Evaluation and Comparison of the Marginal Fit of Porcelain - Fused - to Metal Crowns before and after Porcelain Glazing Fabricated using Two Different Techniques

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Abstract: ***Purpose**: To evaluate and compare the marginal fit of porcelain - fused - to metal crowns before and after porcelain glazing fabricated using conventional lost wax technique and Direct Metal Laser Sintering (DMLS) technique. **Materials & methods**: A total of 44 samples were prepared.22 samples were prepared using conventional lost wax technique and 22 samples using Direct Metal Laser Sintering (DMLS). These samples were sub - divided into 11 samples each of chamfer and deep chamfer finish lines in each group. Marginal fit was tested using Scanning Electron Microscope (SEM) for all the samples before and after glazing. Statistical analysis of the data was done using descriptive statistics to assess the mean and standard deviation of the respective groups, level of significance set at P<0.05. **Results**: A statistically significant difference (P<0.05) was observed between the values of all the groups for marginal fit. DMLS fabricated samples showed the least mean marginal fit (62.63±26.51μm & 87.32±27.87μm) before and after porcelain glazing compared to conventionally (90.97±31.35μm & 118.35±30.07μm) fabricated samples. **Conclusion**: DMLS fabricated samples showed the best marginal fit values compared to conventionally fabricated samples. The study concluded that DMLS technique had an edge over the conventional lost wax technique.***

Keywords: Marginal fit, conventional lost wax, Direct Metal Laser Sintering (DMLS), chamfer, deep chamfer

1. Introduction

Prosthodontists have a wide range of treatment options in restoring extensively damaged or previously restored teeth. Metal ceramic crowns are common because of their accuracy, high strength and esthetics. One of the essentials for success of the restoration is proper tooth preparation that includes proper selection and preparation of the cervical margin. Regardless of the margin geometry, proper placement of the prepared gingival margin in relation to the free gingival margin, the epithelial attachment, and the alveolar housing is imperative.1

The main determinants of a successful restoration are marginal adaptation, biocompatibility, esthetics, and mechanical strength. The success of fixed prosthesis are dependent on numerous factors, the most significant of which is marginal fit.

A successful dental restoration should have 4 distinct properties: marginal adaptation, biocompatibility, esthetics, and mechanical strength. The presence of marginal discrepancy can increase plaque accumulation, alter the distribution of microflora, and contribute to a higher risk of caries in the abutment teeth.2 Restoration adaptation might be affected by a number of factors such as design preparation, location of finish line, restoration material, mold technique, fabrication method, the type of cement, dentist's skills, type of finish line etc. Marginal gap and internal fit of the restoration are crucial factors, since they deal with marginal integrity, structural rigidity, and preservation of periodontal and pulpal health.3

Casting alloys have been an important part of restorative dental treatment for more than a century. Restorations commonly fabricated for fixed prosthetic treatment, such as inlays, onlays, crowns, and fixed partial dentures, were fabricated in the dental laboratory using the lost - wax technique introduced by Taggart in 1907.4

The manufacture of metallic restorations in the dental laboratory has conservatively been conceded out by the lost wax casting method. Conventional casting, recognised as lost - wax casting, was the prime method for manufacturing metallic dental restorations for the last seven decades. However, the evolution of digital technology and the development of CAD - CAM procedures at the beginning of the 1970s set a landmark by introducing automated manufacturing processes.5

Until the early 1980s, most fabrication techniques of dental restorations were based on subtractive manufacturing, either by casting or milling. Recently, the introduction of additive manufacturing provided a completely new concept.5 CAD - CAM technologies have revolutionized prosthodontics by enabling new manufacturing methods and materials. Simple scanning procedure can directly generate a 3 - dimensional cast of a dental impression or of the patient's mouth.5

Various additive techniques were developed to meet the requirements of rapid manufacturing (RM) and rapid prototyping (RP), such as Stereo lithography (SLA), Fused Deposition Modeling (FDM), and Selective Electron Beam Melting (SEBM) or selective laser sintering (SLS). Each technique was used for the manufacture of different dental materials, with SLS being the most commonly used for the fabrication of dental restorations in prosthetic dentistry.5

SLS has been preferred for non - metallic materials (primarily ceramic or polymers), whereas the term DMLS (direct metal laser sintering) or SLM (selective laser melting) is preferred for alloys.6 DMLS is a procedure of manufacturing 3D parts, consolidating layers of powders of several materials (such as polymers, metal and ceramics), under the heat of an intensive laser beam, focused by the data provided by a CAD file. CAD - CAM and direct metal laser sintering (DMLS) manufacturing systems have recently been introduced for fabricating metal frameworks for metal ceramic crowns to overcome the disadvantages of the casting method.5,[6]

Many of the previous studies have focused on evaluation of marginal fit of cast restorations fabricated by different preparation designs, impression techniques, die preparation, spacer thickness, pattern fabrication, investment material and conventional casting techniques.

