Comparative Evaluation of Marginal Accuracy of the Provisional Fixed Dental Prosthesis Using Three Different Materials Produced by Direct Technique: An in Vitro Study

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Abstract:
Purpose: To evaluate and compare the marginal accuracy of the provisional fixed dental prosthesis produced using commercially available auto-polymerized, light cured and dual cured composite resin by direct technique.
Materials and Methods: Total sixty prototypes of interim fixed dental prosthesis were produced using of stainless steel die and three different types of commercially available provisional restorative materials. Prototypes were divided into three equal Groups (A, B and C). Group A (auto polymerized composite resin), B (Light cured composite resin) and C (Dual cured composite resin) consisted of ten prototypes each. All the prototypes were preserved in artificial saliva at ambient temperature and after their sectioning, the measurements were made at 4 marked points (mesial, distal, labial and lingual) of each unit (i.e. tooth number 35,37) under stereomicroscope. The mean vertical marginal discrepancy was measured at 3 lag periods, i.e. at 24 hours, at 2 weeks and at 4 weeks after fabrication. **Results:** The results were statistically analyzed using One-way ANOVA, repeated measure ANOVA and Bonferroni test using SPSS (Statistics software Version 20.0; IBM Corp.) The mean marginal discrepancy of Group C (Tempspan), Group B (Revotek LC) and Group A (Protemp 4) is 141.55 ± 3.66, 105.76 ± 4.89 and 78.18 ± 4.68 respectively at 24 hours, 181.79 ± 3.33, 138.61 ± 3.63 and 102.30 ± 3.87 respectively at 2 weeks. 182.30 ± 3.47, 150.22 ± 8.77 and 116.57 ± 6.68 respectively at 4 weeks. Statistically, significant difference was present in the marginal discrepancy among all the groups at 24 hours, 2 weeks and 4 weeks. **Conclusion:** This study has shown that provisional FDP produced with Auto polymerized composite resin registered the least vertical marginal discrepancy than that of the light cure composite resin and the dual cure composite resin. Provisional FDPs produced from the dual cure composite resin (Tempspan) are likely to exhibit significantly more marginal discrepancy than the auto polymerized and the light cure composite resin.
Keywords: provisional fixed dental prosthesis, marginal accuracy, auto polymerized composite resin, light cure composite resin, dual cure composite resin.

Introduction:

Provisional restoration treatment comprises a sophisticated assemblageof knowledge, practical skills, picking the right material. Thebiological prerequisites of the provisional restorations are aesthetics, convenience, oration, function as well as health of the periodontium and temporomandibular joint. The teeth are to be protected immediately after the preparation with suitable provisional restorations which mirror final restoration.[1,2,3]

One of the uses of the Provisional restorations is to diagnose the condition before reorganizing the whole dentition. It can stabilize the prepared tooth against the untoward migration until the definitive crown is received. It can also aid in determining the outcome even before initializing the treatment as in case of smile designing. In case of challenging full mouth reconstruction, it will be helpful to design a new anterior guidance and built a desirable occlusal schemes.[4, 5].

The ideal mechanical prerequisites of any provisional restoration are that they must be biocompatible, have high finish to resist staining and/or discoloration., high fracture and wear resistance, good dimensional stability, the slightestpossible marginal gap formation[6, 7]

Marginal integrity is one of the most important factors determining the provisional restoration success. The teeth might see a failure due to caries or irreversible pulpal changes due to the accumulation of the fluid underneath the restoration, which contains bacteria and other toxic substance. Apart from the endodontic problems, the teeth might also face the periodontal problemsdue plaque accumulation especially in case of subgingival margin placement. [8]

Acrylic resin is traditionally used materials for provisional restorations, but there are certain drawbacks like polymerization shrinkage, lesser strength, exothermic setting reaction and monomer leach out. Modern composite resins are either light activated, auto polymerized or dual - polymerized composite resin. Dentists prefer composites over the resins because of their improved mechanical and physical properties, simplicity, and reduce polymerization shrinkage and absence of free monomer.

Quite a few invitro studies have been piloted to evaluate and equate the marginal accuracy of both acrylic and composite resin. Some studies show that the provisional restorationsproduced from PMMA have the slightest amount of marginal gap as compared to bis-acryl composite, while some newer studies show that the bis-acryl composite have statistically similar or lower marginal gap when compared to PMMA.[1,2,12]

Search of literature reveals that majority of studies were done to evaluate the marginal accuracy of a single provisional crown and multiple units provisional restoration still remained an area of study. The marginal accuracy depends upon various factors. Among them material mass, ageing and cementation are few important factors. This research focused to compare the marginal accuracy of a three unit FDP produced by commercially available chemically cured, light cured and dual cured composite resin, by direct technique which were preserved in artificial saliva at ambient temperature to mimic the oral environment for the provisional restorations.

Materials and Method:

Preparation of stainless steel die:

The two stainless steel metal dies were fabricated by the laser sintering with the base, which mimic tooth number 35 and 37. It was having1mm of shoulder width, 6° taper and 12° of axial wall convergence.

