Precise marginal adaptation is necessary to achieve better mechanical, biological and aesthetics prognosis of the restorations. Marginal and internal fit are of paramount importance for a successful fixed restoration.[2]

The accuracy of fit of cast restoration is very essential for its longevity. Generally marginal fit and internal fit of restorations are very much influenced by clinical and laboratory factors. Clinical factors are the geometry of tooth preparation, including type of finish line and degree of taper, impression materials, and lastly cement used to lute the restoration in dental office. [3,4] Laboratory factors that affect marginal fit and internal fit are incompatibility of dental materials such as wax, die stone and casting investment, die spacer and the casting technique. [5]

William Taggart in 1907 popularised lost-wax casting technique for dental application, since then, cast metal restorations have been in vogue, and is currently regarded as the gold standard in fabrication of copings. The fabrication of dental cast restoration with the base metal alloys by lost wax technique require impression procedure, preparation of the die, fabrication of pattern, investing and casting. Lost wax technique is extremely technique sensitive and discrepancies are inevitable. Lost wax technique includes so many manual steps, making it inherently prone to chance errors. One of the new techniques for fabrication of alloy copings reported in the literature is Subtractive Manufacturing (SM) and Additive Manufacturing (AM). Notwithstanding the fact that the newer innovative techniques of CAD-CAM are showing very promising results, the Lost-Wax casting technique is a timetested fabrication protocol serving dentistry for more than hundred years and is economically viable to setup. Hence it was chosen as the preferred method for obtaining the copings for this study.

Pattern fabrication employ materials like inlay casting wax, auto polymerizing resins, light cured resins. Wax is popular because of its desirable properties like adequate strength, rigidity, ease of manipulation & absence of residue on burnout. Distortion of wax pattern like shrinkage because of relaxation of internal stress contributes to detrimental effects on cast restoration.

Resins were recommended to overcome the shortcomings of wax as pattern fabricating material. Autopolymerising resins offers strength, rigidity, and dimensional stability if immediate investment is not possible. However, the disadvantage of this material is its polymerization shrinkage. To overcome this, newer light polymerized di-methacrylate modelling resins were introduced which can be manipulated with supposedly increased precision and stability after light polymerization.

However, in recent years, technological methods, which are more efficient, began to be used instead of conventional methods such as three-dimensional (3D) printing and rapid prototyping technologies along with computer-aided design (CAD) and CAM milling and scanning.[5] CAD/CAM system is often used to produce copings, patterns, and frameworks from prefabricated blocks. The short laboratory procedure saves time, and is relatively cost effective in differentiation to other fabrication methods. The disadvantages of this method include the need for process precision, the generation of waste products and wear of the equipment.[6]

The development of 3D printing has been significant, the technical advancement in their performance and the current trend toward lower prices has progressed at an incredible speed. As a result, more delicate and highly precise modeling has become possible, and attempts to use this technology in medical applications have been made. the 3D printer as an additive manufacturing device is believed to be superior to the cutting process.[7]

Historically, precious alloys have been used more frequently for casting, but with the advancement of newer materials and casting techniques higher temperatures required for the melting of base metal alloys could be achieved, and the rising cost of precious metals have increased the popularity of base metal alloys since 1970. The mechanical properties of base metal alloys and low cost of these alloys make them attractive to be used for fixed and removable partial dentures frame works.[8]Co-Cr alloys has become a daily procedure in dental laboratories. The absence of allergic response and its rigidity made Co-Cr to be selected as material of possibility for this study.[9,10]

Many of the past studies have concentrated on evaluation of marginal and internal fit of cast restorations manufactured by different preparation designs, impression techniques, die preparation, spacer thickness, investment material and casting methods. However very few studies have been reported on the assessment of overall fit of cast restorations by comparing the conventional wax pattern technique and autopolymerising pattern resin with the newly introduced 3D printing technique. The present study was planned to compare and evaluate the overall fit of (CoCr) copings casted conventionally by lost wax technique using different pattern techniques made by Inlay casting wax, pattern resin and 3D printed resin.

However, there is dearth of evidence of superiority when the castings have been built upon with dental ceramics. The fit of metal ceramic frameworks may change after the application of veneering ceramic because of framework design, type of alloy, shrinkage of the ceramic during firing, and different coefficients of thermal expansion for ceramic and alloy.[11] Some authors have surmised about the better overall fit after ceramic build-up. Hence this study was envisioned to explore the overall fit of dental castings achieved by conventional lost wax technique and evaluate them before and after five ceramic firing cycles.

Aim and Objective:-

Aim:-

To compare the overall fit of cobalt-chromium copings casted conventionally from inlay casting wax, auto polymerizing pattern resin & 3D printed resin; evaluated before & after ceramic firing cycles.

Objectives:-

1. To study the effect of repeated ceramic firing cycles on the overall fit of cobalt-chromium copings fabricated by inlay casting wax, autopolymerising pattern resin & 3D printed resin.
2. What role does different techniques of pattern fabrication (inlay casting wax, autopolymerising pattern resin, 3D printed resin) play on the overall fit of cobalt-chromium copings?

Material and Methodology:-

This experimental In vitro study was carried out at Department of Prosthodontics, Crown & Bridge. The sample size for the study was taken as 60. A total of 60 samples were made for the study and were divided into three groups. Group A comprised of 20 samples which were made using Inlay casting wax. Group B comprised of 20 samples which were made using pattern resin. Group C comprised of 20 samples which were made using 3D-printed resin.

Methodology:-

Description of custom-made stainless-steel master die and assembly.

A stainless-steel master die (Fig.1) assembly fabricated especially for this study was used to obtain standardized patterns. The master die simulated a crown preparation with a 6^{o} total axial wall taper. The axial height of the die and its occlusal diameter was 6mm and finish line was kept to be 90^{0}shoulder, 1mm in width. The occlusal surface of stainless-steel die had a 1mm groove engraved vertically and horizontally a 0.5mm groove was made to simulate the occlusal anatomy of the tooth and to act as an antirotational mechanism for the copings. It also helped in placing the casted copings in best possible fit in single position before and after ceramic firing cycles.

