COMPARATIVE EVALUATION OF THE EFFECT OF NANODIAMOND NANOPARTICLE REINFORCEMENT AND DIE SYSTEM ON MARGINAL FIT AND MICRO LEAKAGE OF PROVISIONAL CROWNS WITH POLYMETHYL METHACRYLATE - AN IN VITRO STUDY.

Dr Shah Shikha H[1], Dr Gupta Kavita[2], Dr Bora Pranit[3], Dr Sethuraman Rajesh[4], Dr Patel Bindal[5]

Abstract

The aim of this study was to evaluate and compare the marginal fit and microleakage of provisional crown fabricated from polymethyl methacrylate (PMMA) and Nanodiamond modified Polymethyl methacrylate (PMMA) on two different die systems. 44 molars received, and provisional crowns were fabricated according to: Group A: Fabrication on die stone using PMMA. Group B: Fabrication on die stone using PMMA reinforced with Nanodiamond Nanoparticles. Group C: Fabrication on the flexible die using PMMA. Group D: Fabrication on the flexible die using PMMA reinforced with Nanodiamond Nanoparticles. Then marginal discrepancy evaluated with silicone impression replica technique. After the cementation and thermo cycling crowns were stained in 2% methylene blue. Followed by sectioning on buccolingualy and evaluated under a stereomicroscope to obtain digital images. Images were then analysed in software to obtain values for microleakage. Then One-way ANOVA and post-hoc Tukey test was performed. For Marginal accuracy according to ANOVA, the difference is statistically significant with a p-value of 0.015. According to Post-hoc Tukey test the difference between GROUP A and D is statistically significant with a mean difference of 7.95. For Microleakage, according to ANOVA, the difference is statistically significant with a p-value of <0.001. According to the Post-hoc Tukey test, a statistically significant difference was found between all groups.Within the limitations of the study, it can be concluded that in comparison with crowns fabricated using conventional PMMA resin on stone die, the crowns fabricated using reinforced PMMA resin with flexible dies showed less microleakage and marginal discrepancies. Results are within clinically acceptable values. Provisional crowns made with PMMA reinforced with nanodiamond on a flexible die have reduced microleakage.

Keywords: Flexible die, Nanodiamond Nanoparticle, Marginal fit, Microleakage, Provisional crown, Stone die.

[1]Post Graduate Student, The Department Of Prosthodontics Crown & Bridge, K M Shah Dental College And Hospital, Sumandeep Vidyapeeth, Vadodara.
[2]Professor, the Department Of Prosthodontics Crown & Bridge, K M Shah Dental College and Hospital, Sumandeep Vidyapeeth, Vadodara.
[3]Post Graduate Student, The Department Of Prosthodontics Crown & Bridge, K M Shah Dental College And Hospital, Sumandeep Vidyapeeth, Vadodara.
[4]Head & Professor, The Department Of Prosthodontics Crown & Bridge, K M Shah Dental College And Hospital, Sumandeep Vidyapeeth, Vadodara.
[5]Post Graduate Student, The Department Of Prosthodontics Crown & Bridge, K M Shah Dental College And Hospital, Sumandeep Vidyapeeth, Vadodara.

Introduction

Provisional restorations are an extremely important part of fixed prosthodontic treatment. They are fabricated to improve the aesthetics, stability, form and function of teeth for a short period of time until provisional restorations are to be replaced by definitive restorations[1, 2].

A well-fabricated provisional restoration should have ability [3, 4].

- To protect the pulp of prepared teeth,
- Protect the teeth from dental caries,
- Maintain periodontal health,
- Provide a method for immediate replacement of missing teeth, and
- Provide positional stability of the prepared teeth in relation to adjacent and opposing teeth.

The material used to fabricate the provisional needs to fulfill the above mechanical, biological, and aesthetic criteria. There are heat-polymerized and auto-polymerized acrylic resins are available.

Auto-polymerizing acrylic resin is used most frequently but there have been several problems of using poly methyl methacrylate acrylic resin for the fabrication of provisional restorations. Despite its popularity, it has not fulfilled all the requirements in terms of optimal biological properties. Difficulties may be expected with extensive prosthodontic treatment where provisional restorations must be used for a longer time or with long-span provisional bridges.

One of the most serious problems is poor marginal adaptation because of a lack of marginal accuracy. So, due to inappropriate marginal accuracy, there is a tendency for microleakage that leads to increasing the chances of caries, pulpal inflammation or even pulpal degeneration in the case of vital teeth [4].

So, to overcome this all problems, the newer technique of reinforcing different polymers with Nano-diamond Nanoparticle has been reported in the literature [4].

