Scholars Journal of Dental Sciences (SJDS) **ISSN 2394-496X (Online)**
Sch. J. Dent. Sci., 2016; 3(3):88-94 **ISSN 2394-4951 (Print)**

(An International Publisher for Academic and Scientific Resources)
www.saspublishers.com DOI: 10.36347/sjds.2016.v03i03.004

Original Research Article

A Comparative Assessment of Marginal Fit and Marginal Micro Leakage in Copings Obtained By Laser Metal Sintering and Conventional Casting Technique: An In Vitro Study

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Abstract: The objective of this in vitro study was to assess the accuracy of marginal fit and marginal micro leakage of copings obtained from laser metal sintering technique and conventional casting technique. Thirty maxillary premolars extracted for orthodontic purposes were used in the study. They were divided into two groups and disinfected with 5.2% sodium hypochlorite solution. Teeth were prepared using torpedo bur to provide a chamfer finish line; care was taken to maintain a constant taper of the preparation. Marginal misfit was evaluated using a light microscope. The samples were luted using Type I Glass Ionomer cement and immersed in a solution of methylene blue 2% solution for 24 hours. The samples were then sectioned and analysed. The marginal misfit of the copings fabricated using conventional casting and laser metal sintering were 90.60 and 90.0 respectively. Marginal microleakage was scored and 73% of the samples in the lost wax method obtained a score of 0 and 1 whereas 73.3% samples in the DMLS technique obtained a score of 0 and 26.7% obtained a score of 1. 26.7% of the samples in the lost wax technique were observed to give a score of 2 and 3 while none of the samples in the DMLS technique provided those scores. The result was statistically significant. Marginal misfit values were similar for both groups and so the result was not statistically significant. Copings fabricated via the lost wax technique showed higher marginal microleakage values than those in the laser sintered technique.
Keywords: Laser metal sintering, lost wax method, Marginal misfit, Marginal micro leakage, silicone replica technique, casting inaccuracies

INTRODUCTION

The aim of fixed dental restorations is mainly to restore the lost function and esthetics of intraoral structures without causing harm to the oral or systemic health of the patient. The construction of metal substructures to function as copings and crowns with an accurate marginal seal has for long been a crucial factor for long term success of restorations. A wide range of materials and techniques have been used to improve the quality of the fabricated frameworks such as noble alloys, base metal alloys etc. However despite the excellent mechanical properties and lower costs these materials display potential distortions inherent in casting. Errors related to impression making procedures, distortion of wax patterns, defects during the casting and during luting procedures may result in marginal discrepancies.

The fabrication method for base metal alloys such as cobalt- chromium restorations has been conventional casting using the lost wax method. There are many steps involved in the production and so subsequently an increase in the number of variables that can cause discrepancies in the final restoration. A newer technology involving fewer manual steps and hence fewer chances for error has been introduced. The newly developed direct metal laser-sintering (DMLS) system is an additive metal fabrication technology, based on information received from three dimensional CAD, in which metal powder is shot selectively using a data file and fused with a laser to laminate approximately a 20–60μm-thick layer with each shooting to complete a metal structure.

The present study aimed to assess the accuracy of marginal fit and marginal micro leakage of copings obtained from laser metal sintering technique and of those obtained from conventional casting technique and to compare the marginal fit and marginal micro leakage of copings obtained from laser metal sintering and conventional casting technique.

EXPERIMENTAL SECTION

This in vitro study was conducted in the Department of Prosthodontics, A.B. Shetty Memorial Institute of Dental Sciences, Nitte University, Mangalore, on a total of 30 maxillary premolars with normal coronal anatomy which are extracted for orthodontic purposes.

INCLUSION CRITERIA

1. Recently extracted maxillary premolars from patients aged 15-25 years.
2. Teeth with no radiographic or clinical evidence of caries
3. Teeth with intact occlusal morphology.
4. Minimal crown length of 4 mm

EXCLUSION CRITERIA

1. Teeth with developmental anomalies
2. Teeth that exhibit regressive alterations
3. Decalcified teeth
4. Teeth with evidence of trauma
5. Endodontically treated teeth.

