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Research Article

A Comparative Study on the Marginal Fit of Fixed Prosthesis Made by Over Refractory Technique, Conventional Technique and CAD-CAM - An *Invitro* Study

Sushma Reddy[1], Chandrasekharan Nair K[2]*, Jaykar Shetty[3] and Viswanath Gurumurthy[4]

[1]Former Reader, Department of Prosthodontics, Narayana Dental College, Nellore, Andhra Pradesh, India

[2]Professor Emeritus, Department of Prosthodontics, Sri Sankara Dental College, Akathumuri, Thiruvananthapuram, Kerala, India

[3]Former Professor, Department of Prosthodontics, AECS Maaruti College of Dental Sciences, Bangalore, India

[4]Associate Professor, Department of Dental Technology, College of Applied Medical Sciences, King Khalid University, KSA

***Corresponding Author:** K Chandrasekharan Nair Professor Emeritus, Department of Prosthodontics, Sri Sankara Dental College, Akathumuri, Thiruvananthapuram, Kerala, India. **ORCID Id.** https://orcid.org/0000-0003-3114-3015

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Abstract

Purpose of the study: Technical and biological acceptance of a fixed dental prosthesis, to a great extent is dictated by the marginal integrity. It is essential to find out the appropriate technique that provides better marginal adaptability for fixed partial denture framework fabricated with different materials and techniques.

Objectives:

To find out and compare

- The effect of conventional and over refractory casting techniques on the marginal fit of fixed partial denture framework.
- The role of materials viz. nickel Chromium, commercially pure titanium and pressable ceramic on the marginal fit of fixed partial denture framework.
- The effect of different fabrication techniques viz-Casting and CAD/CAM(milling) on the marginal adaptation of fixed partial denture framework.

Materials and Methods: A metal model consisting of three full crown preparations was created to simulate a five unit fixed partial denture situation. The metal model was duplicated in dental stone and in refractory investment materials. The stone casts were used for the conventional casting technique and the refractory casts were used for the over refractory technique. In conventional technique wax pattern was removed from the stone cast and invested where as in over refractory cast technique wax pattern was invested along with refractory cast. To compare the casting technique and CAD/CAM technique one zirconia framework was made using CAD/CAM. Castings were seated on the metal die and the marginal gap was measured under stereo microscope. Data was statistically analyzed with ANOVA.

Results: In conventional technique the mean marginal gap values obtained were - for Nickel chromium (78.21µm ± 4.45µm), Commercially pure Titanium (60.51 µm ± 3.04 µm) and lithium disilicate-pressable Ceramic (39.70 µm ± 3.51µm). In over refractory technique the mean marginal gap values obtained were - for Nickel chromium (39.48 µm ± 3.90 µm), Commercially pure Titanium (31.15 µm ± 2.08 µm) and lithium di silicate-pressable Ceramic (21.28 µm ± 2.48 µm). The marginal gap value obtained for Zirconia with CAD/CAM technique was 16.92 µm ± 2.65 µm. Statistical analysis showed that the effect of conventional casting technique, over refractory casting technique and CAD/CAM technique were statistically significant.

Conclusions

- Over refractory technique showed lesser marginal gap when compared to that of Conventional technique.
- Among the materials used for castings the highest gap was seen in Nickel Chromium followed by Commercially pure Titanium and then by pressable Ceramic both in Conventional and Over refractory techniques.
- When Conventional, Over Refractory and CAD/CAM techniques were compared, lowest marginal gap was seen in CAD/CAM technique with Zirconia.

Keywords: Conventional Casting Technique; Over Refractory Casting Technique; CAD/CAM Technique

Introduction

Marginal adaptation of fixed prosthesis is a critical factor that dictates biological and mechanical success. A misfit at the margin can lead to exposure of the luting cement to oral fluids which will ultimately lead to its dissolution. The space thus created can harbour plaque and which can subsequently initiate the disease process [1]. Marginal gap has been considered as an index of the fit of the restoration. Clinician would like to have a perfectly merged margin of the restoration with the tooth or the implant but the laboratory processes developed and practised so far could not achieve this. Research workers have endorsed a gap of 120 μm at the margins as clinically acceptable [2]. But the undeniable fact is that marginal gap and gingivitis is factually correlated [3,4].

Casting an extensive framework consisting of more than three units connecting teeth or implants can be a challenge because it involves greater possibilities of distortion due to shrinkage of the alloy and defects attributable to laboratory processes. Errors may occur during the process of fabricating patterns, material manipulation or casting. Soldering is traditionally used for uniting long span fixed partial denture components to obtain an acceptable fit. Removal of the wax pattern from the final cast prior to investing, as followed in conventional casting technique, is considered to be the primary cause of distortion manifested by a poor-quality marginal fit. In an attempt to reduce the discrepancy of marginal fit, wax pattern can be made directly over a refractory cast obtained by duplicating the working cast and which will be invested along with the pattern and the technique is known as over refractory casting. Comparative evaluation of both the techniques is rare in the literature.