Although fabrication technique is also important for marginal accuracy of provisional crown. There are two techniques: Direct fabrication and indirect fabrication.

Indirect fabrication technique is the most frequently used method for the fabrication of the provisional crown and produced greater marginal accuracy than a direct technique [5, 6].

Indirect technique is associated with the dimensional stability of die materials.

Die materials currently available include[7].

- Improved dental stone,
- Resin-reinforced stone,
- Epoxy resin,
- Metals (silver and copper plated),
- Polyurethane resin and
- Flexible die material (polyether).

According to the International Standard of Organization type IV and V dental stone are the most widely used die materials this is because of their excellent dimensional accuracy, low cost, and ease of use. However, Gerrow J. et al. Stated that dies made with flexible die material (Impregum) with Vinyl polysiloxane impression material produced better surface detail reproduction then control dies (Type IV dental stone)[8].

One of the most important requirements for an interim restoration is good marginal adaptation. Poor marginal fit allows passage of fluids and bacteria in to the gap and may predispose the tooth to caries and pulpitis. In addition, poorly adapted interim restorations cause mechanical irritation to surrounding tissues and enhance plaque accumulation with subsequent periodontal problems.

A comprehensive search as on PubMed, EBSCO, and MEDLINE did not show any literature on a comparative evaluation of the effect of Nanodiamond Nanoparticles and different die systems on marginal fit and microleakage of PMMA crown.

Hence there exists a need to measure and compare the effect of adding Nanodiamond Nanoparticles on the Marginal fit of Provisional crowns fabricated on two different dies.

The purpose of this in vitro study is to investigate the marginal fit and microleakage of provisional crowns with or without Nanoparticles on two different dies. The ultimate goal of the study is to find the optimal combination of Nanodiamond Nanoparticle and dispersants to reinforce provisional PMMA resin.

Material and Methodology

This study was planned for the evaluation of the effect of two different die systems and the incorporation of Nanoparticles in the PMMA matrix on microleakage in provisional crown. Approval to conduct the study was obtained from the Institutional ethical committee.

Methodology done under the following title:

1. Collection of teeth
2. Preparation of teeth
    a. Mounting
    b. Fabrication of putty index

c. Tooth preparation

3. Making an impression and die preparation
4. Dispersion of the nanoparticle into the monomer
5. Fabrication of provisional crown
6. Categories of provisional crowns
7. Measurement of marginal discrepancy/impression replica method
8. Cementation of provisional crown
9. Thermo cycling
10. Testing for microleakage

44 freshly extracted molars were collected from the Department of Oral and Maxillofacial Surgery, K. M. Shah Dental College and Hospital, Vadodara. The teeth were disinfected using 10% formalin and the roots of the molars were painted with nail varnish up to 1mm beyond the cementoenamel junction and mounted on acrylic blocks using cold-cured resin (DPI).(Fig. 1) The index for each sample was made using Polyvinyl siloxane impression (3M ESPE, Germany) putty index material. Then Tooth preparations were completed at the level of dentin at a cementoenamel junction with a chamfer finish line of 1.2 mm. (Fig. 2)

Figure 1: Mounted Tooth on acrylic blocks using cold-cured resin

Figure 2: Tooth preparations using standard protocol

All the specimens were numbered and Impressions were made using Polyvinyl siloxane impression (Monophase impression material, Imprint^{Tm}II, 3M ESPE, Germany) by the monophase impression technique. All the impressions were inspected for accurate margin reproduction and defects examined under magnification. All impression divided into 2 main group 22 each.

- Group 1 of polyvinyl siloxane impression was poured in die stone (Type IV, Uni base 300, Dentona) (Fig. 3)
- Group 2 of polyvinyl siloxane impression was poured in flexible die material. (Fig. 4)

Figure 3: Die made up of Die-stone

Figure 4: Die made up of Flexible die

(Heavy body Polyether)