However, very few studies have been reported on the evaluation of marginal fit of porcelain fused to metal restorations by comparing the conventional casting techniques and the newly introduced DMLS technique.

Hence, the purpose of this study is, to evaluate and compare the marginal fit of porcelain - fused - to metal crowns before and after porcelain glazing fabricated using conventional lost wax technique and Direct Metal Laser Sintering (DMLS) technique.

2. Methodology

Preparation of stainless steel dies.

Preparation of test samples: Two stainless steel dies were prepared one with a chamfer margin and the other with a deep chamfer margin, depicting the preparations for metal - ceramic restoration of a maxillary central incisor. The labial reduction was 1.3mm, the proximal reduction was 1mm, the lingual reduction was 1mm, the height of the metal dies was 7mm, and width of the chamfer margin was 0.8mm and deep chamfer was 1mm with a convergence angle of 6 degrees.1 (figure 1).

Figure 1: Stainless steel dies mounted on a metal jig

All the measurements were verified using a verniercaliper. Each steel die was marked with three reference points - A, B and C (figure 2).

A- Mid - point of mesio - labial side.
B- Mid - point of labial side.
C- Mid - point of disto - labial side.

Figure 2: Stainless steel dies mounted on a metal jig

All the 44 test samples used in this study were divided into Group - I and Group - II.

Group I: 22 test samples were fabricated using conventional lost wax technique.

Group II: 22 test samples were fabricated using Direct Metal Laser Sintering (DMLS) technique.

Group I: Conventional Lost Wax Technique

22 test samples in group - I were divided into 2 sub - groups: Group - IA and Group - IB.

Group IA: Eleven samples fabricated by conventional lost wax technique with chamfer finish line.

Group IB: Eleven samples fabricated by conventional lost wax technique with deep chamfer finish line. impression of both the steel dies using putty reline technique. (figure 3).

Figure 3: Putty wash impression of both the stainless steel dies

Polyvinyl siloxane impression material (Zhermack, Elite P&P; Prime Ad - silacura light tubes.) was used to make

The impressions were poured with type IV die stone to obtain the stone dies. All the 22 stone dies (Type IV, Kalrock, Kalabhai, Mumbai) were treated with a die hardener (Hartebad, Renfert, Germany) and, three coats of die spacer (Hartebad, Renfert, Germany) was applied 1mm short of margin to create 30µm thickness of space for luting cement. Inlay casting wax (kronenwachs, Germany) was melted and contoured over the stone dies using PKT instruments to prepare the wax pattern for each sample of 0.5mm thickness.1 Wax gauge was used to verify the dimensions of each wax pattern. Sprue was attached to the wax pattern and invested. Casting was performed using cobalt - chromium metal alloy pellets (BEGO, Wironit, Germany) in the regular conventional method following the manufacturer's instructions (figure 4).

Figure 4: Induction Casting Machine (Fornax, BEGO)

All the 22 samples were verified for 0.5mm thickness using a metal gauge (figure 5).

Figure 5: Verification for 0.5mm thickness of the sample using a metal gauge.

22 cobalt chromium samples were thus obtained. Eleven samples with chamfer margin and eleven samples with deep chamfer margin (figure 6, 7).

Figure 6: 11 samples fabricated by conventional technique with chamfer margin.

Figure 7: 11 samples fabricated by conventional technique with deep chamfer margin

Group Ii: Direct Metal Laser Sintering (DMLS) Technique

22 test samples in group II were divided into 2 sub - groups: Group - II A and Group - II B.

Group IIA: Eleven samples fabricated by Direct Metal Laser Sintering (DMLS) technique with chamfer margin.

Group IIB: Eleven samples fabricated by Direct Metal Laser Sintering (DMLS) technique with deep chamfer margin.
Polyvinyl siloxane impression material (Zhermack, Elite P&P; Prime Ad - silacura light tubes.) was used to record impression of both the steel dies using putty reline technique. This impression was scanned using a digital scanner (EOS, Germany) (figure 8). The desired die spacer of 30 μm thickness was programmed, 1mm short of the margin.

Figure 8: Putty wash impression of both the stainless steel dies being scanned

The thickness of each sample was programmed to 0.5mm.1 The stereolithography (STL) file data which was obtained by scanning the impression was forwarded to the computer - aided manufacturing (CAM) bridge, which is a professional software for automatic part placement (figure 9).