Fig. 1:- Metal master die and counter die.

Fabrication of die samples

The stainless-steel die was duplicated in a die stone type IV by using a 1.5mm spacer with polyvinylsiloxane impression material. The stone die was accurately positioned and secured into stainless steel counter die. Each working die was individualized by having a separate impression. The duplicated die samples were divided into 3 groups A, B and C each consisting of 20 samples. The test samples were grouped as follows: Group A: Test samples obtained by inlay casting wax. Group B: Test samples obtained by auto polymerising pattern resin. Group C: Test samples obtained by 3D printed resin.

Fabrication of Inlay Casting Wax Pattern (Group A)

The duplicated dies from the master die were used to obtain standardized wax patterns for group A. A fine coat of die hardener and then die spacer were applied onto the fitting surface of the working die. Also, wax separator was applied on the counter die. The lubricant allowed easy removal of the wax pattern from the die and prevented the pattern from adhering to the stainless-steel former assembly. The inlay casting wax was melted then flowed and filled in the stainless-steel former (Fig.2) and pressed on the gypsum die. The steel former with wax was again heated by flaming for better flow of wax (Fig.2) A trough was designed around the base of the abutment preparation section to collect the overflowing excess inlay casting wax while fabricating the wax pattern. The pressure that built in during fabrication of wax pattern dissipated through slits in the master model former assembly and the excess wax reached the trough via the slits and resulted in wax patterns of equal thickness. The duplicated stone die and counter former assembly were held together for 1 minute with finger pressure and allowed to cool down to room temperature. The die along with the wax pattern was then separated from the former. The excess wax was trimmed using a wax carver. The intaglio surface of each wax pattern was inspected under magnifying viewer of 3X to ensure it was smooth and free from defects. A uniform thickness of 0.5mm was obtained throughout the coping. The wax pattern was checked for uniform thickness using a wax caliper. Using the same technique, 20 wax pattern samples were fabricated.

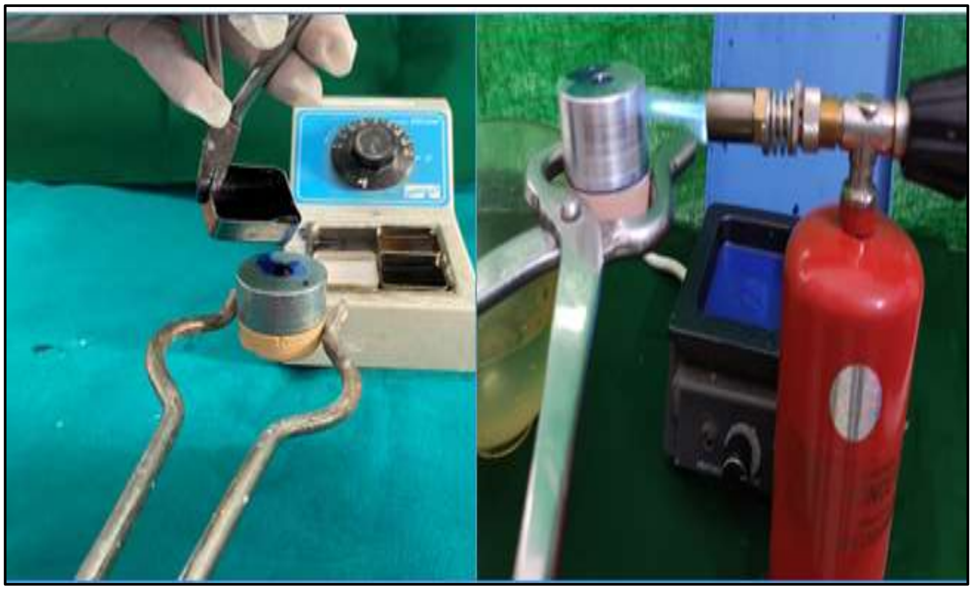


Fig. 2:- Casting wax filled over the die and Heating of wax for proper flow.

Fabrication of Auto polymerizing Resin Patterns (Group B)

The duplicated dies for group B were used to obtain patterns made from auto polymerizing resin. After application of lubricant on the die, the tip of the brush was moistened with liquid and then a small amount of powder was picked up and incrementally added on the die to build up the pattern. To achieve an even thickness, the custom metal template was used by pressing it with finger pressure after orienting it to the slots on the base of the die. After 3 minutes the resin copings were removed from the die and checked on the internal surface. If any fine adjustments were needed, they were done with a bur attached to a micromotor. The patterns were sprued and invested as like the inlay wax patterns. For pattern resins the Methodology burn out holding temperature was maintained at 250^{0} C for 1 hour. (Fig.3). Rest of the procedures followed were the same as for inlay wax patterns.

Fig. 3:- Pattern resin coping tried on die.

Fabrication of 3D Printed Resin Patterns was done by DLP Technique (Group C)

Scanning of the die and generating a virtual design for the coping pattern was done. The duplicated dies were scanned individually by using 3D model scanner.The models were then used to design the copings using a CAD software program. The thickness of the coping was kept as 0.5 mm. After the scanning was completed, 20 coping patterns were designed on the disc a 3D model was generated in the Exocad software. Fabrication of coping patterns was done by 3D Printer. 20 coping patterns were printed using 3D printing resin (FIG. 4).