A total sum of 30 teeth were collected for the study purpose from December 2013 to March 2015 from patients visiting the Dept. of Oral & Maxillofacial Surgery, ABSMIDS Mangalore, to extract their Maxillary premolars for orthodontic purposes. Subsequently the teeth were extracted with 5.2% sodium hypochlorite solution and stored in normal saline solution. They were then divided into two groups of 15 Nos. each. Group 1 consisted of 15 Prepared teeth on which cobalt chromium alloy copings fabricated using laser metal sintering technique while Group 2 consisted of 15 Prepared teeth on which cobalt chromium alloy copings fabricated using conventional lost wax casting technique.

PREPARATION OF TEETH

The teeth were disinfected with 5.2% sodium hypochlorite solution and were mounted using type 3 dental stone to provide stable base. Teeth were prepared using torpedo diamond bur with chamfer finish line all around the teeth. Occlusal reduction was kept minimum 2mm and axial reduction of minimum 1.5 mm was maintained. The taper of preparation was maintained within acceptable range and preparation was finished and polished using finishing burs. All the teeth were prepared by one clinician to eliminate bias.

PREPARATION OF COPINGS

Total 30 prepared teeth were divided into two groups of 15 each. 15 teeth received copings made by conventional casting technique and 15 teeth received copings made from laser metal sintering method. For conventional method die spacer was applied to provide space for cement and wax patterns were fabricated using crown wax. Wax patterns were invested using phosphate bonded investment material and casting of the invested patterns done using Co-Cr alloy. Copings were finished and polished with conventional trimming and polishing burs. Other 15 copings were fabricated using laser metal sintering method (EOSINT M-270) using Co-Cr alloy and copings were finished and polished.