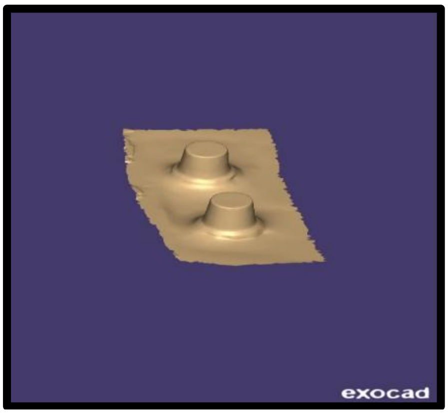


Figure 9: STL file of the scanned impression of two metal dies

The data obtained was forwarded to the building chamber wherein infrared laser beam was used to fuse the cobalt - chromium alloy powder (EOS, Germany), layer by layer to produce the sample, using the Direct Metal Laser Sintering (DMLS) 3D printing machine (EOS, Germany).6 (figure 10).

Figure 10: Direct Metal Laser Sintering (DMLS) 3D printing machine (EOS, Germany).

22 cobalt chromium samples were thus obtained.

Eleven samples with chamfer margin and eleven samples with deep chamfer margin (figure 11, 12).

Figure 11: 11 samples fabricated by DMLS technique with chamfer margin

Figure 12: 11 samples fabricated by DMLS technique with deep chamfer margin.

Testing of Marginal Fit of the Samples
All the fabricated samples were seated on their respective steel dies with three reference points:
A- Mid - point of mesio - labial side.
B- Mid - point of labial side.
C- Mid - point of disto - labial side.

The measurements were determined by measuring between the reference mark on each steel die and the most apical point on the margin of the sample in a direction parallel to the long axis of the die. The sample and steel die assembly were placed over the platform of Scanning Electron Microscope (SEM) (TESCAN - VEGA3 LMU). The marginal fit was determined by measuring the space (marginal opening) between the margin of the sample and the reference mark of the steel die.7 (figure 13).

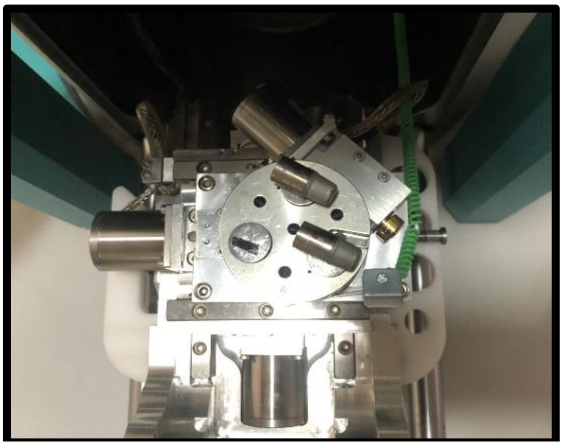


Figure 13: Mounting of samples on the platform of SEM.

Ceramic build up and porcelain glazing was done for all the samples. (Figure 14)

Figure 14: ceramic build - up & porcelain glazing done for the samples

The marginal fit of all the 44 samples obtained were assessed before and after porcelain glazing. (figure 15).

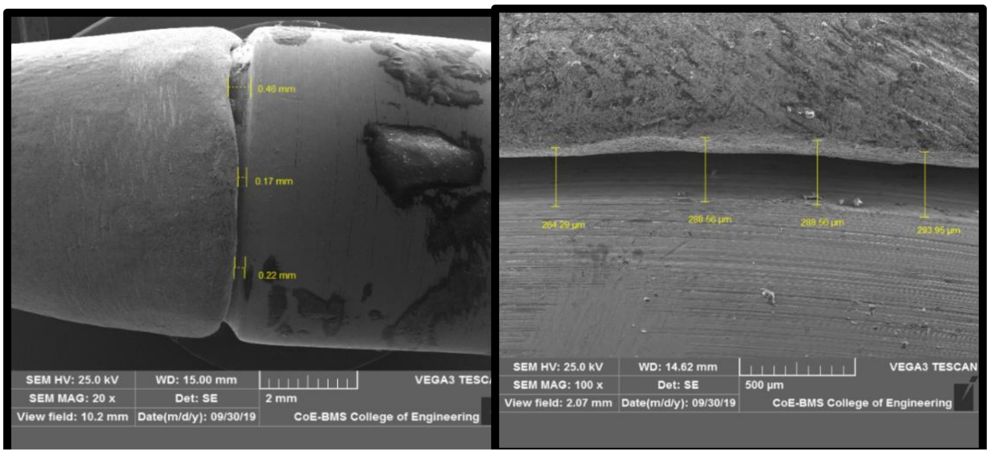


Figure 15: Determination of marginal fit.