Prototype fabrication:

- **Direct technique using Autopolymerized composite resin. Group A (Protemp 4)**
  - A tray adhesive was applied on the custom tray and the polyvinyl siloxane impression of a three unit FDP stainless steel metal dies were made to get external surface form (ESF) and excess material was removed.
  - The die representing the prepared teeth was lubricated with white petrolatum.

- The material was dispensed into the matrix and reseated on the dies to get internal surface form (ISF).
- The matrix was retrieved along with the restorative materials from die between 1:40-2:50 minutes from the onset of mixing. The material was left in the matrix for 5 minutes so as to complete the curing process and achieve smooth and shiny surface.
- The unwanted composite resin was cut under magnification from the set restoration. Ten such prototypes were produced then subjected to microscopic evaluation of marginal accuracy.

❑ **Direct technique using light cured composite resin. Group B (Revotek LC)**

- A clear stent was produced using a thermoplastic vacuum sheet using a thermoplastic vacuum former over the three unit FDP stainless steel metal die to get external surface form (ESF).
- It was lubricated with white petrolatum and filled with light polymerized composite resin to get internal surface form (ISF).
- The loadedclear stent was placed onto the die and cured for 10 seconds per unit for the initial set and then removed and final cured for 20 seconds per surface as per manufacture instructions. Ten such prototypes were produced and subjected to microscopic evaluation of marginal accuracy.

- **Direct technique using dual - cure composite resin. Group C (Tempspan)**
- A tray adhesive was applied on custom tray and polyvinyl siloxane impression of three unit FDP stainless steel metal dies were made to get external surface form (ESF) and excess material was removed.
- The die representing the prepared teeth was coated with white petrolatum.
- The material was dispensed into the matrix and reseated on dies to get internal surface form (ISF).
- The matrix was retrieved together with the provisional restoration from the die between 1:30-1:45 minutes from the insertion time. The material was left in the matrix for 2 minutes so as to complete the curing process. The restoration was light cured for 20 seconds per section for instantaneous curing.
- The unwanted composite resin was cut under magnification from the set restoration. Ten such prototypes were produced and subjected to microscopic evaluation of marginal accuracy.

Grouping of prototypes:

A comparative study of marginal accuracy of FDP produced using chemically cured, light cured and dual cured composite resin by direct technique with prototype size of 30 were divided into 3 groups:

- Group A: Temporary FDP made from Autopolymerized composite resin (10 prototypes)
- Group B: Temporary FDP made from Light cured composite resin (10 prototypes)
- Group C: Temporary FDP made from Dual cured composite resin (10 prototypes)

Evaluation of marginal accuracy:

- The marginal gap between the margins of the provisional restorations and finish line of the stainless steel die was measured.
- All the prototypes were preserved in artificial saliva at room temperature and after their sectioning, the measurements were made at 4 marked points (mesial, distal, labial and lingual) of each unit (2^{nd} premolar and 2^{nd} molar) under stereomicroscope.
- The marginal discrepancy was evaluated in μm for all the prototypes prepared for above mentioned three groups.
- The mean vertical marginal discrepancy was measured at 3 lag periodsafter fabrication:

- 24 hours after fabrication
- 2 weeks after fabrication
- 4 weeks after fabrication

Statistical evaluation:

The mean value of marginal discrepancy (μm) at 4 marked points (mesial, distal, labial and lingual) of each unit (2nd premolar and 2nd molar) was taken for statistical evaluation. Statistical analysis was performed using, One way ANOVA, Repeated measure ANOVA and Bonferroni test using SPSS (Statistics software Version 20.0; IBM Corp.) Level of Significance $P \leq 0.05$ was set.

Results:

The following results were obtained from this study which evaluated the marginal accuracy of three different types of provisional restorative materials. The materials were divided into three Groups as Group A (Auto polymerized composite resin), Group B (Light cured composite resin) and Group C (Dual cured composite resin). Each Group had 10 prototypes. Readings were made per prototype at each time interval of 24 hours, 2 weeks and 4 weeks.

Discussion:

The provisional restorations provide pulpal protection from the various chemical, mechanical and biological irritants. It also helps in chewing, speaking and aesthetics. After losing the contact with adjacent teeth, the provisional restorations help in stabilizingthe prepared abutment teeth until the final restoration is made.Provisional restorations can also help the prosthodontist to develop a new occlusal scheme and provide an environment conductive to periodontal health, evaluate and reinforce the patient's oral homecare.[6, 7]

Polymethylemethacrylate is the material of choice for the fabrication of the direct provisional restorations since time immemorial. They have the quite suitable properties in terms of wear resistance, color stability, surface finish andaesthetics. But with the advancement in the material sciences, the newer materials with better properties have taken the place of PMMA. some major drawbacks of the PMMA are monomer leach out, curing shrinkage, exothermic reaction.[29, 37, 38, 39, 40]

The visible light cured (VLC) materials, has camphoroquinone as photoinitiator, which initiates the polymerization process of urethane dimethacrylate in the presence visible light. They also add silica particles as fillers to reduce the curing shrinkage (0.388%).[12] Upon polymerizationVLC materials do not release free monomerrendering improved biocompatibility. There are evidence that VLC materials are cheaper and faster in producing provisional restorations. [43, 44]

In the direct technique, a matrix is fabricated either by vaccum-formed materials or by polyvinyl siloxane (PVC) putty material. PVC matrix can be made directly from the diagnostic wax up but for thermoplastic vacuum-formed materials, a stone cast made from the duplication of the diagnostic wax up is required.Therefore PVC matrix provides better details by providing provisional restorations with better marginal adaptation.[1, 2] Null hypothesis of this study was there is no difference in the marginal accuracy of provisional fixed dental prosthesis produced using commercially available auto-polymerized, light cured and dual cured composite resin by direct technique. Null hypothesis was rejected in this study because significant difference was found in marginal accuracy of Provisional FDP materials at different time intervals.