Fig. 1: Coping fabricated by Conventional lost wax method

Fig. 2: Coping fabricated by direct metal laser sintering

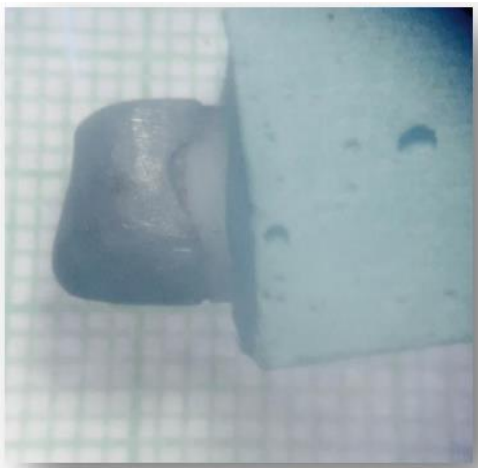

Fig. 3: Microscopic view of Conventional coping showing marginal misfit

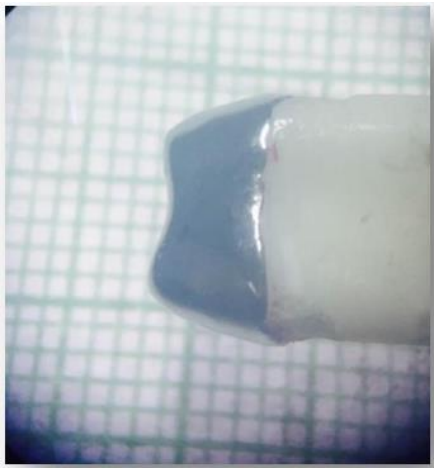

Fig. 4: Microscopic view of DMLS coping showing marginal misfit

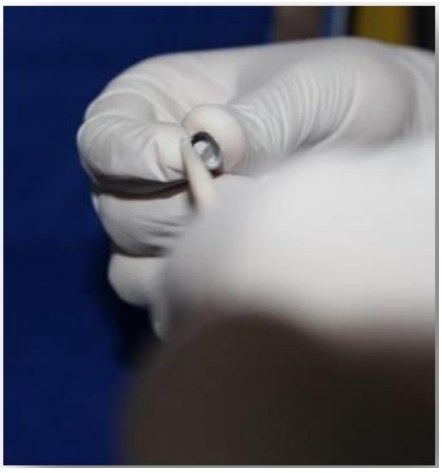

Fig. 5: Loading of Glass ionomer cement onto intaglio surface of coping

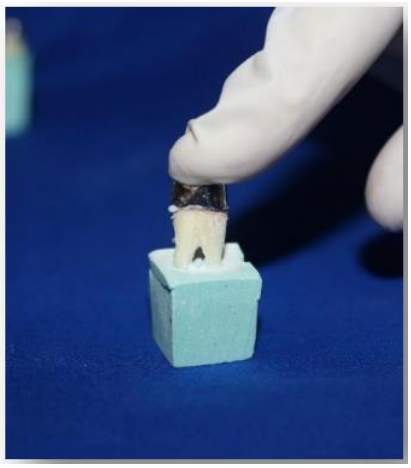

Fig. 6: Application of finger pressure onto coping

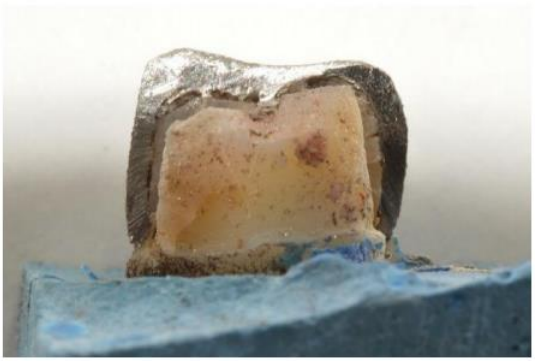

Fig. 7: Microleakageobserved in Conventional coping

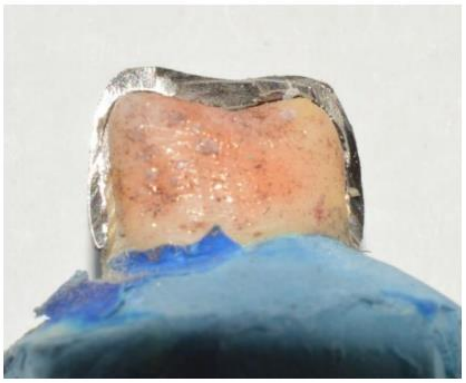

Fig. 8: Microleakage in DMLS

METHOD OF MEASURING MARGINAL MISFIT

After coping fabrication, they were set aside into two different groups. The plaster encasing the 15 copings fabricated via the Lost wax technique were demarcated 'C' for control. The other 15 copings fabricated via the direct metal laser sintering technique were not marked. The copings were then viewed under a light microscope to assess the marginal misfit.

METHOD OF MEASURING MARGINAL MICROLEAKAGE

The internal surface of coping was luted with Glass ionomer cement and copings were positioned on teeth using firm finger pressure to make sure they seat accurately till the margin of tooth. Excess material was wiped off using cotton. A 2% methyhlene blue solution was made by dissolving 2 ml of methylene blue dye in distilled water after which the samples were immersed in the solution for a period of 24 hours. After 24 hours the samples were removed from the solution and wiped clean. The copings were sectioned labio-lingually along with the tooth using metal cutting disk. Sectioned specimen shows thin film of glass ionomer cement material present between metal coping and tooth surface. The penetration of the methylene blue dye was graded on a score from 0-3 adapted from a method by Tjan [1]. The marginal micro leakage of each structure was the average score recorded on the axial surface. After which an observation was made under the light microscope.

The data thus obtained in relation to marginal misfit and the marginal micro leakage of both the groups were evaluated using Mann Whitney U test and Fisher's Exact test respectively with SPSS computer software to determine the effect of the two different manufacturing methods of crown fabrication.