Statistical Analysis of Data

The data was analyzed using the statistical package SPSS 20.0 (SPSS Inc., Chicago, IL).

The level of significance was set at p $p<0.05$.

Descriptive statistics was performed to assess the mean, standard deviation and confidence interval of the respective groups. Normality of the data was assessed using Shapiro Wilkinson test. Since the data was not following normality, inferential statistics to find out the difference between the groups was done using non parametric tests such as, Wilcoxon Sign rank test (within group) and Mann Whitney U test (between group) to find out the difference between the groups.

3. Results

Marginal Fit

Table 1: Grouping of Samples

Groups	Method of Fabrication	Finish Line	Parameters Tested
Group IA, IB	Conventional Method of Fabrication	Chamfer, Deep Chamfer	Marginal Fit, Before Glazing of the Samples
Group IIA, IIB	DMLS Method of Fabrication	Chamfer, Deep Chamfer	Marginal Fit, Before Glazing of the Samples
Group IA, IB	Conventional Method of Fabrication	Chamfer, Deep Chamfer	Marginal Fit, After Glazing of the Samples
Group IIA, IIB	DMLS Method of Fabrication	Chamfer, Deep Chamfer	Marginal Fit, After Glazing of the Samples

Table 2: Marginal Fit Values of Tested Specimens of Group IA &Group IB Before Glazing

Group Name	Name of the Specimen	Sample No.	Marginal Fit Values (µm) of IA Samples	Marginal Fit Values (µm) of IB Samples
Group IA & IB: Conventionally Fabricated	Conventionally Fabricated Specimens With Chamfer & Deep Chamfer Margin	1	117.00 86.30 104.00	43.60 25.80 44.50
		2	64.52 115.75 131.66	117.34 95.49 55.06
		3	136.58 150.49 75.07	25.20 31.10 27.20
		4	154.26 82.92 78.04	115.07 68.99 75.37
		5	145.13 147.28 80.94	43.70 43.00 36.30
		6	108.00 117.00 83.00	120.77 30.79 30.19
		7	29.50 19.20 35.20	54.48 58.90 37.99
		8	106.97 145.10 157.01	115.80 91.27 61.07
		9	48.68 88.09 121.63	116.70 100.62 43.86
		10	159.92 104.94 58.24	117.18 78.09 90.06
		11	60.16 128.62 111.73	108.00 117.00 83.00

Table 3: Marginal Fit Values of Tested Specimens of Group IIA & Group IIB Before Glazing

Group Name	Name of the Specimen	Sample No.	Marginal Fit Values (µm) of IIA Samples	Marginal FIT Values (µm) of IIB Samples
Group IIA & IIB: DMLS Fabricated	DMLS Fabricated Specimens With Chamfer & Deep Chamfer Margin	1	60.85 98.22 106.28	60.60 56.00 65.60
		2	113.99 64.90 82.22	23.10 20.20 41.40
		3.	143.00 169.00 127.00	60.60 56.00 65.60
		4	60.60 49.00 48.50	70.88 61.66 49.54
		5	86.61 60.68 99.29	50.00 70.30 57.30
		6	103.47 84.82 97.88	89.45 60.08 86.47
		7	95.93 61.87 61.40	23.10 20.20 41.40
		8	43.70 43.00 36.30	67.15 31.79 31.11
		9	67.97 85.59 68.66	35.74 75.66 45.70
		10	64.40 49.50 62.80	82.89 72.68 76.53
			83.30	70.88

		11	109.81 60.95	61.66 49.54

Table 4: Marginal Fit Values of Tested Specimens of Group IA & Group IB after Glazing

Group Name	Name of the Specimen	Sample No.	Marginal Fit Values (μm) of IA Samples	Marginal Fit Values (μm) of IB Samples
Group IA & IB: Conventionally Fabricated	Conventionally Fabricated Specimens With Chamfer & Deep Chamfer Margin	1	127.16 92.56 111.21	44.91 26.43 45.31
		2	68.49 122.98 142.78	122.57 100.22 58.03
		3	139.44 153.85 79.62	26.20 33.05 29.57
		4	155.88 85.80 78.80	121.85 72.52 75.57
		5	154.57 155.21 87.18	46.03 45.30 37.35
		6	117.30 127.96 88.95	128.79 32.19 31.99
		7	29.70 20.00 36.67	59.56 63.33 39.31
		8	115.87 149.56 163.22	124.31 92.72 62.47
		9	51.29 94.32 127.35	127.39 104.13 45.57
		10	171.18 105.19 60.23	124.55 82.75 91.54
		11	63.54 129.27 112.04	111.12 123.81 85.40