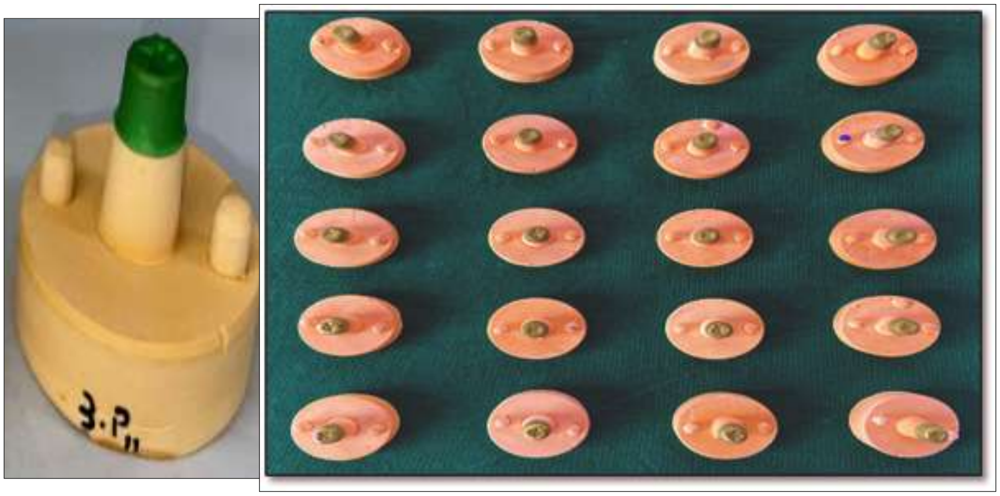


Fig. 4:- 3D printing coping patterns tried on die.

Fabrication of Cobalt-Chromium Copings

A 2.5 mm diameter preformed round wax sprue was attached at a 45-degree angle to the occlusal surface of each pattern, placed on their respective dies. The horizontal runner bar was connected to feeder sprue of 5mm diameter which was bent to semicircle in shape. The patterns were placed at $120^0$to each other in the assembly. One investment ring with 3 patterns one from each group were invested into a silicone casting ring as a Ringless casting technique was envisaged a 6-mm distance was provided between the margin of the coping and top of the casting ring. A surfactant spray was sprayed on all wax patterns and dried with two short air blows. The phosphate bonded investment in the ratio of special liquid to distilled water was approximately 80:20 in volume for the investment, as recommended by the manufacturer, was hand mixed in rubber bowl with plaster spatula for 15 seconds and then vacuum mixed for an additional 120 seconds. A single-step investment technique was followed. Bench setting of 3 hours based on the manufacturer's recommendations was followed. After bench set time, the set investment mould was placed in the burnout furnace. Burn out of the pattern was done by placing the investment in the furnace at room temperature and it was heated continuously till 950^0 for 45 min. Casting was done with cobalt-chromium alloy (Co 64.0%, Cr 28.5%, Mo 5.0%, Mn 1.0%) melted in an induction casting machine the casting procedure was performed quickly that prevented heat loss resulting in the thermal contraction of the mould. The cobalt-chromium alloy was heated sufficiently till the alloy ingot turned to molten state and the crucible was released and the centrifugal force ensured the completion of the casting procedure. Following the casting procedure, the investment was bench cooled to room temperature. Divestment was done that retrieved the cast coping from the investment. Care was taken to prevent damage to the margins. Adherent investment was removed from the castings by sandblasting with 100µm Al2O3 at 80 psi pressure. The internal surface was inspected under magnification of 3x and relived of all nodules with a tungsten carbide round bur No.2 and was cleaned in an ultrasonic cleaner resulting in completed copings to provide the best fit. Such 60 samples of metal copings were fabricated and tried on the sample die. (Fig. 5).

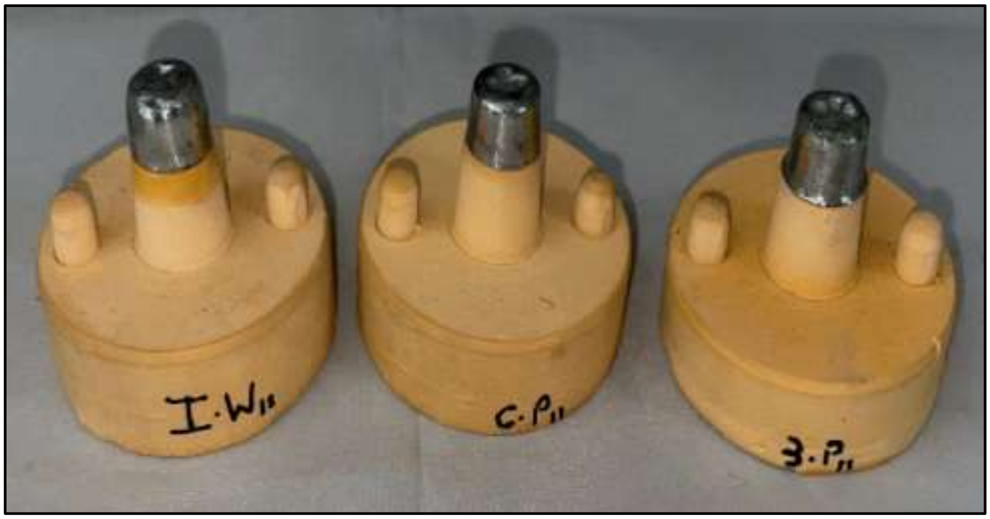


Fig. 5:- Group A, Group B and Group C coping trial on die.

Porcelain build-up of copings

The copings were then cleaned ultrasonically. An oxidized layer was obtained by placing the copings in a ceramic furnace. The first and second opaque firing were done and they were checked using a stent made of clear acrylic of 1 mm space. Then dentin and enamel were applied and the subsequent firing cycles were performed. Then these models were finished and polished with appropriate finishing burs. This simulated the clinical situation by replication of 5 firing cycles representing oxidation firing, two opaque firing, dentin firing and enamel firing, the minimum firing cycles required for the fabrication. The same procedure was followed for every sample of Group A, B and C (Fig.6).

Fig. 6:- Group A, Group B, Group C completed coping trial on die after ceramic firing cycle.