Multiple unit castings have aggravated the possibility of incorporating greater errors. However, recently happened popularity of dental implants has made it necessary to use a greater number of multiunit single piece castings. The advancements in science and technology have ushered in an era of all ceramics and CAD/CAM and the evaluation of marginal gaps in multiple unit prostheses has become relevant but the situation has become more complex. Factual comparisons of marginal gaps in prostheses fabricated through conventional castings, pressing of ceramics and CAD/CAD milling have rarely been attempted.

A comparison of pressable ceramics utilizing conventional and over refractory technique has not attracted the attention of the research worker. Hence the present study was designed to evaluate the marginal discrepancies of single piece FPD framework fabricated with over refractory casting technique and the conventional casting technique. Currently, in addition to better controlled casting procedures, copings can be milled using machines from a ceramic block. This is done with computer aided design/computer assisted manufacturing (CAD/CAM) systems. Introduction of these new techniques permitted the usage of materials like zirconia, to produce dental prostheses. Numerous materials which were once considered as improbable are gaining acceptance in day to day clinical practice, thanks to the technological advancements and superior aesthetics. And copings produced by these CAD/CAM systems purportedly enhance the marginal fit of dental restorations. So, CAD/CAM technology was also included in this study which is expected to generate data useful for laboratory processing of multiple unit castings necessitated by the implant therapy. This study aimed at comparing conventional casting technique, over refractory technique and CAD/CAM technique in achieving acceptable marginal fit for the restorations. Different materials like Nickel Chromium alloys, commercially pure titanium and different ceramics were included. The test parameter used for comparison was the measurement of marginal gap.

The objectives of the present study were

To find out and compare

- The effect of casting techniques viz-conventional and over refractory on marginal fit of fixed partial denture framework.
- The role of materials viz-Nickel Chromium, commercially pure titanium, pressable and machinable ceramics on the marginal fit of fixed partial denture framework.
- The effect of different fabrication techniques viz-Casting and CAD/CAM on the marginal adaptation fixed partial denture framework.

Methodology

An aluminium die consisting of three preparations representing a five unit FPD was made. The specimen design was adapted from Giovani Correa., *et al*. Schiffleger BE., *et al.* [6,7]. Three simulated full crown preparations were machined and fixed to a base. 1.5mm wide shoulder was given to all the preparations. The axial surfaces were given occlusal convergence of 16º and the cervico occlusal height was 5mm (Figure 1,2). The metal die was duplicated in lab silicone to fabricate working casts. Working casts for conventional technique were made in dental stone and for over refractory technique, refractory investment material was used (Figure 3,4).

Preparation of Nickel Chromium (Ni-Cr) castings

- Conventional Technique: Working casts made of dental stone were immersed in clear slurry water for three minutes and a layer of die spacer was applied. 1mm thick wax pattern was made using an electrical dipping unit. The three wax copings were connected with 4mm thick wax cylinders and 5mm thick wax cylinder was used as major sprue [6,7]. The waxed framework was invested in a ring using phosphate bonded in-

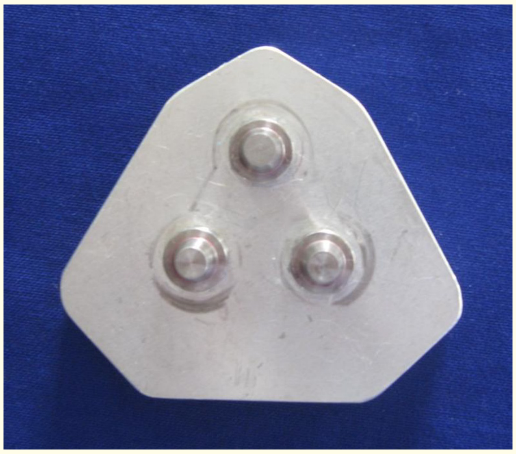

Figure 1: Aluminium die.

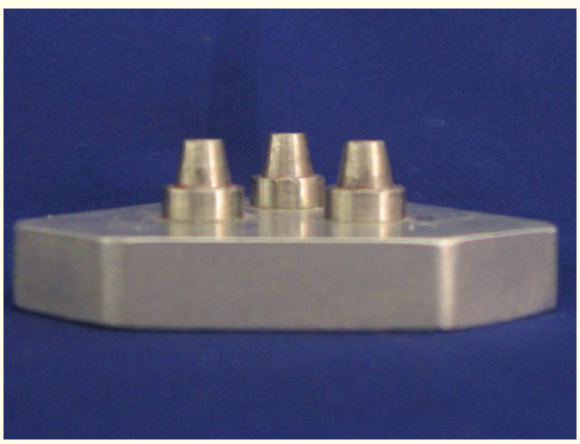

Figure 2: Aluminium die.