In this study marginal accuracy of 3 unit FDPs produced from three provisional materials Auto-polymerized composite resin (Protemp 4), Light cured composite resin (Revotek LC) and Dual cured composite resin (Tempspan) were evaluated after they preserved in artificial saliva at room temperature and measurements were made and compared using a stereomicroscope connected with an image analysis software. (Table 2)

The present study results revealed that the mean vertical marginal discrepancy of three unit FDPs produced using dual cured composite resin Group C (Tempspan), light cured composite resin Group B (Revotek LC) and auto cured composite resin Group A (Protemp 4) were 78.18 ± 4.68, 105.76 ± 4.89 and 141.55 ± 3.66 at 24 hours, 102.30 ± 3.87, 138.61 ± 3.63 and 181.79 ± 3.33 at 2 weeks and 116.57 ± 6.68, 150.22 ± 8.77 and 182.30 ± 3.47 at 4 weeks respectively. (Table 3, 4, 5) (Graph 1, 2, 3)

When Group A (Auto-polymerized composite resin) was compared to the Group B (Light cured composite resin) and Group C (Dual cured composite resin), the results where statistically significant ($P \leq 0.05$) and Group A (Auto-polymerized composite resin - Protemp 4) showed better marginal accuracy compared to Group B (Light cured composite resin - Revotek LC) and Group C (Dual cured composite resin - Tempspan). (Table 6, 10) (Graph 4, 8)

This finding can be explained by the fact that the chemical compositions of group A (Auto-polymerized composite resin - Protemp 4) is Bis-EMA (Ethoxylated Bisphenol A Glycol Dimethacrylate) resin matrix, whereas group B (Light cured composite resin - Revotek LC) has UDMA (Urethane Dimethacrylate). The Bis-EMA molecule used in bis-acryl resin in composites has a rigid central structure that reduces its ability to rotate and participate in the polymerization process. The Bis-EMA molecule is less influenced compared to other resin during polymerization. In addition, the fact that Group A (Auto-polymerized composite resin - Protemp 4) is hydrophobic, it ensures minimal water uptake and thus reducing the plasticizer action.[22, 27, 45]

Group A (Protemp 4) was supplied as a cartridge based dispensing system with auto mix technique resulting in a more accurately proportioned and consistent mix and handling of the material was better compared to the other materials used in the study. The results were similar in accordance to previous studies where the concluded auto cured bis-acryl composite resin where better when compared to light cured and dual cure [1, 21, 23, 29, 30, 33]

When group Group B (Light cured composite resin - Revotek LC) was compared to the Group A (Auto-polymerized composite resin - Protemp 4) and Group C (Dual cured composite resin - Tempspan), the results where statistically significant ($P \leq 0.05$) and Group B (Light cured composite resin - Revotek LC) showed decreased marginal accuracy compared to Group A (Auto-polymerized composite resin - Protemp 4) and better marginal accuracy when compared to Group C (Dual cured composite resin - Tempspan). (Table 6, 10) (Graph 4, 8)

The reason can be attributed to the fact that the urethane dimethacrylate-based resin matrix in Group B (Light cured composite resin - Revotek LC) is more susceptible to dissolution than the Bis-acryl matrix. Due to the less filler particles (15-35 % by weight) which slowly leach out, it increases the plasticizing action and thus reducing its mechanical properties ultimately affecting the marginal integrity. The light cure material has tendency to shrink towards the light source, resulting in pull back from the marginal areas resulting in poor marginal adaptation.[27, 33, 45]

When Group C (Dual cured composite resin - Tempspan) was compared to Group A (Auto-polymerized composite resin - Protemp 4) and Group B (Light cured composite resin - Revotek LC), the results where statistically significant ($P \leq 0.05$) and Group C (Dual cured composite resin - Tempspan) showed increased marginal discrepancy. (Table 6, 10) (Graph 4, 8)

The chemical compositions of group C (Dual cured composite resin - Tempspan) has Bis-GMA (Bisphenol A–Glycidyl Methacrylate) and UDMA (Urethane Dimethacrylate) along with matrix of polyfunctional methacrylates EBPADMA (Ethoxylated Bisphenol A Dimethacrylate) and HDDMA (Hexane Diol Dimethacrylate) etc. The large amount of polymerization that takes place at the beginning for the dual cure provisional resin causes increase in mechanical strength at the initial phase of polymerization. Due to this high

initial mechanical strength, flexibility at the partially polymerized stage is reduced which made them difficult to handle thus affecting the marginal integrity.[21, 25, 32, 45]