Evaluating the Overall Fit

Measurement of Overall Fit for Groups A, B, C Before Ceramic Firing: All the duplicated dies from groups A, B and C were scanned individually by using the 3D model scanner and the STL files were saved with their respective name and number. Each casting was seated on its respective stone die. Grooves on the occlusal surface of the die prevented rotation of the casting and ensured seating of the copings at the same position as the wax pattern. Silicone replica technique was used to get the inner surface of the coping. This replica was scanned and they were saved as STL file with their respective name and number. 50 Measurements were made using GeoMagic Control X v.2018.1.1; 3D Systems, Morrisville, NC, USA.in which the inner surface of the coping was overlapped onto their respective dies. Root Mean Square values were used for readings. (Fig.7)

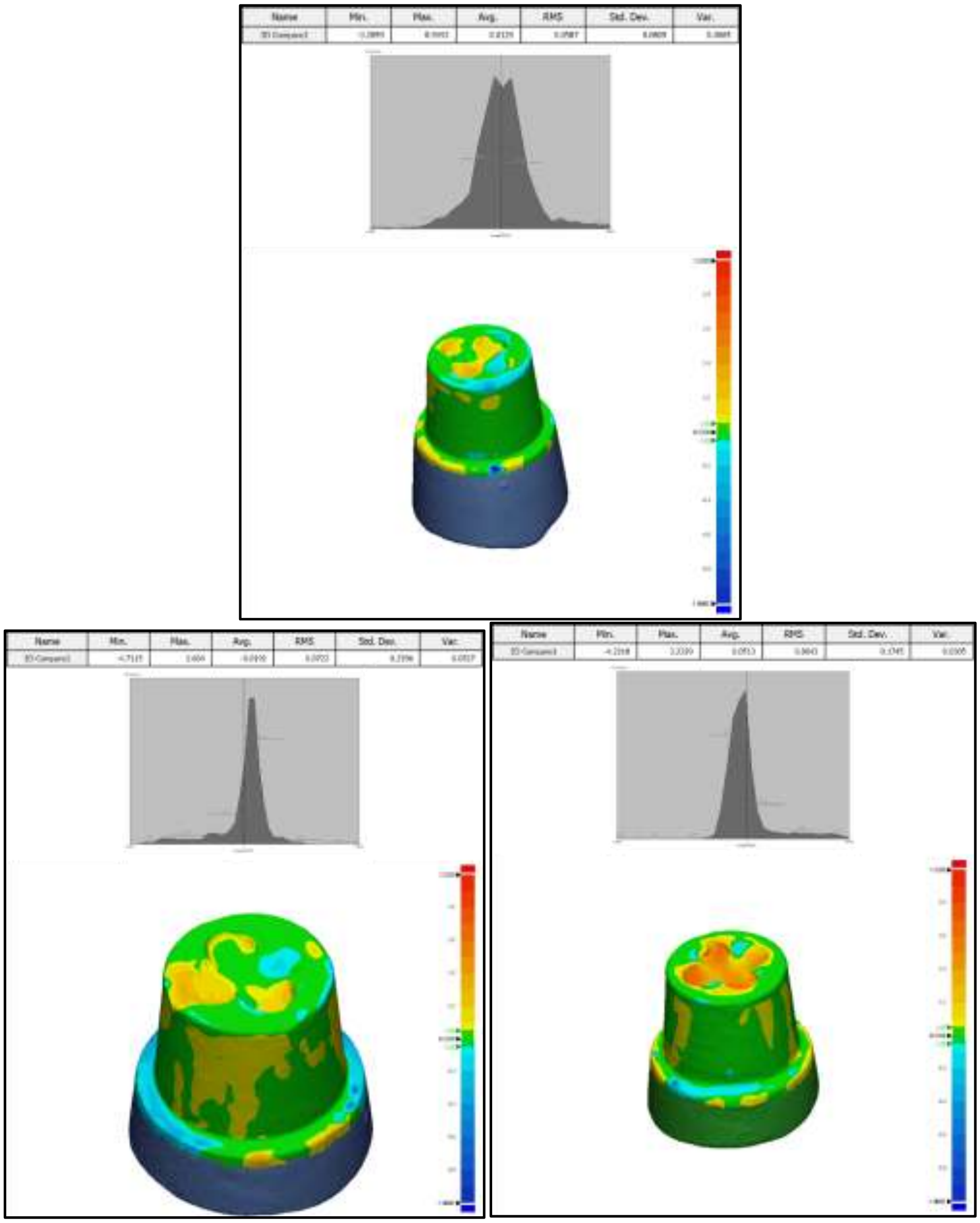


Fig. 7:- Representative figure showing measurement of overall fit for Group A, Group B and Group C before ceramic firing.

Measurement of Overall Fit for Groups A, B, C After Ceramic Firing: After completion of the ceramic layering. The same technique was used to get the STL file. Measurements were made using GeoMagic Control X v.2018.1.1; 3D Systems, Morrisville, NC, USA. (Fig.8)