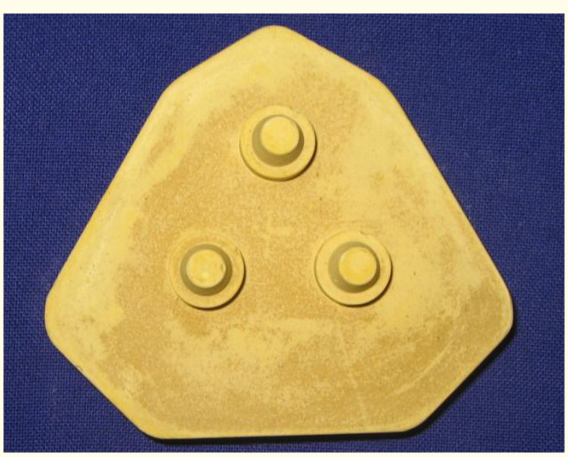

Figure 3: Working cast made in dental stone.

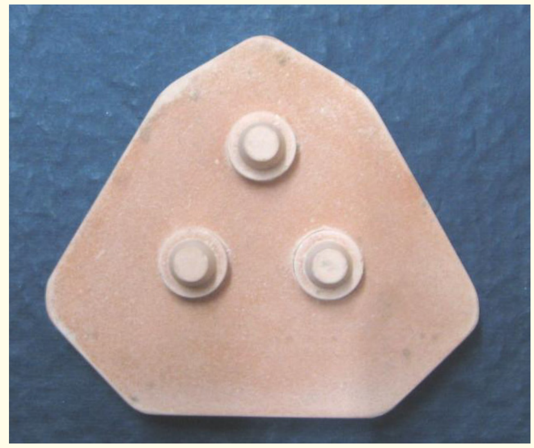

Figure 4: Refractory cast used in over refractory technique.

vestment for Ni-Cr frame work. Ni-Cr casting was done using induction casting machine. Air borne particle abrasion with 100 µm aluminium oxide was done and sprues were cut. Subsequently air borne particle abrasion was repeated externally and internally with 150 µm aluminium oxide (Figure 5,6).

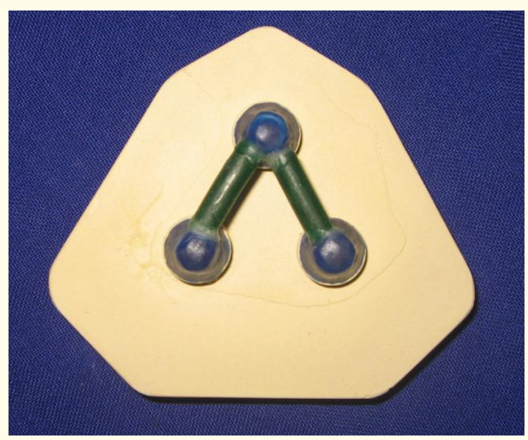

Figure 5: Wax pattern.

Figure 6: Completed casting.

- **Over refractory Technique:** The working casts made of phosphate bonded refractory material (Wirovest) were dry heated at 70 ºC for 40 minutes and liquid surface hardener (Okodur; Dentaurum) was applied and were heated for an additional 10 minutes. The technique of making wax patterns was similar to that used in conventional method but the wax patterns were invested along with the refractory die. The casting (Ni-Cr ingots) and the divestment of the frame work was done in a similar manner.

Ceramic pressed castings

- **Conventional Technique:** Working casts were made of dental stone and wax patterns were made similar to the metal casting technique. Height of the wax sprue including the wax pattern was limited to 15-16 mm and the spruing angle was 45-60º. The waxed framework was removed from the cast and placed in a silicone investing ring which could accommodate 1 ingot and the space between the wax pattern to the silicone ring was maintained at 10 mm (Figure 7,8).

Figure 7: Furnace used for pressing ceramic.

- **Investing:** Investing was carried out with IPS Empress Esthetic Speed. The IPS silicone ring was carefully positioned on the investment ring base. The investment ring was filled with investment material. The investment material was allowed to set for a period of 30 minutes and it was subjected to preheating as per manufacturer's specifications. IPS Empress Esthetic Ingots and EP 600 furnace were used for further processing.