Group C (Dual cured composite resin - Tempspan) showed less marginal accuracy compared to Group A (Auto-polymerized composite resin - Protemp 4) and Group B (Light cured composite resin - Revotek LC) due to high reaction rate, density of cross links at the same time low degree of conversion. The presence of barium glass filler in the composition which are more susceptible to aqueous attack compared to quartz fillers as seen in Group B (Light cured composite resin - Revotek LC also the presence of oxygen inhibiting layer leading to voids in the critical marginal areas.[27, 31, 45, 47, 48]

These results are comparable to previous studies conducted where they concluded that temporary crowns produced from a dual-cured composite provisional material are likely to exhibit significantly more marginal discrepancy than auto cure bis-acryl provisional material and handling techniques play a vital role in marginal integrity of provisional restorations. [1, 21, 25]

One of the limitations of this study was that measurements obtained in vitro may not be similar to that of the oral environment. The arch curvature, length of span and different pontic design were not taken into consideration as these factors may affect the marginal integrity. Another limitation of this study was that only three provisional restorative materials were used which may not be applicable to other materials.

Interim resin materials lose the close marginal adaptation over a period of time. Each brand of resin with newer and better properties must be checked separately for their sustainability in the oral environment. Further studies of the relationship between physical properties and clinical performance are needed to guide development of more durable and accurate materials especially for long span interim restoration.

Conclusion:

Considering the limitations of this study, the following conclusions can be drawn from the results:

1. The mean vertical marginal discrepancy of auto-polymerized composite resin (Protemp 4) was least than that of the light cure composite resin (Revotek LC) and dual cure composite resin (Tempspan).
2. Auto-polymerized composite resin (Protemp 4) shows better marginal accuracy for long term as compared to light cure composite resin (Revotek LC) and dual cure composite resin (Tempspan) after fabrication of provisional FDPs.
3. Provisional FDPs produced from a dual cure composite resin (Tempspan) exhibit significantly higher marginal gap than auto polymerized and light cure composite resin.

Conflict of interest: None

Tables and Graphs:

Table 1: Three commercially available provisional restorative materials

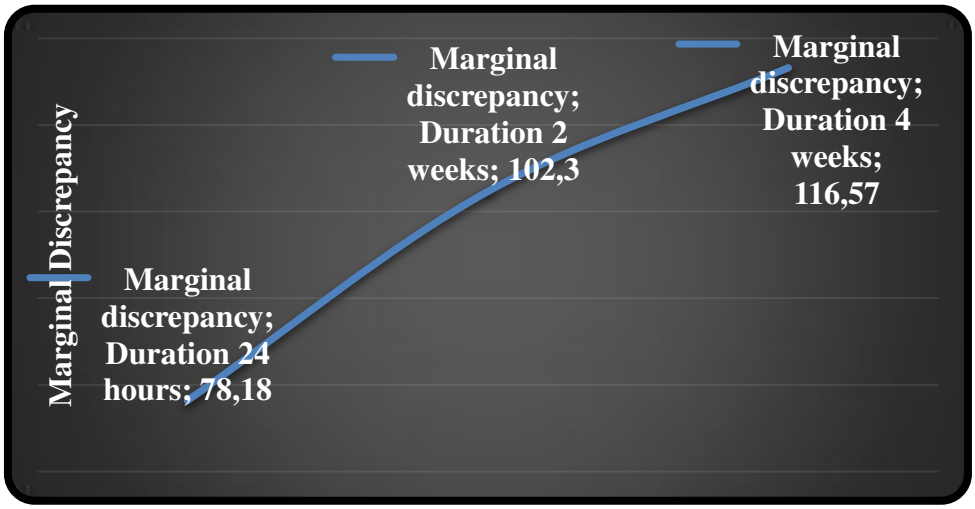
SR. NO	MATERIAL	BRAND NAME	COMPANY NAME
1.	Autopolymerized composite resin	PROTEMP 4	3M ESPE
2.	Light cured composite resin	REVOTEK LC	GC
3.	Dual cured composite resin	TEMPSPAN	PENTRON CLINICAL

Table 2: Mean and standard deviation (SD) for marginal discrepancy of Group A (Autopolymerized composite resin – Protemp 4) at various time intervals

Time	Numbers	Marginal Discrepancy (µm)		F Value	P Value
		Mean	SD		
24 hour	10	78.18	4.68	138.270	≤ 0.05 *
2 weeks	10	102.30	3.87		
4 weeks	10	116.57	6.68		

(Level of significance P ≤ 0.05, * Significant Result)

Marginal discrepancy value was at 78.18 ± 4.68 at 24 hours, 102.30 ± 3.87 at 2 weeks and 116.57 ± 6.68 at 4 weeks in Autopolymerized composite resin group. Statistically, significant changes were present in marginal discrepancy in Protemp 4 from 24 hours to 4 weeks.