Table 5: Marginal Fit Values of Tested Specimens of Group IIA & Group IIB after Glazing

Group Name	Name of the Specimen	Sample No.	Marginal Fit Values (μm) of IIA Samples	Marginal Fit Values (μm) of IIB Samples
Group IIA & IIB: DMLS Fabricated	DMLS Fabricated Specimens With Chamfer & Deep Chamfer Margin	1	66.26 100.49 115.48	64.08 56.63 67.88
		2	116.98 68.67 82.98	24.36 21.35 41.53
		3	148.16 181.34 131.03	61.43 58.08 67.72
		4	64.51 51.54 48.89	71.80 63.12 50.73
		5	91.20 63.40 99.45	53.79 73.29 58.02
		6	108.96 91.48 100.65	90.29 61.12 91.31
		7	104.85 66.99 62.21	24.71 21.44 41.74
		8	44.56 47.04 37.14	67.74 32.70 33.04
		9	69.66 92.85 73.31	37.58 76.96 48.71

		10	69.00 50.12 63.14	88.88 77.03 77.57
		11	84.24 110.71 67.01	76.78 66.65 50.51

Table 6: Comparison of Marginal Fit (Conventional v/s DMLS)

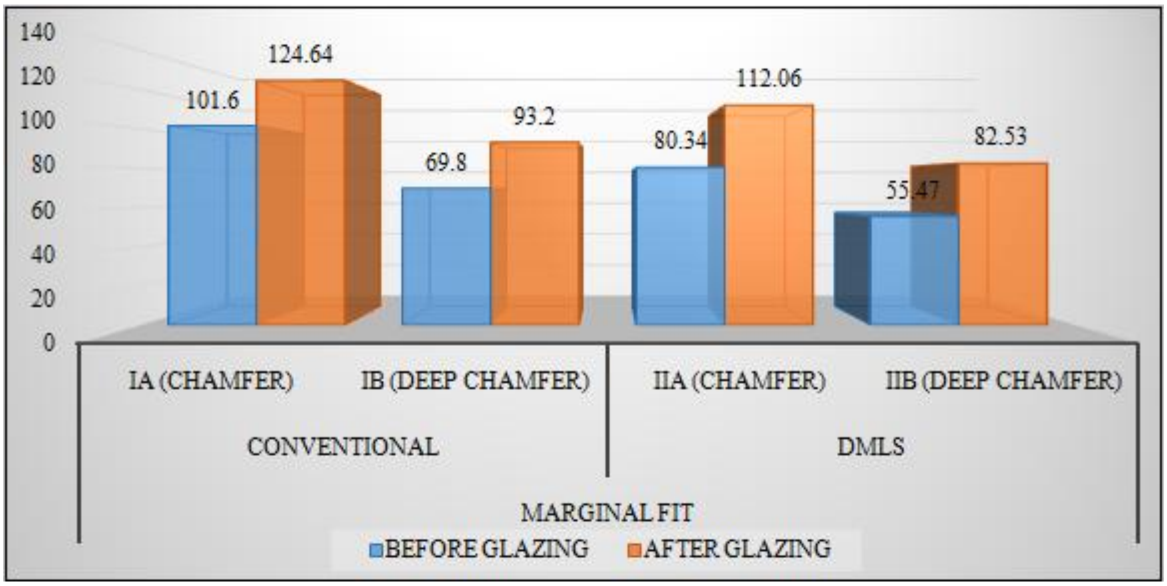
	Before Glazing	After Glazing	Z Value	Confidence Interval	P Value	Percentage Change
Conventional	90.97±31.35	118.35±30.07	- 2.20	- - 52.19 to - 2.08	0.04*	30.01%
DMLS	62.63±26.51	87.32±27.87	- 2.18	- 48.26 to - 1.11	0.04*	40.3%
Z Value	2.27	2.29				
Confidence Interval	5.89 to 2.89	2.278 to 57.89				
P Value	0.04*	0.03*				

***P<0.05 is statistically significant (Mann Whitney U test/Wilcoxon Sign rank test)**

Table 7: Comparison of Marginal Fit (Chamfer v/s Deep Chamfer)

	Before Glazing	After Glazing	Z Value	Confidence Interval	P Value
Chamfer	90.97±31.35	118.35±30.07	- 2.20	- - 52.19 to - 2.08	0.04*
Deep Chamfer	62.63±26.51	87.32±27.87	- 2.18	- 48.26 to - 1.11	0.04*
Z Value	2.27	2.29			
Confidence Interval	5.89 to 2.89	2.278 to 57.89			
P Value	0.04*	0.03*			