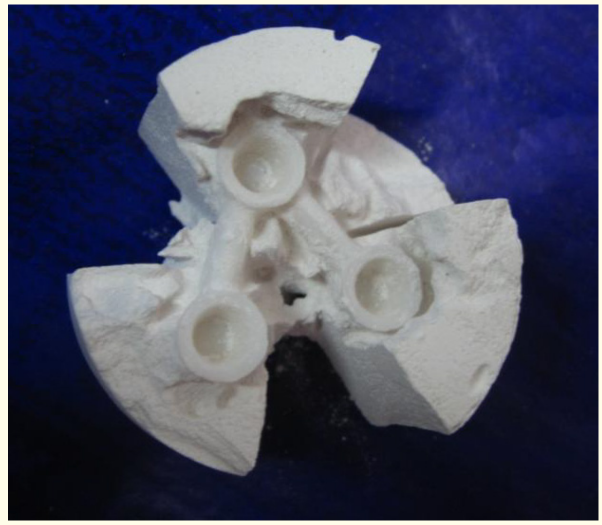

Figure 8: Pressed ceramic specimen.

- **Pressing:** The press temperature of the IPS Empress Esthetic ingots was 1075 °C. Once the preheating cycle was completed, the investment mould was removed from the preheating furnace. The hot IPS Empress Esthetic ingot and plunger were placed into the hot mould. The mould, was then placed central to the hot press furnace. The selected program was started. The mould was removed from the furnace immediately after the program was completed and was placed on the cooling grid to cool the mould to room temperature.
- **Divesting:** After cooling to room temperature, the length of the aluminium oxide plunger was marked on the cooled investment mould. The investment mould was sectioned using a disk. This predetermined breaking point enabled reliable separation of the aluminium oxide plunger and the pressed ceramic material. The investment mould was broken at the predetermined breaking point using a knife. Rough divestment was carried out with glass polishing beads at 4 bar (60 psi) pressure. Later for fine divestment, only 2 bar (30 psi) pressure was applied.
- **Finishing:** The area to be ground was wetted and a fine diamond disk was used to cut the sprues at low speed using light pressure. The attachment points of the sprues were smoothened out (Figure 9).
- **Over refractory Technique:** The working casts were made of IPS Empress Esthetic Speed refractory material. The technique of making wax patterns was similar to that used in conventional method but the wax patterns were invested along with the refractory die. The casting (IPS Empress Esthetic ingots) and the divestment of the frame work was done in a similar manner.

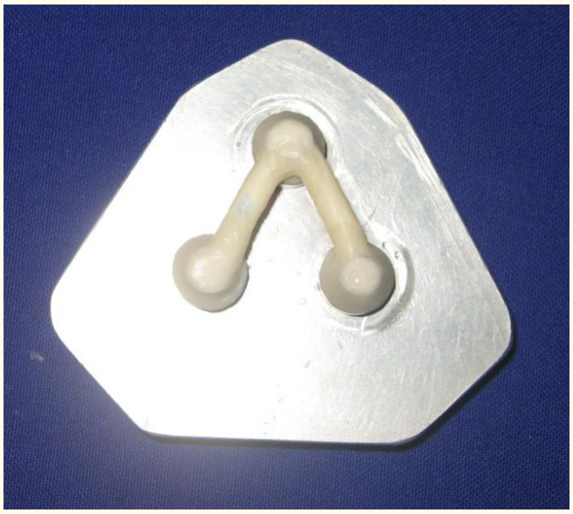

Figure 9: Pressed ceramic specimen.

Titanium castings

- **Conventional Technique:** Working cast was made of dental stone and the wax patterns were made as described in previous steps. The waxed framework was removed from the cast and invested in a ring using magnesia bonded investment. Ingot of CP Ti (Tritan; Dentaurum) melted with arc-melting and was casted using titanium vacuum- casting machine (Rematitan; Dentaurum) set to 0.95-bar argon pressure. After casting, the mould was immediately quenched in cold water. The frame work was divested using air borne particle abrasion with 100 µm aluminium oxide at 60 bar pressure. Sprues were cut and air borne particle abrasion was repeated externally and internally with 150 µm aluminium oxide at 80 bar pressure (Figure 10).

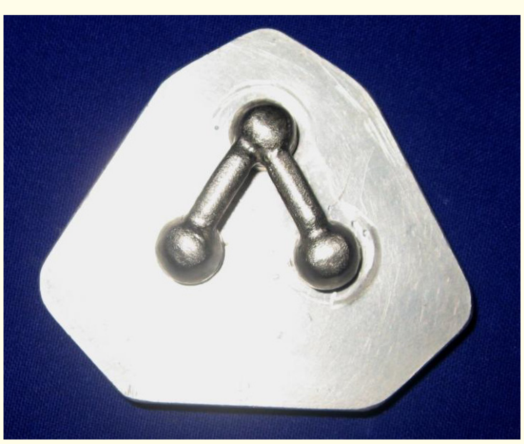

Figure 10: cp Titanium casting.