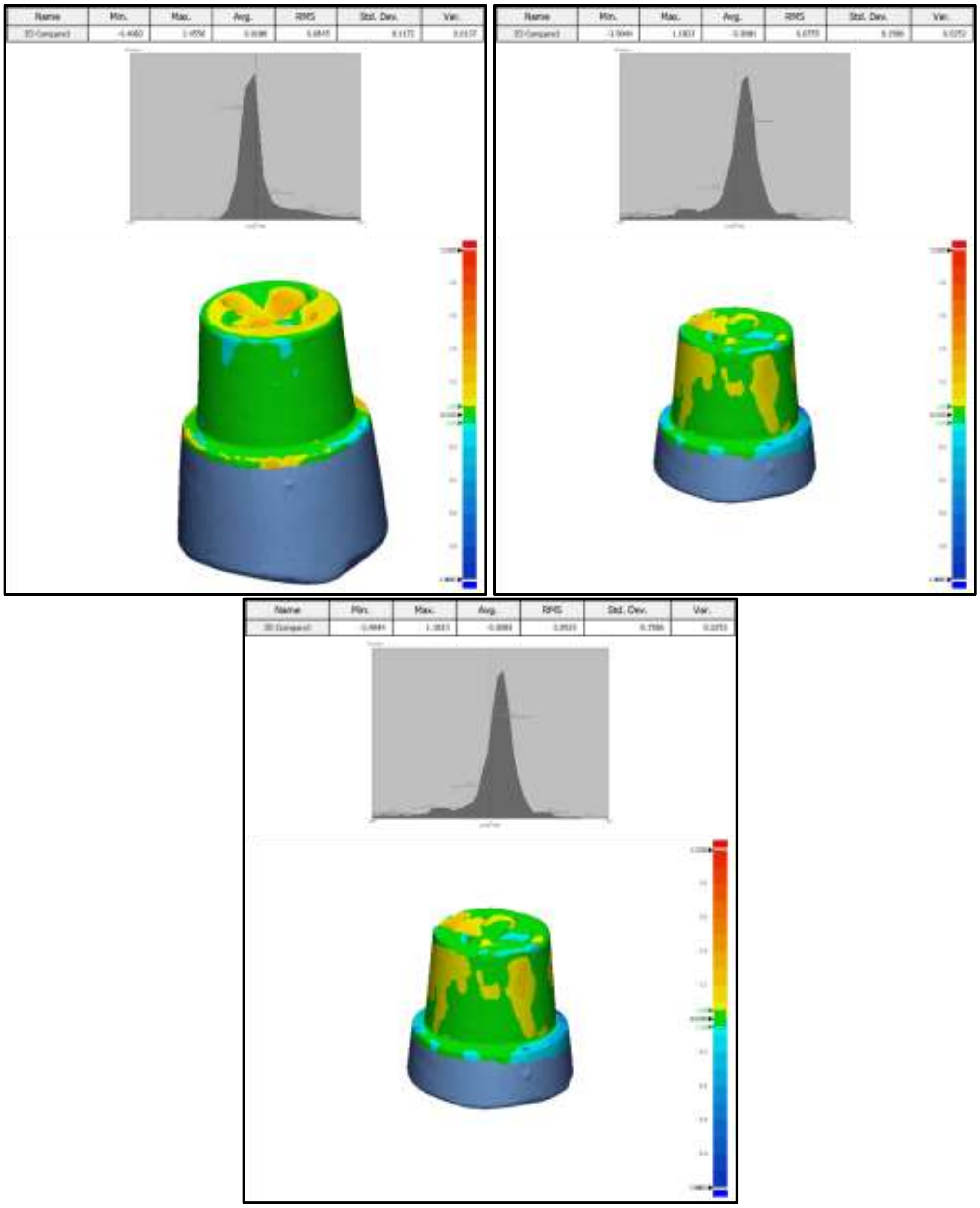


Fig. 8:- Representative figure showing measurement of overall fit for Group A, Group B and Group C after ceramic firing.

Data Analysis

Statistical Product and Service Solutions (SPSS) version 21 for Windows (Armonk, NY:IBMcorp) software was used to analyse the data. Statistical analysis was done by using tools of descriptive statistics such as Mean, and Standard Deviation for representing the overall fit. One-way ANOVA ‘F’ test was applied to compare overall fit among the three study groups. Post hoc data analysis which follows One way ANOVA was done by using Tukey’s multiple comparison test. Post hoc test analyses multiple pair-wise individual comparisons between three study groups. Probability $p<0.05$, considered as significant as alpha error set at 5% with confidence interval of 95% set in the study. Power of the study was set at 80% with beta error set at 20%.

Results:-

Descriptive statistics for the Overall discrepancy (before ceramic firing) was compared between Group A, Group B and Group C using the one-way ANOVA test.(Table1 & Graph1) The mean value and standard deviation for Group

A (Inlay casting wax) was 64.83µm and (3.7). For Group B (Pattern Resin) was 70.721µm and (2.21), for Group C (3D printed resin) 58.75µm and (1.87) respectively. Intergroup comparison was done using One-Way ANOVA Test followed by Tukey's post hoc test. The F test value was 97.660 and P value was p<0.001 i.e., a highly significant difference was found between overall discrepancy between Group A (Inlay casting wax), Group B (Pattern Resin) and Group C (3D printed resin). On intergroup comparison with Tukey's post hoc test it was found that there was highly significant difference between Group A and Group C, Group B and Group C and significant difference between Group A and Group B.

Before Ceramic Firing	Mean	SD	SE	Minimum	Maximum
Group I (Inlay Casting wax)	64.83	3.70	0.82	61.0	74.25
Group II (Pattern Resin)	70.72	2.21	0.49	67.5	74.0
Group III (3D Printed Resin)	58.75	1.87	0.41	55.75	62.5