***P<0.05 is statistically significant (Mann Whitney U test/Wilcoxon Sign rank test)**



Graph 1: Comparison of Marginal Fit of Both the Groups

Comparison of Marginal Fit between the Groups

The comparison of Mean values of marginal fit before and after glazing procedure, reported statistically significant difference in both group I (90.97±31.35µm & 118.35±30.07µm) and group II (62.63±26.51µm & 87.32±27.87µm), analysed using Mann Whitney U test ($p<0.05$). Group II samples showing a better marginal fit compared to group I samples (40.3% v/s 30.01%) (table 6, graph 1). Whereas between group comparison at both intervals (before glazing and after glazing) also showed statistically significant differences ($P<0.05$).

Also, the test reports demonstrated statistically significant difference between chamfer (90.97±31.35 µm & 118.35±30.07 µm) and deep chamfer (62.63±26.51µm & 87.32±27.87 µm) ($p<0.05$) at both before glazing and after glazing intervals, suggesting better marginal fit for deep chamfer finish line compared to chamfer (table 7, graph 1).

4. Discussion

Metal - ceramic crowns and bridges are common restorations used in prosthodontics because of their casting accuracy, the high strength properties of the metal, and the cosmetic appearance of porcelain.[8, 9]

Casting alloys have been an important part of prosthodontic treatment for more than a century. Restorations commonly fabricated for fixed prosthetic treatment, such as inlays, onlays, crowns, and fixed partial dentures, fabricated in the dental laboratory using the lost - wax technique introduced by Taggart in 1907.4Fabrication of a restoration using the impression is the foremost step. Subsequently, time is required by the dental laboratory technician for careful pouring of the stone die or cast from the impression, preparation of the cast, then fabrication of the wax pattern, investing, and casting.4 Casting technology is undergoing a radical shift and a process of industrialization is taking place in dentistry.

The use of digital dental technology is on the rise and manufacturing processes are being automated. Dental restorations that have long been conventionally produced from metal through the use of casting techniques is getting automated and this technique is a direct import from 3D printing and rapid prototyping technologies used in general manufacturing.1[0]

Direct Metal Laser Sintering (DMLS) and Selective laser melting (SLM) are synonyms and can be used interchangeably. Direct Metal Laser sintering (DMLS) technique is a relatively new technique. Manufacturers claim that the technique is easy to use, produces accurate restorations, simplified post processing procedures, free of porosity unlike conventional castings and improved electromechanical characteristics.1[0] Direct Metal Laser Sintering (DMLS), one of the additive manufacturing techniques, fabricates metallic structures by fusing fine layers of metal powder by means of a focused laser beam. These new CAD - CAM based techniques are considered promising alternatives to traditional casting.1[1]

A recent study reported that the marginal fit and internal gap of Co - Cr dental alloys depends on the fabrication technique. In addition, the fit of the Co - Cr metal framework in metal - ceramic restorations may deteriorate during the firing cycles used for ceramic application, depending on the framework design, alloy type, ceramic shrinkage during firing, and the difference in thermal expansion for ceramic and alloy.1[1]

The marginal fit of the dental restoration is an important criteria while evaluating the clinical acceptability of crowns and bridges and to fulfil biological, physical and aesthetic requirements of restorations.1[2]

Although clinical evaluations of marginal and internal gap discrepancies have their limitations and inherent errors, it is important to investigate new techniques and technologies. However, deterioration of the initial fit of the metal coping has been observed after the porcelain firing cycle. Studies on marginal distortion have identified many factors, such as the mismatch of porcelain - metal thermal contraction, alloy type, and margin design, as contributing to the distortion. Considerable controversy continues to exist in the literature with regard to the effect of these factors.8

The marginal fit of metal - ceramic crowns has been the focus of various investigations. Therefore, several studies have stated that an excellent marginal fit will minimize recurrent caries, and plaque accumulation, thereby reducing periodontal disease. A good marginal fit seems to be one of the most important technical factors for the long - term success of metal - ceramic crowns.9

Many studies have been done to improve the marginal fit of the restorations. Multiple protocols to minimize the errors and yield best marginal fit of the restorations also have been suggested. However, studies comparing discrepancies of the restorations made using conventional lost wax and DMLS techniques is also lacking.