- **Over refractory Technique:** The working casts were made of magnesia based bonded refractory material (Rematitan Plus - Dentaurum) which were dry heated at 70 ºC for 40 minutes. Surface hardener (okodur; dentaurum) was applied and the casts were heated for an additional 10 minutes. The technique of making wax patterns was similar to that used in conventional method but the wax patterns were invested along with the refractory die. The casting (CP Ti ingots) and the divestment of the frame work was done as in the above experiment.

Framework prepared with CAD/CAM technology (Figure 11-15)

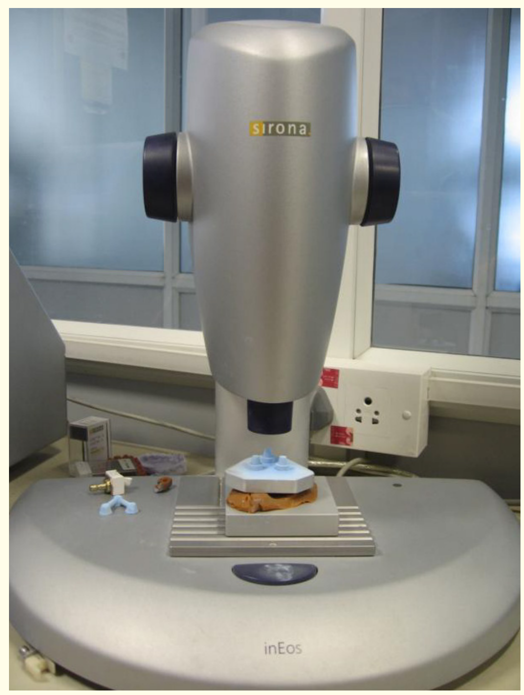

Figure 11: Scanning of the die.

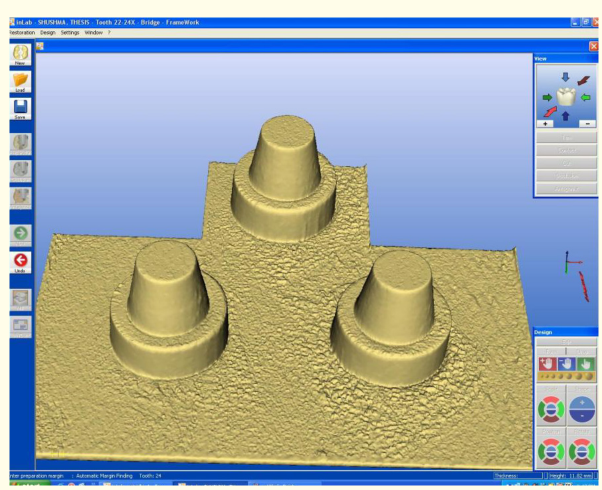

Figure 12: Image of the scanned die.

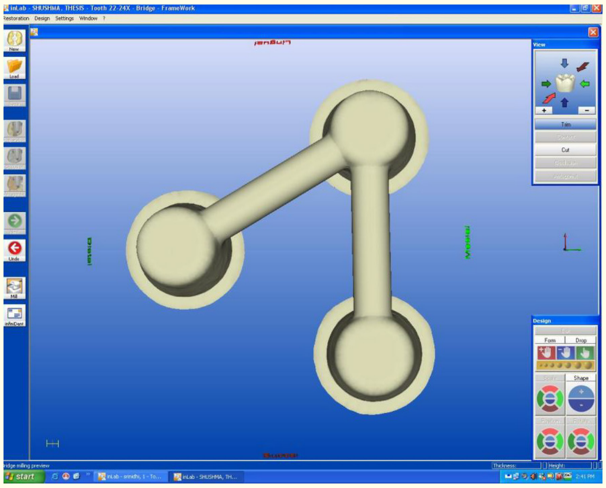

Figure 13: Virtual image of the pattern created by the software.

Aluminium die was scanned under inEos digital scanner and using Cerec 3D software, a 3D virtual image of the pattern of 1mm thickness was designed. As the size of the ceramic block available for milling was not sufficient to accommodate the design of wax pattern, two copings connected with a sprue and one coping separately were milled. For the two copings InCoris ZI ceramic block 55/19 having a size of 15.5x 19x 55mm was selected and milling process was started. The block was inserted in the workpiece spindle so that its groove fitted into the locking pin of the workpiece spindle and the door of the milling unit was closed. When the milling process was completed, the restoration was removed and sintered in the SIRONA inFire HTC furnace for 8 hours. For the single coping with an extension InCoris ZI ceramic block 40/15 having a dimension of 15.x 14x 40mm was selected and milled. It was also sintered as in the above case. Both the ceramic units were then joined using feldspathic porcelain.