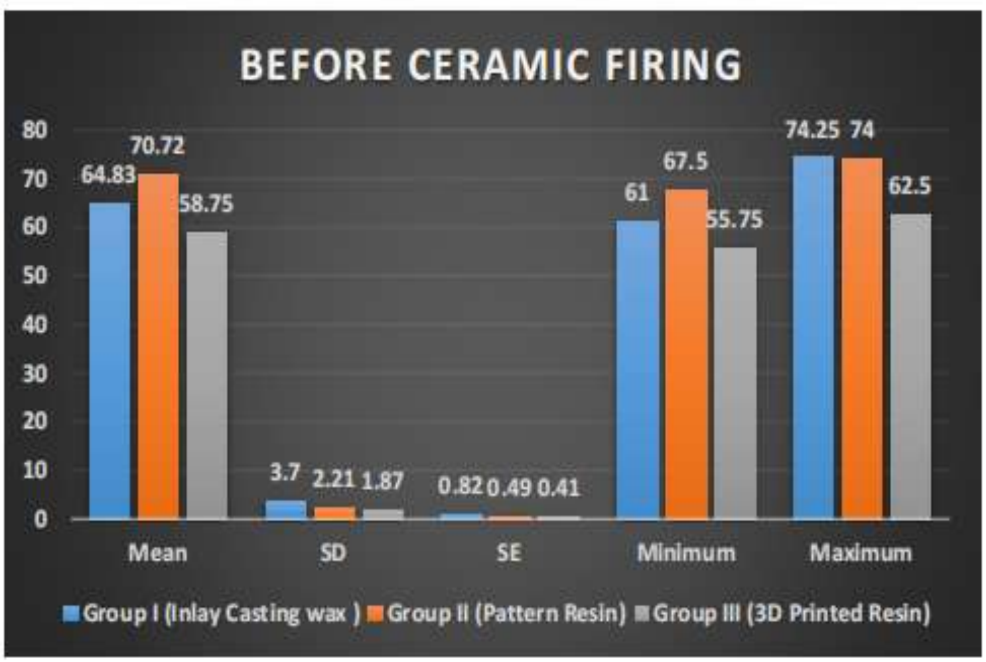
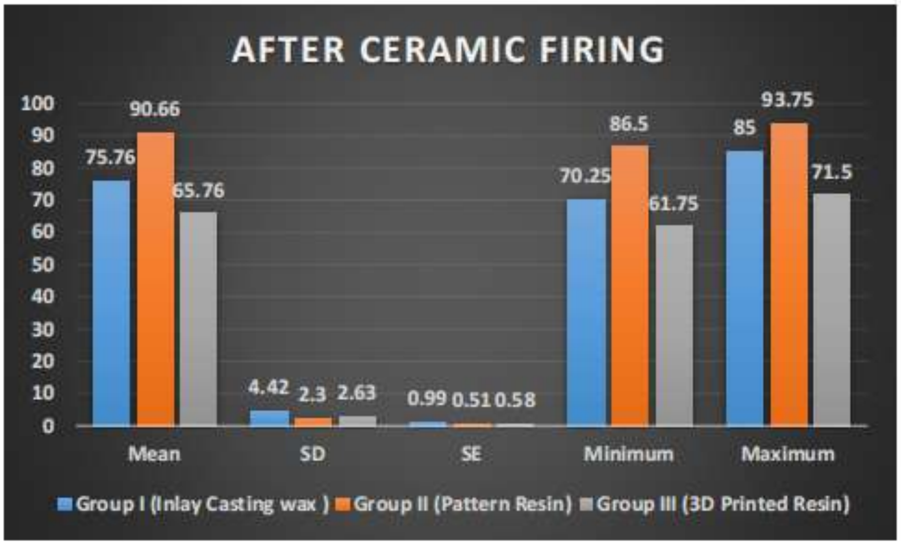


Table 1&Graph 1:- Descriptive statistics of overall fit of cobalt-chromium copings casted conventionally from inlay casting wax, pattern resin & 3d printed resin; evaluated before ceramic firing cycles.



After Ceramic Firing	Mean	SD	SE	Minimum	Maximum
Group I (Inlay Casting wax)	75.76	4.42	0.99	70.25	85.0
Group II (Pattern Resin)	90.66	2.3	0.51	86.5	93.75
Group III (3D Printed Resin)	65.76	2.63	0.58	61.75	71.5

Table 2& Graph 2:- Descriptive statistics of overall fit of cobalt-chromium copings casted conventionally from inlay casting wax, pattern resin & 3d printed resin; evaluated after ceramic firing cycles.

Descriptive statistics for the overall discrepancy (after ceramic firing) was compared between Group A, Group B and Group C using the one-way ANOVA test. (Table 2 & Graph2).The mean value and standard deviation for Group A (Inlay casting wax) was 75.76µm and (4.42). For Group B (Pattern Resin) was 90.66µm and (2.3), for Group C (3D printed resin) 65.76µm and (2.36) respectively. Intergroup comparison was done using One-Way ANOVA Test followed by Tukey's post hoc test. The F test value was 295.64 and P value was $p<0.001$ i.e., a highly significant difference was found between overall discrepancy between Group A (Inlay casting wax), Group B (Pattern Resin) and Group C (3D printed resin). On intergroup comparison with Tukey's post hoc test it was found that there was highly significant difference between Group A, Group B and Group C.

Overall intragroup comparison of mean overall discrepancy between three groups Group A (Inlay casting wax), Group B (Pattern Resin) and Group C (3D printed resin) at all production stages was done using One-way ANOVA-F test followed by Tukey's post hoc test for pairwise comparison.

In Group A (Inlay casting wax), (Table 3& Graph 3). Mean overall discrepancy value before ceramic firing i.e., 64.83µm (3.70) was increased after ceramic firing to 75.76µm (4.42).It was observed that there exists statistically significant increase ($p<0.001$) in overall discrepancy at different successive production stages. Increase in overall gap was found to be of statistical significance ($p<0.001$) in before v/s after ceramic build up stage.

In Group B (Pattern Resin), (Table 3& Graph 3). Mean overall discrepancy value before ceramic firing i.e., 70.72µm (2.21) was increased after ceramic firing to 90.66µm (2.3). It was observed that there exists statistically significant increase ($p<0.001$) in overall discrepancy at different successive production stages. Increase in overall gap was found to be of statistical significance ($p<0.001$) in before v/s after ceramic build up stage.

In Group C (3D Printed Resin), (Table 3& Graph 3). Mean overall discrepancy value before ceramic firing i.e., 58.75µm (1.87) and increasing after ceramic firing to 65.76µm (2.63). It was observed that there exists statistically significant increase ($p<0.001$) in overall discrepancy at different successive production stages. Increase in overall gap was found to be of statistical significance ($p<0.001$) in before v/s after ceramic build up stage.