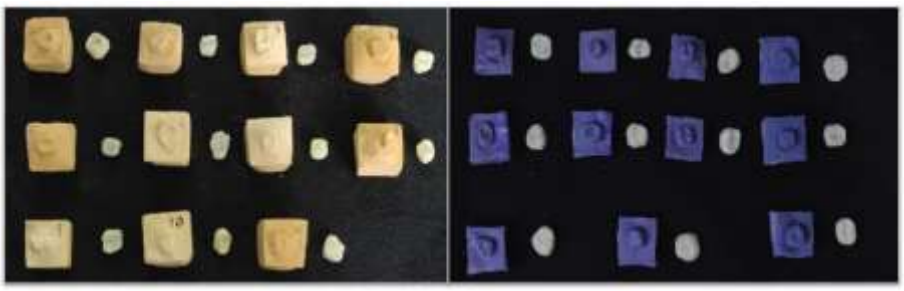
Then, 0.10 wt % of Nanodiamond Nanoparticle (Nanodiamonds, purified, grade G01, Reinste, Nanoventures) (Fig. 5) was dispersed in the monomer by excessive stirring at 800rpm for 10 minutes under sonication. Provisional crowns were fabricated on two different dies with two different materials, one was Polymethyl Methacrylate (PMMA) and the other being Polymethyl methacrylate (PMMA) reinforced with Nanodiamonds Nanoparticles, using a putty index.

Figure 5: 0.10 % Nanodiamond Nanoparticle dispersed into monomer under sonication

Acc

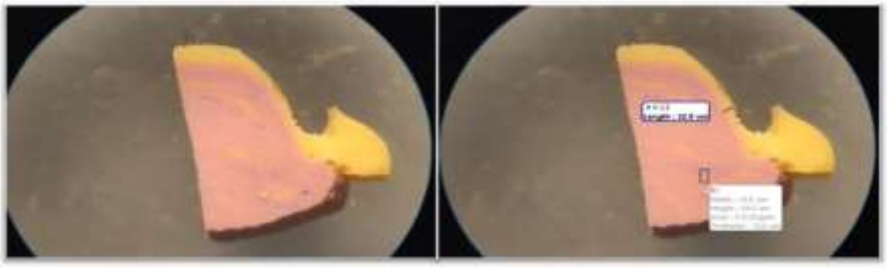
ording to fabrication of Provisional crowns both groups were further divided into 4 groups of 11 each. (Fig. 6)

Figure 6: Provisional crowns



Group A: Fabrication of provisional crown on die stone using Polymethyl Methacrylate;
Group B: Fabrication of provisional crown on die stone using Polymethyl methacrylate reinforced with Nanodiamond Nanoparticle.
Group C: Fabrication of provisional crown on flexible die material using Polymethyl Methacrylate;
Group D: Fabrication of provisional crown on flexible die material using Polymethyl methacrylate (PMMA) Reinforced with Nanodiamond nanoparticles.
Fabricated crowns were evaluated for the marginal discrepancy with the silicone impression replica technique. The replica impression was then evaluated for buccal, lingual, mesial, and distal area marginal discrepancy using a stereomicroscope and Motic image plus 2.0 program. (Fig. 7)

Figure 7: Digital photograph of a section taken under a stereomicroscope and measured using Motic image plus 2.0 program.



Then the crowns were cemented. After cementation, all the specimens were thermo cycled using two water baths. The specimens were immersed for 20 s in each of the baths: first in the 5°C bath and then in the 60°C bath with an interval of 10 s between the two immersions. With this protocol, 250 cycles were conducted for each sample. After thermo cycling was completed, the samples were immersed in a 2% methylene blue solution for 1 hour. Samples were then washed under running water for 15 min to remove any superficial excess stains. The stained specimens were obtained. Next, the buccal and lingual surfaces of the mounted specimens were marked, using the height of the contour as the reference. Subsequently, the specimens were embedded in polymethyl methacrylate (pink color) resin using a putty index. (Fig. 8) Figure 8: Embedded In Polymethyl-methacrylate Resin

Later, they were sectioned vertically in a buccolingual direction by a die-cutting machine

and each section of the specimen was digitally photographed under a stereomicroscope (Motic China group co., Ltd, China) at 100x magnification with a DSLR camera. (Fig. 9) These images were then transferred to a personal computer. The length of dye penetration was determined by Motic image analysis software. Photographs of the specimens were assessed at each marginal point and

scoring was done using the criteria proposed by Tjan et al [9].

Figure 9: Digital photograph of a section taken under stereomicroscope and measuring using Motic image plus 2.0 program.

Score Description

0—No microleakage.

1—Microleakage less than 1/3rd the axial wall length.

2—Microleakage more than 1/3rd but less than 2/3rd the axial wall length.

3—Microleakage all along the axial wall length.

4—Microleakage on the occlusal surface.

The scoring was done by another independent observer. The obtained data was then subjected to one way ANOVA test and Post Hoc test.