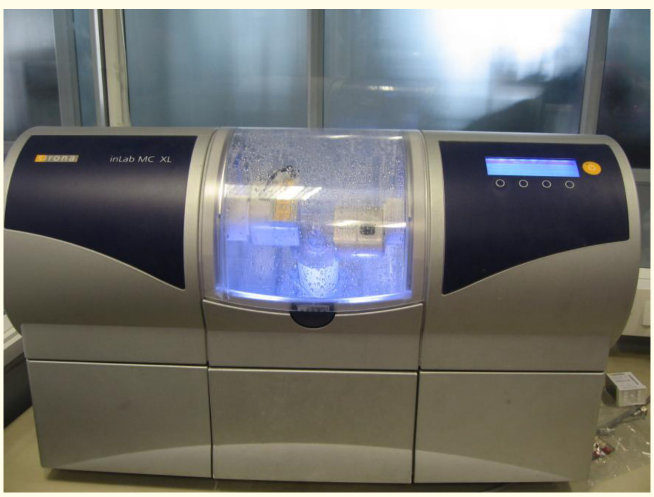

Figure 14: Milling of the ceramic block.

Figure 15: CAD-CAM milled ceramic pattern.

Marginal fit measurements (Figure 16-19).

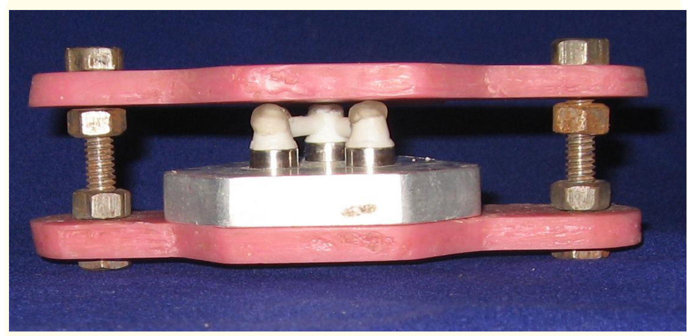

Figure 16: Die and specimen held under pressure.

Figure 17: Otereo microscope used for measring gap.

Figure 18: Marginal gap of Nickel Chromium specimen.

Figure 19: Marginal gap of CAD-CAM ceramic specimen.

The castings were placed on the metal die and the marginal discrepancies were measured as the linear distance (mm) between the marginal edge of the coping and the cervical edge of the metal die. Each framework was repositioned on the metal die and axially loaded with 9 kgf to avoid uncontrolled displacement or seating error by application of finger pressure. For the reading, the base of the metal die with the framework was positioned between 2 acrylic plates and screws were fixed. The base of this unit was placed vertically and supported by the opposing side, which facilitated edge alignment in the same optical reading plane and facilitated measurement of the surfaces. Marginal gap measurements were recorded at 10 positions for each coping, using a stereo microscope at 10x magnification. Marginal gap measurements were made on 30 locations in each specimen and the average for each framework was considered as a single experimental unit for statistical analysis.

The observations were tabulated and the data was analysed. Two-Way ANOVA was used to find out whether there existed a significant difference between the materials (Ni-Cr, Pressable and machinable Ceramics, Titanium) and the techniques (Conventional and Over-refractory). One-Way ANOVA was used to find out whether there existed a significant difference between Conventional, Over-refractory and CAD/CAM techniques. Post hoc-test using Bonferroni method was used to carryout multiple comparisons, ie. to find out among which pair or groups existed a significant difference. SPSS version 13 and Minitab version 14 software was used.

Results

In the present study, two factors influenced the marginal gap (μm) viz. casting techniques and the materials used for fabricating the fixed prosthesis. The casting techniques used were of two types – Conventional and Over-Refractory. Three types of materials were used viz. Ceramics, Ni-Cr and Titanium. CAD/CAM ceramic was also included but the comparison was made separately for the obvious reason that casting process was not involved in it. The factors and their levels are given in table 1.

Factor	Levels
Technique	Conventional, Over-Refractory
Material	Ceramic, Ni-Cr, Titanium

Table 1: Factor and levels.

Test Procedure

- **Null Hypotheses:** There is no significant difference between the different materials, different techniques and the interaction (joint effect) of various factors. All statistical testing was performed with an alpha level equal to 0.05 ($\alpha = 0.05$.).
- **Decision Criterion:** p-values were compared with the level of significance. If $P < 0.05$, the null hypothesis was rejected and accepted the alternate hypothesis. If $P > 0.05$, the null hypothesis was accepted. If there was a significant difference, multiple comparisons (post hoc-test) were carried out using Bonferroni method to find out among which pair or groups there existed a significant difference.