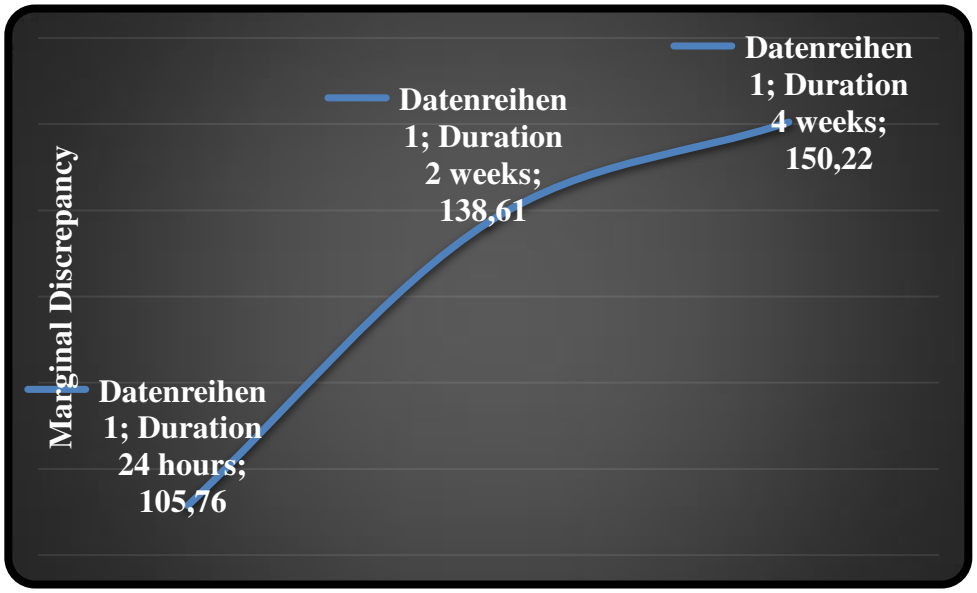
Graph 1 : Mean for marginal discrepancy of Group A at various time intervals

Table 3: Mean and standard deviation (SD) for marginal discrepancy of Group B (Light cured composite resin – Revotek LC) at various time intervals

Time	Numbers	Marginal Discrepancy (µm)		F Value	P Value
		Mean	SD		
24 hour	10	105.76	4.89	139.739	≤ 0.05 *
2 weeks	10	138.61	3.63		
4 weeks	10	150.22	8.77		

(Level of significance P ≤ 0.05, * Significant Result)

Marginal discrepancy was 105.76 ± 4.89 at 24 hours, 138.61 ± 3.63 at 2 weeks and 150.22 ± 8.77 at 4 weeks in Light cured composite resin group. Statistically, significant changes were present in marginal discrepancy in Revotek LC from 24 hours to 4 weeks.



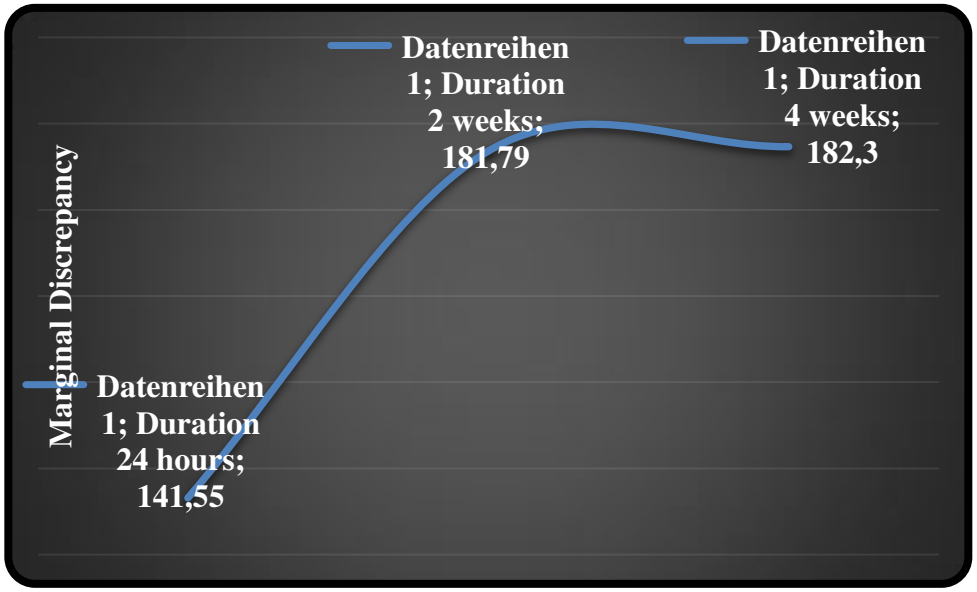
Graph 2 : Mean for marginal discrepancy of Group B at various time intervals

Table 4 : Mean and standard deviation (SD) for marginal discrepancy of Group C (Dual cured composite resin – Tempspan) at various time intervals

Time	Numbers	Marginal Discrepancy (µm)		F Value	P Value
		Mean	SD		
24 hour	10	141.55	3.66	448.297	≤ 0.05 *
2 weeks	10	181.79	3.33		
4 weeks	10	182.30	3.47		

(Level of significance P ≤ 0.05, * Significant Result)

Marginal discrepancy value was 141.55 ± 3.66 at 24 hours, 181.79 ± 3.33 at 2 weeks and 182.30 ± 3.47 at 4 weeks in Dual cured composite resin group. Statistically, significant changes were present in marginal discrepancy in Tempspan from 24 hours to 2 weeks whereas no significant difference were present from 2 weeks to 4 weeks.