	Before Firing Mean (SD)	After Firing Mean (SD)	Change due to firing Mean (SD)
Group I (Inlay Casting wax)	64.83 (3.70)	75.76 (4.42)	10.92 (3.61)
Group II (Pattern Resin)	70.72 (2.21)	90.66 (2.3)	19.93 (0.97)
Group III (3D Printed Resin)	58.75 (1.87)	65.76 (2.63)	7.01 (3.41)
One way Anova F test value	F = 97.660	F = 295.64	F = 102.484
P value, Significance	P< 0.001**	P< 0.001**	P< 0.001**

**p< 0.001 – highly statistical significant difference

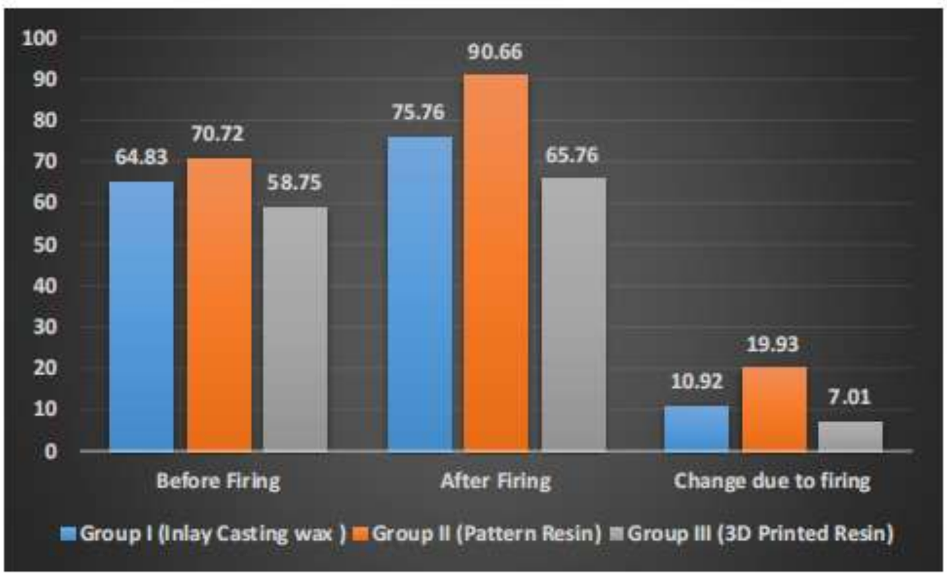


Table 3& Graph 3:- Overall comparative statistics of cobalt-chromium copings casted conventionally from inlay casting wax, pattern resin & 3d printed resin; evaluated before, after and change in ceramic firing cycles using One-way ANOVA F test.

The results obtained in this study using Group A (Inlay casting wax), Group B (Pattern Resin) and Group C (3D printed resin). for overall fit were comparable and within acceptable limits. However, a statistically significant difference was found in overall fit between Group A (Inlay casting wax), Group B (Pattern Resin) and Group C (3D printed resin) before and after ceramic firings.

Discussion:-

The purpose of this study was to evaluate the overall fit of cobalt chromium copings casted conventionally from inlay casting wax, pattern resin & 3D printed resin; which were evaluated before & after ceramic firing cycles. Many studies in the recent years have been reported about obtaining metal copings directly using CAD/CAM milling technique and DMLS technique. However very few studies have been reported on the assessment of overall fit of cast restorations by comparing the conventional wax pattern technique with the newly introduced Additive: - 3D printing technique and pattern resin which have been casted using the century old Lost wax technique.

The basic data obtained in this study showed a mean discrepancy (Before Ceramic Firing) as 64.83µm for Group A (Inlay casting wax), 70.72µm for Group B (Pattern Resin) and 58.75µm for Group C (3D Printed Resin). Highly significant difference was found between Group A (Inlay casting wax), Group B (Pattern Resin) and Group C (3D printed resin). On intergroup comparison with Tukey's post hoc test it was found that there was highly significant difference between Group A and Group C, Group B and Group C and significant difference between Group A and Group B.

A.Iglesias[12] in his study concluded that, marginal gap for full crown patterns ranged from 10 to 23 µm. The marginal gap produced by incremental technique was equal or smaller than the bulk technique. In his study, incrementally added autopolymerising resins showed marginal gap. The results of this study correlated with the study done by Rajagopal et al[13]in his study he had compared inlay wax and two types of resins. the values differed within a range of ± 6 µm for both resins. When comparing the values for inlay wax, both the studies showed different distortion levels. Results of the study done by Sushma et al[14] showed a mean marginal discrepancy of 165.62 microns for inlay wax, 177.7 microns for light cure resins and 184.43 microns for Autopolymerising resins.Studies conducted by Shillinburg et al., Pagiano et al., and Cahi et al., have shown that auto polymerized resin pattern materials undergo a polymerization shrinkage of 1%–7% on storage for 24 hours.[13,15] Sakshi Malhotra et al[16] , carried out a study to evaluate the marginal discrepancy of castings fabricated with conventional and accelerated casting technique by using two type of pattern materials. Mean marginal gap with conventional casting using inlay wax was 70µm whereas by accelerated casting was 87.5 µm. Mean marginal gap using auto polymerizing resin with conventional method was 89.37 µm which was similar to that obtained by accelerated casting technique i.e., 89.37 µm. The results concluded that castings made with inlay wax as pattern material had less marginal discrepancy than the auto polymerizing pattern resin material.[17] Patterns made from resins showed lesser expansion and caused tight binding of castings with the die. The reason might be as "the resin patterns can distort because of polymerisation shrinkage, and they can suppress setting expansion of the investments more than wax patterns because of the higher rigidity of the cured resin. If resins undergo less expansion, they might bind in the upper 1/3rd of the die and may cause incomplete seating in the marginal region, sequentially causing more overall discrepancy. This might be a reason for observation of more discrepancy in patterns made by resins after casting. [16,17]

The data obtained in this study for the overall discrepancy (after ceramic firing) was compared between Group A, Group B and Group C and the mean value and standard deviation for Group A (Inlay casting wax) was 75.76µm and (4.42). For Group B (Pattern Resin) was 90.66µm and (2.3), for Group C (3D printed resin) 65.76µm and (2.36) respectively. Highly significant difference was found between overall discrepancy between Group A (Inlay casting wax), Group B (Pattern Resin) and Group C (3D printed resin). The current study had considered 5-cycles of porcelain firing, which is akin to clinical reality.