Statistical technique used: Two-Way ANOVA

From the ANOVA table (Table 3), it was observed that casting techniques viz. Conventional and Over refractory are significant factors influencing marginal gap ($P < 0.001$). Materials used for fabrication viz. Nickel chromium, Ceramic and Commercially pure Titanium are also significant factors that can influence marginal gap ($P < 0.001$). The interaction (joint effect) of techniques and materials on gap was also found to be significant ($P < 0.001$).

Main effects plot (Figure 20)

It was observed that fabrication techniques had greater influence on marginal gap than the materials used. Between the two different techniques, higher gap was found in conventional technique when compared to Over-Refractory technique. Among the different materials, Ni-Cr yielded a higher gap, followed by Titanium and Ceramic materials. The difference in mean gap recorded using Conventional technique and Over-Refractory technique was found to

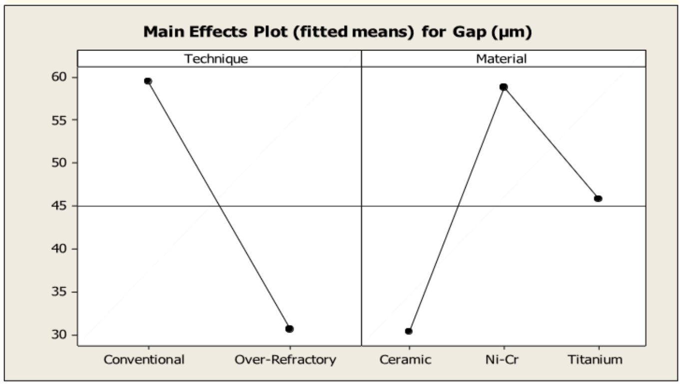

Figure 20: Main effects plot.

be statistically significant (P < 0.001). The difference in mean gap recorded among different materials is also found to be statistically significant (P < 0.001). (Table 2,3).

In order to find out among which pair of materials there existed a significant difference, multiple comparisons test was carried out using Bonferroni method and the results are given in table 4. It was observed that there was a significant difference between Ceramic and Ni-Cr material with respect to the mean marginal gap recorded (P < 0.001). Also, the difference in mean marginal gap between Ceramic and Titanium material was also found to be statistically significant (P < 0.001). Statistically significant difference was also observed for the mean difference in gap between Ni-Cr and Titanium also (P < 0.001). Higher mean gap was noticed in Ni-Cr compared to the other two materials and this difference was statistically significant. Ceramic material recorded the lowest gap compared to Titanium and this difference was also statistically significant.

Material	Conventional Technique					Over-Refractory Technique				
	Mean	Stddev	Min	Median	Max	Mean	Stddev	Min	Median	Max
Ceramic	39.70	3.51	32.47	39.71	45.97	21.28	2.48	15.94	20.92	25.98
Ni-Cr	78.21	4.45	70.04	78.26	87.78	39.48	3.90	32.98	38.93	47.59
Titanium	60.51	3.04	54.65	60.12	67.34	31.15	2.08	27.09	31.09	35.01

Table 2: Mean gap recorded among different factors and levels.

Source	df	Sum of squares(SS)	Mean SS	F	P-Value
Technique	1	112261.432	112261.432	10044.415	<0.001*
Material	2	72504.203	36252.102	3243.600	<0.001*
Technique x Material	2	9305.634	4652.817	416.303	<0.001*
Error	534	5968.253	11.177	---	---
Total	539	1296192.528	---	---	---

Table 3: Two-way ANOVA.

It was noticed that Over-Refractory technique always provided a lower marginal gap when used with any of the materials. The mean gap recorded in Over-Refractory technique using any of the three materials yielded a lower gap compared to Conventional technique. Therefore, the best combination is to use Over-Refractory technique with pressable Ceramic material (Figure 21).

It was noticed that there is a statistically significant difference

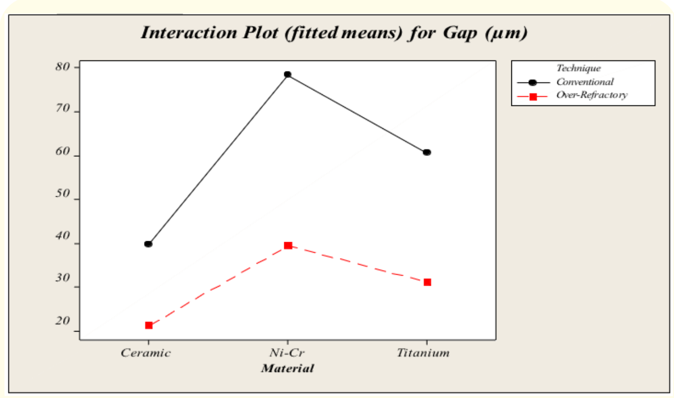

Figure 21: Interactions plot.

between Conventional technique and Over-Refractory technique with respect to the mean marginal gap (P < 0.001). Also, the difference in mean gap recorded between Conventional and CAD/CAM technique was found to be statistically significant (P < 0.001). The difference in mean gap between Over-Refractory and CAD/CAM techniques was also found to be statistically significant (P < 0.001) (Figure 22,23).