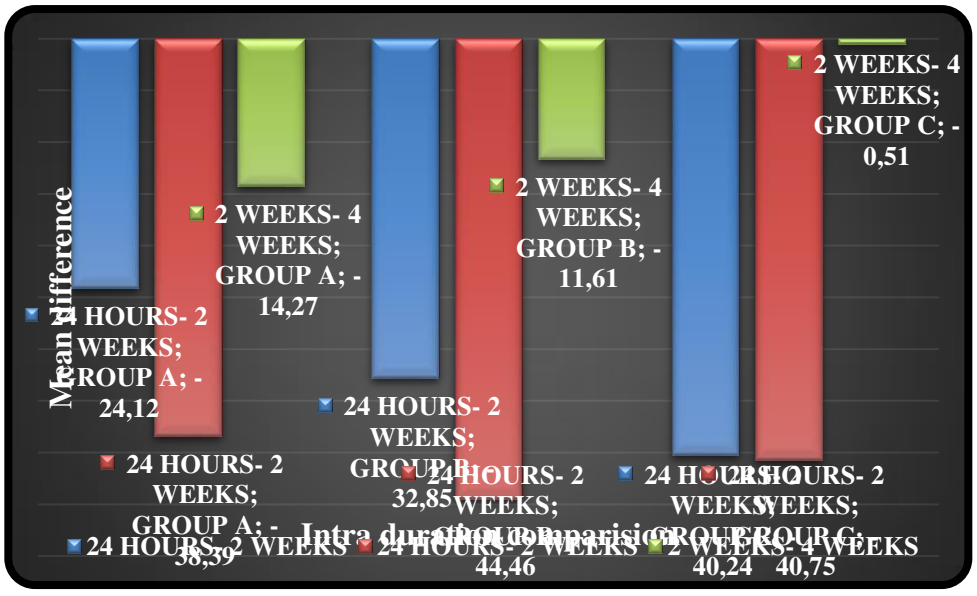


Graph 3 : Mean for marginal discrepancy of Group C at various time intervals

Table 5 : Multiple comparisons within the groups for marginal discrepancy at various time intervals

Group	Time		Difference	P Value
Group A	24 hours	2 weeks	-24.12	≤ 0.05 *
		4 weeks	-38.39	≤ 0.05 *
	2 weeks	4 weeks	-14.27	≤ 0.05 *
Group B	24 hours	2 weeks	-32.85	≤ 0.05 *
		4 weeks	-44.46	≤ 0.05 *
	2 weeks	4 weeks	-11.61	≤ 0.05 *
Group C	24 hours	2 weeks	-40.24	≤ 0.05 *
		4 weeks	-40.75	≤ 0.05 *
	2 weeks	4 weeks	-00.51	> 0.05 **

(Level of significance P ≤ 0.05, * Significant Result, ** Non Significant Result)

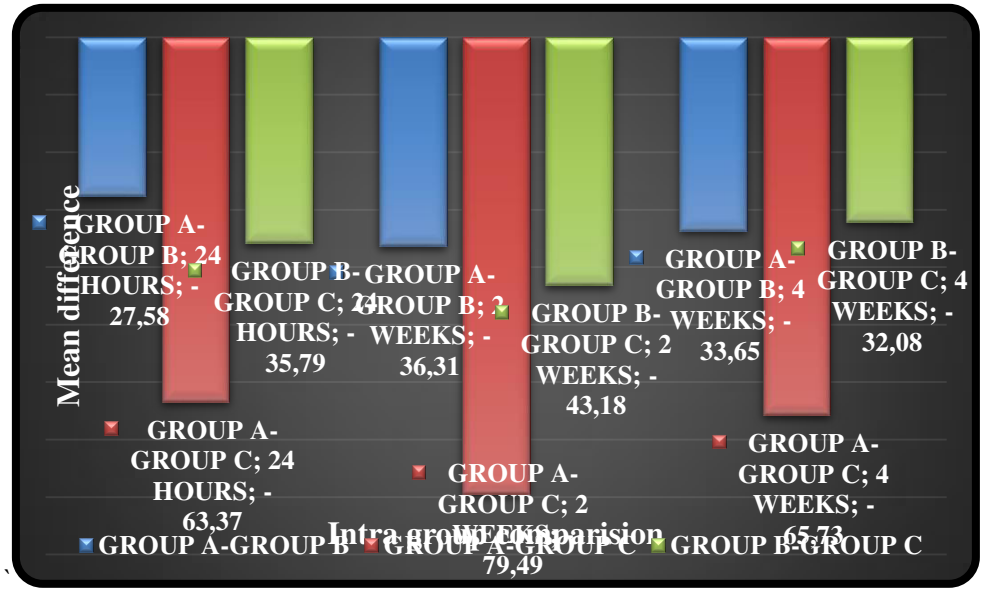


Graph 4 : Mean difference in marginal accuracy within three groups at various time intervals

Table 6 : Multiple comparisons within the groups for marginal discrepancy at various time intervals