RESULTS

The results obtained were depicted in Tables 1 & 2 and Graphs 1 & 2.

Table 1: Marginal misfit for each group

Group	N	Mean (SD)	Median (Q1-Q3)	Mean Difference (95%CI)	U statistic	p-value
Lost wax	15	168.36(151.72)	90.60(70.10-275.70)	69.34(-14.73, 153.41)	87.50	0.30(NS)
DMLS	15	99.02(47.38)	90.00(50.8-137.50)			

Values in µm
Mann Whitney U test
*P<0.05 statistically significant
p>0.05 non-significant, NS

Table 2: Marginal microleakage for each group

	Group		Total
	Lost wax	DMLS	
0	4(26.7%)	11(73.3%)	15(50.0%)
1	7(46.7%)	4(26.7%)	11(36.7%)
2	3(20.0%)	0	3(10.0%)
3	1(6.7%)	0	1(3.3%)
Total	15(50.0%)	15(50.0%)	30(100.0%)
	Fisher's exact value-7.52, p<0.05*		

Fisher's Exact test
*P<0.05 statistically significant
p>0.05 non-significant, NS

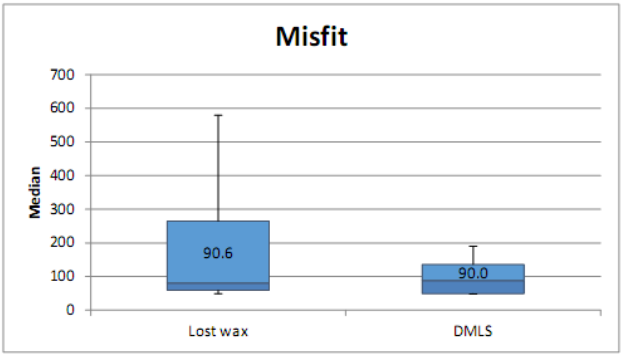

Fig. 1: Graphical representation of comparison of marginal misfit of copings fabricated with two different methods

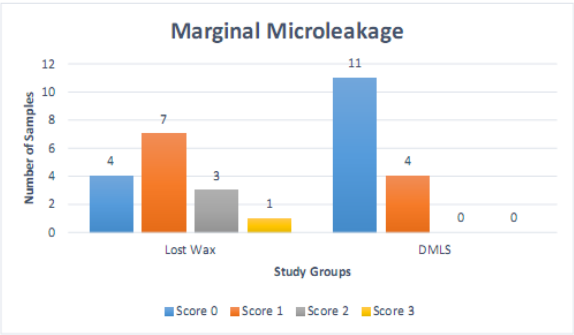

Fig. 2: Graphical representation of comparison of marginal micro leakage of copings fabricated by two different methods on different teeth surfaces

Table 1 shows the misfit values between copings fabricated with the conventional lost wax technique and the direct metal laser sintering technique. Similar values for marginal misfit were observed. The median value for the conventional lost wax technique was 90.60 whereas that for the copings fabricated with DMLS technique was 90.00. p value is not statistically significant p=0.30 (Fig. 1).

Table 2 shows the marginal micro leakage of copings fabricated with laser metal sintering method and conventional casting method based on scores from 0-3. A statistically significant difference was observed between the copings fabricated by the conventional lost wax and the DMLS technique. The results of marginal micro leakage were observed to be inversely proportional to each other. About 73% of the samples in the lost wax method obtained a score of 0 and 1 whereas 73.3% samples in the DMLS technique obtained a score of 0 and 26.7% obtained a score of 1. 26.7% of the samples in the lost wax technique were observed to give a score of 2 and 3 while none of the samples in the DMLS technique provided those scores. The results were statistically significant. $p<0.05$ (Fig. 2).