Discussion

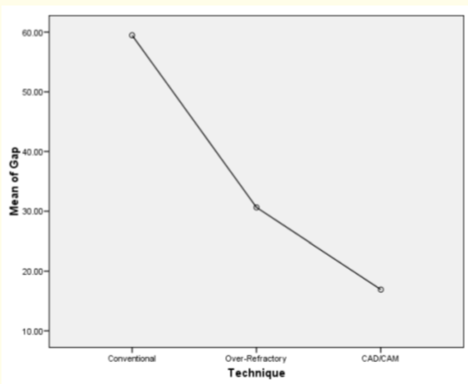

Figure 22: Means plot (micrometer) comparing three techniques.

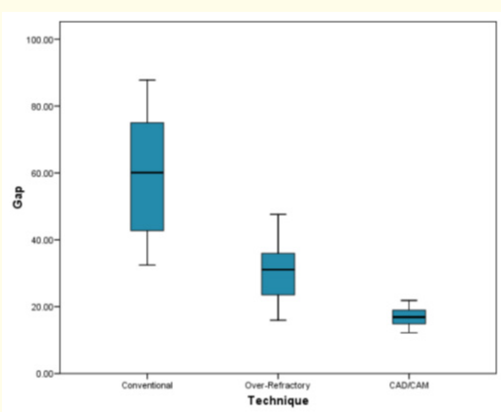

Figure 23: Box plot comparing the three techniques (marginal gap).

Fabrication of fixed prosthesis involve many intricate processes which are capable of incorporating errors that can cause marginal misfit [5]. An over refractory technique in which patterns are made over a refractory cast and invested along with cast was used by Correa G., *et al*. in order to improve the marginal fit [6].

Very rarely comparisons have been made between conventional castings and over refractory castings in determining the efficiency of providing accurate marginal fit. Most of the available studies have included noble, Titanium and Ni-Cr alloys but ceramics have never been subjected to evaluation [5,7]. Other than the sophisticated casting procedures, copings are fabricated using computer assisted systems which are supposed to have superior marginal adaptation and they were also included in the comparisons [8].

On comparison, the over refractory technique gave better results than conventional technique when single-piece multi-unit FPD frameworks were fabricated from Ceramic, CP Ti, or Ni-Cr. The difference that existed between conventional and over refractory techniques was statistically significant. The overall mean gap recorded in conventional technique was 59.47 ± 16.20 μm and in over refractory technique was 30.64 ± 8.00 μm.

It can be observed that both fall into the 120-μm limit of acceptable marginal fit [2]. Ideally, we have to aim for a no gap situation and CAD/CAM was expected to provide it, because of its precision and its capacity to eliminate the human element. We measured the marginal gap for the zirconia framework fabricated by CAD/CAM technology. The marginal gap value obtained ranged from 12.22μm to 21.87μm with a mean value of 16.92 ± 2.65 μm, which was the lowest among all the materials and techniques and the difference was statistically significant. Beuer F., *et al*. [11] found similar results in their study on comparing multi unit fixed dental prosthesis, retainers and single-crown copings which were 25 ± 29 μm and 13 ± 12 μm respectively. Based on the present results, ceramic multi-unit frameworks presented with comparatively better marginal fit values irrespective of the casting techniques used. Over-refractory technique decreases the need for soldering to join segments of multiple unit castings. For multi-unit FPD fabrications, the over-refractory technique has to be considered as a preferred method.

The need for incorporating refractory cast in the mould has to be accepted as a routine procedure because of the superior marginal fit it provides irrespective of the material used i.e., alloys or ceramics. CAD/CAM technology definitely provides superior results, which casting techniques may not achieve. It can be concluded that– use of over refractory casting technique produced lesser marginal gap when compared to that of conventional technique. Among the materials used for castings the highest gap was seen in Nickel Chromium followed by Commercially pure Titanium and pressable Ceramic both in Conventional and Over refractory techniques. When conventional, over refractory and CAD/CAM techniques were compared lowest marginal gap was seen with CAD/CAM crowns made in Zirconia.

Conclusions

- Over refractory casting technique showed lesser marginal gap when compared to that of Conventional casting technique.
- Among the materials used for castings, the highest marginal

gap was seen in Nickel Chromium castings, followed by Commercially pure Titanium and then by pressable Ceramics. This was evident both in conventional and over refractory casting techniques.

- When Conventional, Over Refractory and CAD/CAM techniques were compared, lowest marginal gap was seen in CAD/CAM fabricated Zirconia prosthesis.

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