Therefore, the current study was conducted to compare the marginal fit and internal gap of porcelain fused to metal crowns fabricated using conventional lost wax technique and direct metal laser sintering (DMLS) technique before and after glazing.
Studies have shown that the marginal fit of metal - ceramic crowns is influenced by the type of finish line and the firing procedures of veneering porcelains.1[3]Gemalmaz D et al concluded that, a significant difference was observed between veneered and non - veneered copings at the porcelain firing cycles. The increase in marginal gap in veneered copings after the body porcelain firing cycle may be a result of porcelain contamination on the inner surfaces of the copings.8

In the present study, the marginal fit of group IA samples was 101.60±38.97 µm before porcelain glazing compared to 124.64±40.71µm after porcelain glazing, showing statistically significant differences within the groups.

Xu D et al in their study reported that, the mean marginal gap width of the crowns fabricated by conventional lost wax technique was 170.19 µm which was significantly wider than that of the selective laser melting fabricated crowns 102.86 µm.1[4]Shillinburg et al. reported that, the marginal fit changes during porcelain firing were dependent on the design of the margin. They found that shoulder finish lines with or without bevel, compared with beveled and non - beveled chamfered margins, produced less distortion at the labial margins, which is in consistent with the present study.8

Vojdani M et al conducted a study wherein they reported the mean marginal gap in chamfer margin design before and after the porcelain application was 49.8µm and 68.2 µm, respectively. The mean marginal gap in rounded shoulder margin design was 35.2 µm before and 63.06 µm after the porcelain application. The marginal fit of shoulder copings was significantly better than chamfer copings.1[5]
In the present study, the marginal fit of group IB samples was 69.80±33.73µm before porcelain glazing as compared to 93.20±35.76µm after porcelain glazing showing statistically significant difference between chamfer and deep chamfer at both before glazing and after glazing interval.

Rahshenas N at al conducted a study wherein they reported the mean marginal gap of 20.6639 µm for samples with deep chamfer finish line and 30.4100 µm for samples with shoulder finish line. Therefore, samples with deep chamfer finish line had a lesser value of marginal gap, which is in consistent with the present study.1[6]

In the current study, the marginal fit of group IIA samples was 80.34±30.33µm before porcelain glazing compared to 112.06±31.90µm after porcelain glazing, showing statistically significant differences within the groups.

Chekkarraj S et al in their study reported that, copings fabricated by DMLS technique showed a lesser marginal gap compared to copings fabricated by the conventional technique. Copings with chamfer and radial shoulder finish lines fabricated by same technique had no statistically significant difference, as reported in the present study.1[7] The marginal fit of group IIB samples was 55.47±19.30µm before porcelain glazing compared to 82.53±19.98µm after porcelain glazing, showing statistically significant difference between chamfer and deep chamfer groups at both before glazing and after glazing interval.

Sundar MK et al concluded in their study that the mean marginal fit of copings before and after ceramic addition in metal laser sintered group with deep chamfer finish line was 53.63 µm while the lost wax technique group showed higher values of 70.83 µm which was statistically significant.1[8]

Al Maaz et al conducted an in vitro study to determine the effect of 3 different finish line designs on the marginal and internal gaps of metal copings made using the SLM technology. Three Ivorine right maxillary central incisors were prepared with a chamfer, deep chamfer, or shoulder finish line for a metal ceramic restoration. The study concluded that, SLM - fabricated Co - Cr copings on teeth prepared with a deep chamfer finish line demonstrated the lowest marginal gap.1[9]Shiratsuchi H et al in their in vitro study suggested that finish line designs may influence the marginal adaptation of electroformed metal - ceramic crowns. Clinically, a deep chamfer and a rounded shoulder design facilitate marginal adaptation and preferred for a metal - ceramic of crown.1[3]

All finish line designs tested showed significantly different marginal fit discrepancies between the before and after porcelain application. These results indicate that the firing procedures for veneering porcelains affect the marginal adaptation of metal - ceramic crowns. This marginal distortion probably results from the shrinkage of porcelain and could be attributed to the rate of oxide formation on the metal alloy.1[3, 20]

In the overall comparison of the marginal fit of samples fabricated by conventional lost wax technique, samples showed the values of 90.97±36.35µm and 118.35±30.07µm before and after glazing respectively but in the DMLS group, samples showed the values of 62.63±26.51µm and 87.32±27.87µm before and after glazing respectively, suggesting statistically significant differences in the overall marginal fit between the two groups.