DISCUSSION

The marginal fit of fixed prosthesis has been a subject of dispute for the past few decades and is of paramount importance when considering the longevity of the restoration. An excellent marginal fit provides a hermetic seal for the prosthesis minimizes plaque accumulation and reduces the chances of recurrent caries and periodontal inflammation. There has been no consensus on a clinically acceptable marginal gap for fixed restorations through the literature.

American Dental Association (ADA) specification No.8 [2] indicates the thickness of luting cement for a dental crown should not exceed 25µm when using type I luting agent. A cement gap of 120µm has been suggested as maximum whereas other studies have shown that 50µm - 100µm is acceptable [3]. Fraunhofer [4] suggested that the clinically acceptable marginal gap after cementation should be less than 150µm and 120µm. In addition it was indicated that a marginal gap of less than 80µm was difficult to detect under clinical situations.

The lost wax technique was introduced by Taggart in 1907 [5]. Primarily, the clinician proceeds to make an impression which might be uncomfortable for the patient due to the retraction cord and the need for anaesthesia. Initially, noble alloys were selected because of their biocompatibility. When the cost of production increased, consequentially manufacturers focused on less expensive alternatives to reduce the cost. Nickel-chromium and cobalt-chromium alloys are now used instead because of their lower unit production costs and ease of fabrication.

Though there have been various recent advances in investing materials, alloy composition and casting techniques to improve the marginal adaptation and seating of cast restoration the casting procedure is highly technique sensitive and discrepancies are quite common. Among the several direct metal forming techniques, selective laser sintering offers many benefits due to its capability to directly build three dimensional metallic components from metal powders with minimal or no post processing requirements.

Laser sintering today is one of the pioneering commercial processes for quick fabrication of functional prototypes and tools. Deckard and Beaman introduced this methodology [6]. It creates a solid 3 dimensional object by bonding powdered materials using laser beam energy. It works on the principle of 3 D printing. Laser sintering is associated with a physical process for heat transfer and sintering of powder. Recently computer models have been used to further study the laser sintering process. These models take into account the thermal phenomenon involved in the diffusion process. The thermal gradients in the powder bed can then be related to thermal stresses which enable a skilled operator to predict warpage or distortion of the fabricated parts. An indirect laser sintering procedure, a polymer phase is used to bond the powder particles. During the irradiation phase the polymer phase is melted and upon cooling the powder particles fuse together.

The aim of the present study was to assess the marginal misfit and marginal micro leakage of Co-Cr copings fabricated by conventional method and laser metal sintering method. It was not possible to standardize all the clinical samples due to variation in anatomic structure of each prepared tooth for coping fabrication. Although utmost care was taken to maintain almost same height and taper of the prepared tooth. Marginal misfit was assessed for both groups under the light microscope. Measurement data was obtained by placing the specimens under the light microscope so that the marginal area could be viewed from a perpendicular viewpoint.

Samples from the control group showed a wider variation at the margin than the laser sintered group. The laser sintered group had consistent values which fell in the acceptable range of marginal misfit and were more reliable. The larger the number of samples and measurements, the greater the precision of the analysis [7]. The sample size was small leading to a gross variation in the values for marginal fit observed in the control group. The study revealed that the median value for the vertical misfit was similar in both groups which are not statistically significant.

A statistically significant difference was observed for marginal micro leakage between the

copings fabricated by the conventional lost wax and the laser sintered technique. Around 73% of the samples in the lost wax technique obtained a score of 0 and 1 whereas 73.3% samples in the laser sintered technique obtained a score of 0 and 26.7% obtained a score of 1. 26.7% of the samples in the lost wax technique were observed to give a score of 2 and 3 while none of the samples in the laser sintered technique provided those scores. The results were statistically significant and show higher microleakage among the samples in the control group.

Microleakage can be associated with marginal misfit, however there is no strong correlation between the two scores when demonstrated [1, 8-10].Marginal misfit has been generally observed to increase after a cementation procedure [11] as the cement maybe discontinuous and may affect the proper seating of the crown [12]. The presence of marginal misfit does not always denote the presence of micro leakage. Many other variables such as tooth structure, luting agent used, consistency of luting agent and technique of luting play an influential role on micro leakage.