Although, there is a marginal increase after build up as compared to the values of coping stage, on statistical analysis it is found to be highly significant when the three techniques of fabrication are compared to each other as the p value is $p<0.001$. This finding is directly contrary to the work of Kocaagaoglu et al[11] who stated that neither fabrication protocol nor repeated ceramic firings had any statistically significant effect on internal discrepancy values ($P>.05$). Marginal discrepancy values were also statistically unaffected by repeated ceramic firings ($P>.05$).

Overall discrepancy values ($P<0.001$) with auto polymerizing Pattern Resin technique resulted in higher values than Inlay casting wax or 3D printed resin ($P<0.001$). Overall discrepancy values did not vary much between Inlay casting wax and 3D printed resin (P<0.001). All groups demonstrated clinically acceptable adaptation after repeated ceramic firing cycles; However, the Inlay casting wax and 3D printed resin groups demonstrated better adaptation than that of auto polymerizing pattern resin group.

After the fabrication process, the metal frameworks go through several firing stages, including oxidation, opaque porcelain and dentin & enamel porcelain and glaze porcelain firing. The fit between the abutment tooth and restoration changes depending on the distortion produced by the firing stages. There is evidence to claim that the oxidation process of metal frameworks and porcelain firing cycles leads to an increase in the marginal discrepancy at the cervical region.[18] As early as 1964, Howell noted that there was a change in the “marginal fit” of porcelain-to-metal crowns with repeated firings. Others have reported that porcelain-to-metal crowns do not fit as well after porcelain firing. The hypothesis has been that the shrinkage of the porcelain results in a change in the integrity of the casting. One theory contends that during the cooling portion of the firing cycle any differential in the rate of contraction between the metal substructure and the adhering porcelain produces interfacial stress.” This stress then acts to deform the restoration, producing discrepancy. Apparently, a stronger more rigid restoration deforms less than does a weaker less rigid one.[19] The majority of discrepancy is known to develop during the oxidation cycle for metal copings. This is often attributed to the release of residual stresses incurred during casting, grinding, or polishing phases of the procedure. As the prosthesis cools from the firing temperature, the difference in thermal contraction between the metal coping and the porcelain may result in additional discrepancy.[20]Anusavice et al[21] expressed that distortion of metal-ceramic crowns during porcelain firing cycles is frequently attributed to thermal incompatibility stresses. Although, considerable controversy exists in the literature over whether crown distortion is due primarily to metal-porcelain incompatibility or to other unrelated factors. The largest gap changes were observed for crowns with chamfer and chamfer-bevel configurations, compared with shoulder and shoulder-bevel geometries.Buchanan et al[19] Reported greater marginal distortion of a base metal alloy compared with an Au-Pt-Pd alloy when the alloy was fired with porcelain. These changes occurred primarily during the metal oxidation cycle. These authors speculated that the larger marginal discrepancy of the base metal alloy was due to the formation of a thicker oxide layer on the casting surface.

On overall intra-group comparison of mean overall discrepancy between Group A, group B and group C before v/s after ceramic build up stage was done it was observed that there exists statistically significant increase in overall discrepancy before v/s after ceramic build up stage.

It can be discerned from this study that the mean overall discrepancy values were the lowest for 3D printed resin technique irrespective of the stages involved, while though Inlay casting wax technique had higher values of overall gap compared to 3D printed resin, but the readings were very close. Highest discrepancy was noted for the pattern resin technique irrespective of the stages. In short, the clinical acceptance of the gaps varies quite across different studies. Hung et al[22] reported that practical range for clinical acceptability of fit seems to be approximately 50 to 75µm. However, McLean[23] concluded in a 5-year clinical study of 1000 restorations that 120µm was the maximum acceptable marginal opening. As far as the production stages are concerned viz. before & after ceramic firings, the mean overall discrepancy values increased gradually from coping stage to after porcelain build up stage irrespective of technique of pattern fabrication for copings. 3D printing technique, is one of the rapid developing systems, it is an additive fabrication method gaining grounds in prosthetic dentistry. It is free from involvement of any human error, giving a precision fit and promising results, and eliminates consumption and wastage materials unlike lost wax technique and pattern resin. However, cost intensive setup precludes its presence in wider locales. Lost wax technique although suffers from multiple technique sensitive and labourintensive stages yet it delivers near perfect results. It is a time-tested fabrication protocol serving dentistry for more than hundred years and is economically viable to setup in mofussil precinct and remote locations.

Conclusion:-

Within the inherent limitations of this in-vitro study, the undermentioned inferences may be drawn amongst the three-pattern materials tested for overall fit of the cast copings.

1) The copings obtained by 3D printed resin technique revealed the best overall fit before and after ceramic firing cycles amongst the three fabrication techniques.

2)The mean overall fit decreased progressively for the crowns after ceramic firing cycles.

3) The values of overall gap obtained by the Pattern resin technique is within acceptable limits and comparable to the inlay casting wax-based fabrication technique before and after ceramic firing cycles.

4) The mean overall discrepancy of the copings obtained by Inlay casting wax, Pattern resin, 3D printed resin were within clinically acceptable limit, irrespective of the ceramic firing cycles involved.

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