Results

The Oneway ANOVA (Table 1 & 3) followed by Post-Hoc Tukey test (Table 2 & 4) showed a significant difference among the groups (p value < 0.001). The mean values show that the marginal discrepancy and micro leakage was highest in Group A (43.56 µm ± 4.62 SD) & (31.78µm ± 3.13 SD) and least for Group D (35.61µm ± 4.09 SD) & (10.83µm ± 2.72 SD). Provisional crowns made on stone die without incorporation of Nanodiamond Nanoparticle shows more marginal discrepancy of 43.56 ± 4.62 µ compared to Provisional crowns made on stone die with incorporation of Nanodiamond Nanoparticle which showed a marginal discrepancy of 39.10 ± 7.13 which is not statistically significant (p 0.245). Provisional crowns made on stone die without incorporation of Nanodiamond Nanoparticle shows more marginal discrepancy of 43.56 ± 4.62 µ compared to Provisional crowns made on flexible die without incorporation of Nanodiamond Nanoparticle which showed a marginal discrepancy 40.48±5.69 which is not statistically significance(p value 0.561). Provisional crowns made on stone die without incorporation of Nanodiamond Nanoparticle shows more marginal discrepancy of 43.56 ± 4.62 µ compared to Provisional crowns made on flexible die with incorporation of Nanodiamond Nanoparticle which showed a marginal discrepancy 35.61 ± 4.09 µ, which is statistically significant (p value 0.008).

Table 1: Summary statistics (ANOVA) for marginal fit

Group	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum	ANOVA P VALUE
					Lower Bound	Upper Bound			
A	11	43.56	4.62	1.32	34.76	52.36	36.07	51.8	0.015
B	11	39.10	7.13	1.91	24.84	53.36	28.32	47.65	
C	11	40.48	5.69	1.63	29.10	51.86	33.30	50.52	
D	11	35.61	4.09	1.17	27.43	43.79	30.22	40.57	
Total	44	35.61	4.09	1.17	24.84	43.79	28.32	40.57	

Table 2: Summary of Post Hoc Tukey test for marginal fit

(I) GROUP	(J) GROUP	Mean Difference (I-J)	Std. Error	P VALUE
A	B	4.46	2.35	0.245
A	C	3.08	2.35	0.561
A	D	7.95*	2.35	0.008

B	C	-1.37	2.35	0.935
B	D	3.49	2.35	0.456
C	D	4.87	2.35	0.18

Table 3: Summary statistics (ANOVA) for micro leakage

Group	**N**	**Mean**	**Std. Deviation**	**Std. Error**	**95% Confidence Interval for Mean**		**Minimum**	**Maximum**	**ANOVA P VALUE**
					Lower Bound	Upper Bound			
A	11	31.78	3.13	0.94	25.22	38.34	25.95	37	<0.001
B	11	26.16	1.11	0.33	23.82	28.5	23.8	28.55	
C	11	19.68	2.65	0.79	14.12	25.24	13.8	23	
D	11	10.83	2.72	0.82	5.13	16.53	6.7	15.25	
Total	44	22.11	2.40	0.72	17.07	27.15	17.56	25.95	

Table 4: Summary of Post Hoc Tukey test for micro leakage

(I) GROUP	**(J) GROUP**	**Mean Difference (I-J)**	**Std. Error**	**P VALUE**
A	B	5.61*	1.12	<0.001
A	C	12.10*	1.12	<0.001
A	D	20.94*	1.12	<0.001
B	C	6.48*	1.12	<0.001
B	D	15.32*	1.12	<0.001
C	D	8.84*	1.12	<0.001

Provisional crowns made on stone die without incorporation of Nanodiamond Nanoparticle shows more microleakage of 31.78 ± 3.13 µ compared to Provisional crowns made on stone die with incorporation of Nanodiamond Nanoparticle which showed a microleakage of 26.16 ± 1.11 which is statistically significant (p< 0.001). Provisional crowns made on stone die without incorporation of Nanodiamond Nanoparticle shows more microleakage of 31.78 ± 3.13 µ compared to Provisional crowns made on flexible die without incorporation of Nanodiamond Nanoparticle which showed a microleakage 19.68±2.65 which is statistically significance(p value <0.001). Provisional crowns made on stone die without incorporation of Nanodiamond Nanoparticle shows more microleakage of 31.78 ± 3.13 µ compared to Provisional crowns made on flexible die with incorporation of Nanodiamond Nanoparticle which showed a micro leakage 10.83 ± 2.72 µ, which is statistically significant (p value < 0.001).

Discussion

Accurate crown margins, depends on various factors involved in fabrication of provisional crown such as type of material, fabrication technique.

Material

- Auto polymerized polymethyl methacrylate (PMMA) resins and
- Bis-acrylic resin have been widely used in the fabrication of interim fixed restorations.