Glass ionomer cements are clinically appealing dental restorative materials [13]. Glass ionomer cements possess unparalleled properties as adhesive materials. The fluoride releasing properties of these cements reveal anticariogenic properties, and other properties include biocompatibility and low toxicity. Resin modified glass ionomer cement was chosen in this study as it is a commonly used permanent luting agent for fixed prostheses in a clinical set up.

Two techniques have been advocated to measure the marginal gap, the cross sectioning technique and the silicone replica technique. Shearer *et al*[14] reported statistically significant differences in using both the techniques and promoted the usage of the sectioning technique over using the silicone replica technique. Various experimental setups have been used to measure marginal gap under different scenarios which greatly influences the outcome. Making measurements in vivo or in vitro [15-17], before or after the cementation procedure [18, 19] using a chamfer or a shoulder finish line [20] the sample size and the number of surfaces being measured [21] all play a profound role to affect marginal fit.

The type of cement being used also affects the marginal fit and microleakage. As mentioned earlier Resin modified glass ionomer cement was used to lute the copings to the substructure. A study done by Davis [22] suggested that the gap assessed by light bodied silicone indicator paste were comparable with those castings using a luting cement. In this study a cementation technique was used.

LIMITATIONS AND SCOPE FOR FURTHER RESEARCH

The future scope of this study includes using a larger sample size to obtain more accurate results, using more measurement points on the samples to get an accurate reading of the marginal misfit and marginal micro leakage, assessment of more luting cements so as to understand the nature of micro leakage and so to evaluate the correlation between marginal misfit and marginal micro leakage, assessment of thickness of die spacer to be used and difference between marginal misfit before and after cementation.

CONCLUSION

The copings fabricated using the direct metal laser sintering technique exhibited a mean marginal misfit value of 99.02 μm which fell well within clinically acceptable range. 73.3% of the samples exhibited a score of 0 when assessed for the marginal micro leakage among the laser metal sintered group.The copings fabricated using the conventional lost wax technique showed a mean marginal misfit value of 168.36 μm. 73.4% of the samples exhibited a score of 0 and 1, with majority of the samples showing the latter among the conventionally cast group.

The copings fabricated via the conventional lost wax technique demonstrated a higher value of vertical marginal misfit. The marginal micro leakage scores of the conventional lost wax group were higher than those of the laser sintered group.

Although the marginal misfit values fell within acceptable range for the lost wax group, there were samples that exhibited vertical marginal misfit values greater than 300 μm and so further investigations need to be carried out using larger sample sizes to obtain more accurate results. The marginal micro leakage exhibited by the lost wax group was higher than that in the laser sintered group and was statistically significant. Laser sintering metal prostheses provide reliable marginal misfit and marginal micro leakage values and can be used for fabrication of routine crowns and copings.

SUMMARY

A study was conducted to assess the accuracy of marginal fit and marginal micro leakage of copings obtained from laser metal sintering technique and of copings obtained from conventional casting technique. Atotal of 30 maxillary premolars, 15 in each group with normal coronal anatomy which are extracted for orthodontic purposes were collected for the study in A. B. Shetty Memorial Institute of Dental Sciences, Deralakatte, Mangaluru.

The marginal misfit and marginal micro leakage was assessed between copings fabricated using conventional casting technique and direct laser metal sintering. The misfit values were recorded after viewing

under a light microscope and the micro leakage was assessed after cementation of the samples using Type I Glass ionomer cement, and scored based on the dye penetration along the axial surface of the tooth – cement interface. The values were then noted and compared.

Direct metal laser sintering is a new and upcoming technique and has shown promise in the field of dentistry. The prostheses fabricated via this technique have shown comparable results to conventional techniques if not superior to it. However further studies are required to confirm this.

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