Therefore, in the current study DMLS group samples produced a better marginal fit compared to conventional lost wax technique group, before and after glazing. The better marginal fit of Laser sintered metal copings are attributed to the precise, selective laser sintering and rapid solidification of cobalt chromium powder which occurs in small sections, thus minimizing the chance of shrinkage of the alloy.1[2]

The DMLS technique allows the metal powders to consolidate, and thus, detail reproduction is excellent.2[1] Therefore, the marginal fit values in group I was greater than group II. This may be explained with the technician's skill, deformation of the wax pattern, and shrinkage of the impression material or expansion of the gypsum that can all affect marginal fit of a conventional cast restoration.2[2]

No universally accepted values exist for the marginal accuracy of restorations. According to American Dental Association (ADA) Specification No.8, the marginal gap width range between 25 to 40 µm has been suggested as a clinical goal, but this goal is seldom achieved. Fransson et al reported that the marginal discrepancy value of the restorations should theoretically be between 25µm and 50 µm. However, it is difficult to achieve this value clinically. McLean and Von Fraunhofer reported that the maximum clinically acceptable marginal discrepancy was 120 µm for the long - term success of restorations.2[3, 24, 25]
Although statistically significant differences in marginal fit occurred between different types of finish lines and fabrication techniques used in the present study (from 62.63 µm to 118.35 µm), all results were below 120 µm, which is the clinically acceptable maximum discrepancy. The marginal fit values obtained in this study indicated that both copings could meet the clinical requirement after porcelain glazing. However, DMLS copings exhibited better marginal fit compared to conventional lost wax group, which means that the marginal fit of DMLS copings is superior to cast copings in clinical use.2[3]

The results of Sharma M et al study reported, that the mean marginal gap of samples fabricated by DMLS group was 27.9 ± 2.4 µm and for conventional lost wax technique group was 40.4 µm, which were statistically significant. The DMLS samples demonstrated superior marginal fit compared to that of samples fabricated by conventional lost wax technique, which is in consistent with the present study.2[6]Kaleli N et al in their study reported, that the lowest marginal discrepancy values were observed in restorations prepared by using the DMLS method compared with conventional lost wax technique group. The marginal discrepancy increased after porcelain application, compatible with the present study.2[7]

Therefore, the marginal fit discrepancy for both the groups increased after porcelain glazing. Although the application of porcelain glazing at a high temperature affected the marginal fit, the marginal fit values of all the groups were within the clinically acceptable range. Various observations on the marginal discrepancy caused after the porcelain firing could be attributed to following reasons. The release of casting induced compressive stresses as a result of initial oxidation cycle, formation of an oxide layer on the internal surface of the metal ceramic alloy during heating, thermal incompatibility stresses, different coefficients of thermal expansion of the alloys 14.2×10 - 6K - 1 for the base alloy and the ceramic 12.0–12.6×10 - 6 K - 1, contamination of the internal surfaces of the coping with porcelain, reduction in the resilience of the metal because of rigidity of porcelain, grain growth of the alloy, constricting the diameter of the crown, improper support of the framework during firing, inadequate framework design at the gingival level, inadequate design of the framework as a whole.9[20, 28]

The copings obtained using the DMLS technique showed a better marginal fit than those from the conventional technique attributed to the total elimination of casting and manual errors in DMLS. The marginal discrepancy in the conventionally casted samples could also be caused by the high - temperature heating of the alloy beyond its melting point, which affects its viscosity and flow.1[7]

5. Limitations of the Study

The present in - vitro study had some limitations.
1) Oral environment was not simulated.
2) The mid - point of three reference points for testing of marginal fit on the stainless steel dies was not justified according to the clinical scenario.

6. Conclusion

Within the limitations of the study, the following conclusions were drawn:

The difference in marginal fit values for the samples between conventional lost wax technique group and Direct Metal Laser Sintering (DMLS) group was statistically significant before and after glazing.

The maximum value for marginal fit was obtained by conventional lost wax technique group, chamfer sub - group after glazing, and minimum value for marginal fit was obtained by Direct Metal Laser Sintering (DMLS) group, deep chamfer sub - group before glazing.

Selective laser sintering and rapid solidification of cobalt chrome powder in small sections minimize the chances of alloy shrinkage for laser sintered metal copings. The high density of laser - sintered crowns when small - sized particles (3–14 µm) are combined with a very fine point laser of 0.1 mm, contributes to a stronger and void - free coping, and the resulting restorations are accurate.4[0]

Preliminary research suggests that the surfaces of laser - sintered Co - Cr alloy crowns are rougher than the surfaces of crowns conventionally cast from the Co - Cr alloy of similar composition, which may positively affect the metal ceramic bond. It is interesting that the composition of the Co - Cr alloy for laser sintering does not contain tungsten and has lower molybdenum content, compared to the composition of the Co - Cr alloy for casting. Presumably, laser sintering of the former Co - Cr alloy is facilitated by the absence or diminished percentage of such refractory metals, which have much higher melting temperatures than cobalt and chromium. Future research in this area is recommended.4

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