But one of the major limitation of PMMA material is polymerization shrinkage. Shrinkage produces distortion that may have negative effects on the precise fit of provisional crowns

and it may also produce internal stresses within the restoration [5, 19, 11].

Bis-GMA composites are also available but Adnan S et Al.[12, 13] stated in there study had shown that they tend to break when placed in areas of moderate stress. So, for these reasons a new era of reinforcing PMMA resin with Nanoparticles has inevitably dawned in order to improve the properties of PMMA resin.

Nanoparticle according to'

- Ravindranath C et al[14] suggested Zro_2 ,Tio_2 and other metal oxides with 3% volume
- Yasangi et Al[10] suggested glass fibre with 6% volume and
- Popi p et al [11] suggested Nanodiamond Nanoparticles at 0.10 % volume which will increase the mechanical properties of PMMA.

In the present study Nanodiamond Nanoparticle is used as a reinforcing agent because of following reasons:

- It create a chemical bond to the polymer matrix which is hard to break[15].
- It is used in very low concentrations[11].
- It showed less cytotoxic effect on human cell[15].
- It decreases the polymerization shrinkage [15].

Fabrication technique:-

Indirect technique is the most frequently used method for fabrication of the provisional crown. Crispin et al[16] and Mondey et al[6] showed that an indirect technique produced provisional restorations with greater marginal accuracy than a direct technique.

Indirect technique is associated with the dimensional stability of die materials

Die materials that are currently available includes improved dental stone, resin reinforced stone, epoxy resin, metals (Silver and copper plated), polyurethane resin and flexible die material (polyether and medium body PVS).

- Moulding et al[17] compared the marginal accuracy of provisional crown made on polyvinyl siloxane flexible die model & stone model, and reported that there were no significant differences found among the control, stone casts, and medium-viscosity polyvinyl siloxane flexible die groups.

In the present study polyether flexible die material was used to fabricate provisional crown because of following reasons: [17]

- More rapid setting time.
- Easy of removal of provisional restoration.
- Easy of handling.
- Easy repair or remake of the interim restorations

G. Boberic et al[18] in 1998, stated in their research that a heavy-bodied material is recommended as flexible die material because of its stiffness and lesser tendency to distort during procedures. So for this reason heavy-body polyether elastomer was used as a flexible die material in this study.

Marginal Accuracy

McLean et Al. and Fransson et al[3]. Stated that after cementation the satisfactory marginal gap should be less than 120 µm and 150 µm respectively. The greater values of marginal discrepancy may compromise the biological and periodontal integration of the crown and FDP's. The mean marginal discrepancies for die stone group was 45.647µm and that for the flexible die group was 43.049µm which were lesser than the post luting clinically accepted marginal gap of 120 µm.

In the present study for the purpose of standardization, resin based temporary luting cement was used with film thickness of 5 µm as mentioned by manufacturer.

So, the null hypothesis that stated, no difference in marginal adaptation amongst the four groups was partially rejected, Group-A and Group-D showed statistically significant difference with a mean difference of 7.95 and p value of 0.008.

Micro-leakage

In the present study, Group A has shown the highest score and highest value of micro leakage, 31.78 ± 3.28 SD and group D has least value of micro leakage 10.83 ± 2.85 SD.

This is because of less polymerization shrinkage of reinforced provisional crown.

"As found in literature Nanodiamond Nanoparticle reduces the volumetric changes, which lead to less shrinkage in dental resin. We know that microleakage is related to dimensional changes of provisional crown materials due to polymerization shrinkage."

And also because of accurate detail reproduction of flexible die which made crown more precise and accurate.

Gerrow J et al[8] in 1998 concluded that dies made on flexible die(polyether) produced a better surface detail reproduction and study done by popi et al[11] in 2011 who demonstrated that with the addition of ND Nanoparticle the overall mechanical properties of interim prostheses were improved. Research results of

our study demonstrated the same results, wherein Group D showed excellent marginal accuracy and least microleakage.

Conclusion

The result of this study lead to the following conclusions:

- All specimens showed marginal discrepancy and microleakage within the clinical acceptable value.
- Marginal discrepancy of reinforced provisional crowns fabricated on flexible die is less when compared to unreinforced provisional crown fabricated on Conventional type IV die stone.
- When Nanodiamond Nanoparticle was used with PMMA for fabrication of provisional crowns, it significantly effects the marginal fit and micro leakage of crowns. So it can be inferred that using reinforced PMMA for fabrication of provisional crowns, significantly improves the marginal fit and micro leakage of crowns.

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