Time	Group		Difference	P Value
At 24 hours	Group A	Group B	-27.58	≤ 0.05 *
		Group C	-63.37	≤ 0.05 *
	Group B	Group C	-35.79	≤ 0.05 *
At 2 weeks	Group A	Group B	-36.31	≤ 0.05 *
		Group C	-79.49	≤ 0.05 *
	Group B	Group C	-43.18	≤ 0.05 *
At 4 weeks	Group A	Group B	-33.65	≤ 0.05 *
		Group C	-65.73	≤ 0.05 *
	Group B	Group C	-32.08	≤ 0.05 *

(Level of significance P ≤ 0.05, * Significant Result, ** Non Significant Result)



Graph 5 : Mean difference in marginal accuracy within three groups at various time intervals

Figures **:**

Figure 1 : Schematic representation of die

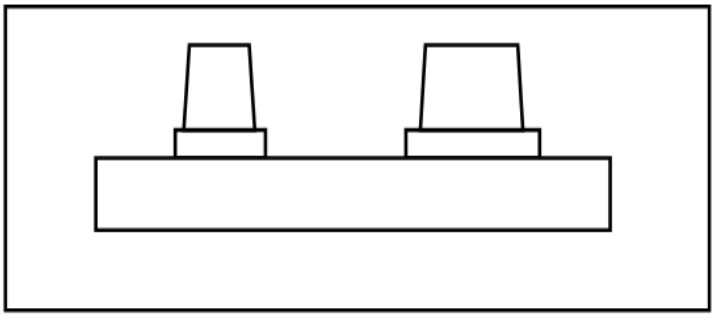


Figure 2 : Stainless steel die

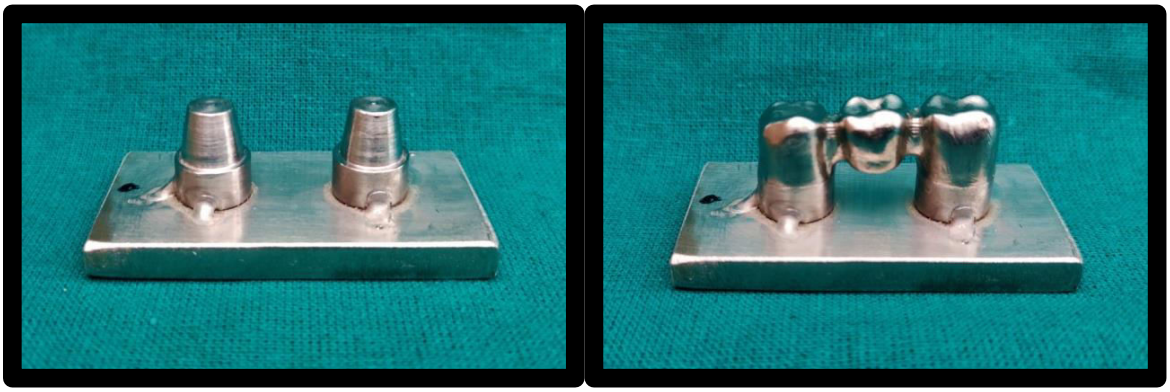


Figure 3 : Custom tray and Polyvinyl Siloxane matrix

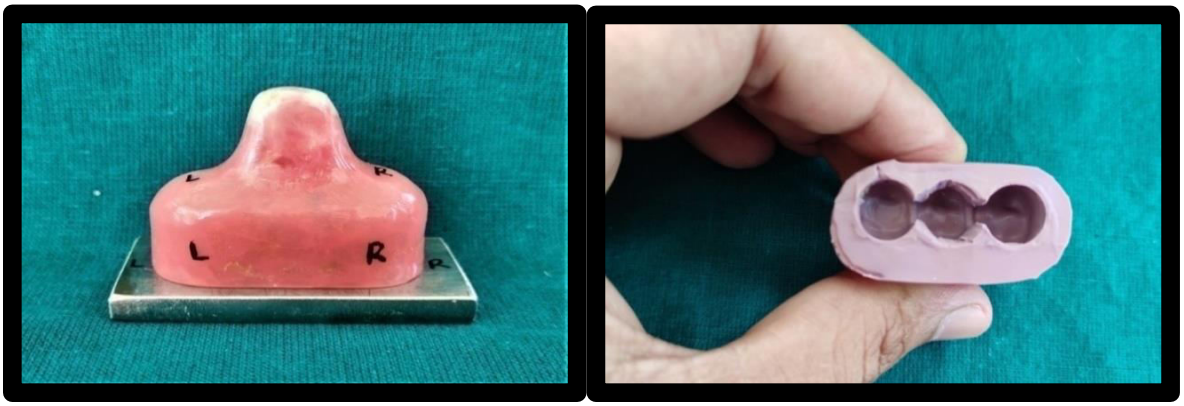


Figure 4 : Prototype fabrication

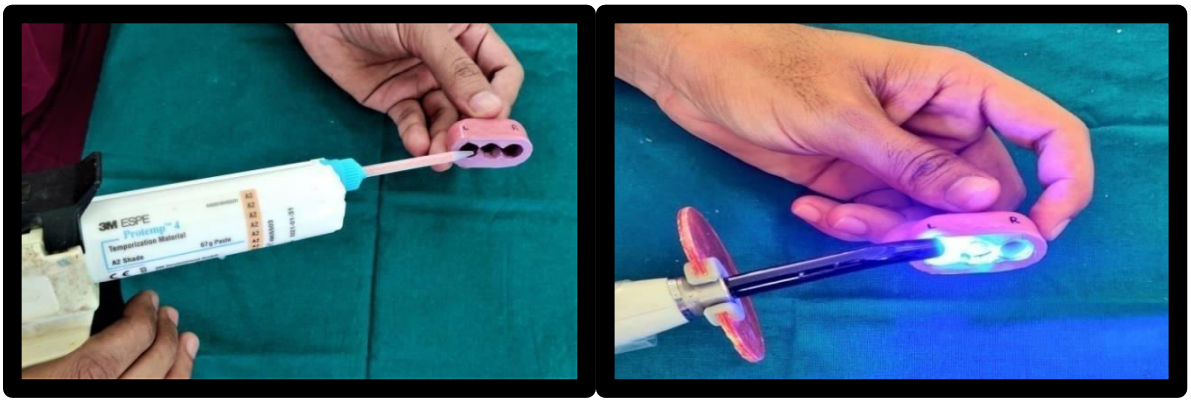


Figure 5 : Vacuum forming machine and Vacuum formed matrix

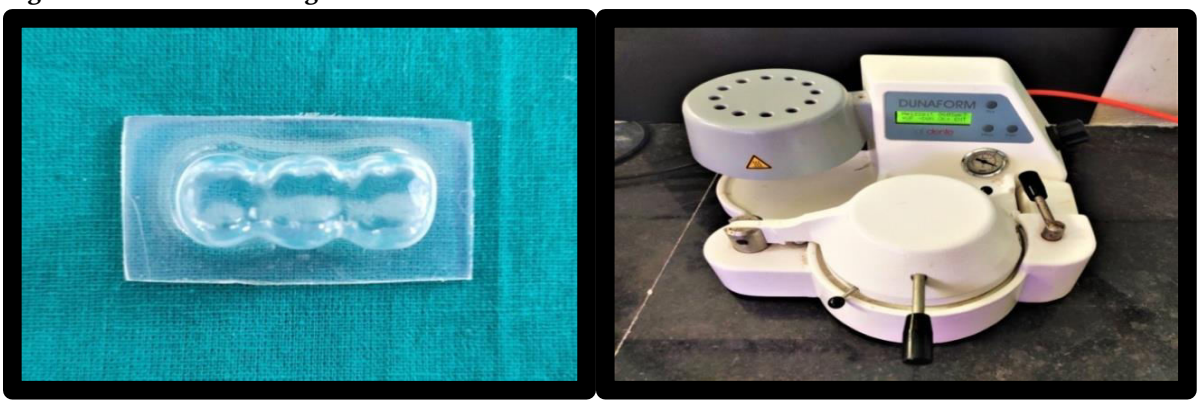


Figure 6 : Total prototypes and Sectioning of FDP

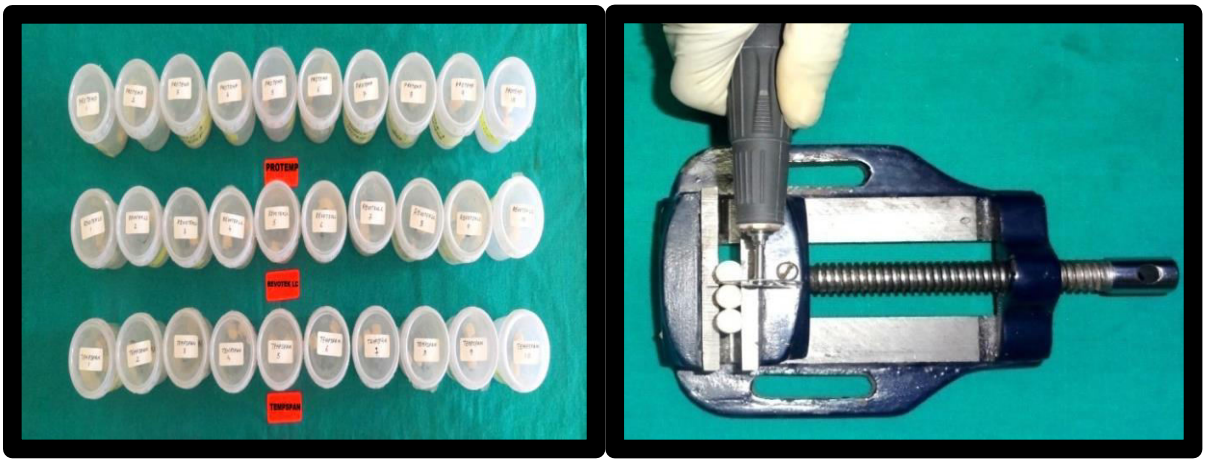


Figure 7 : Image of Marginal discrepancy and Stereomicroscope with Camera and installed Image Analysis Software (Magnification 20 X)