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A COMPARATIVE EVALUATION OF MARGINAL FIT OF DIRECT METAL LASER SINTERED COBALT CHROMIUM CROWNS FOR THREE DIFFERENT MARGIN PREPARATION DESIGN BEFORE AND AFTER CEMENTATION WITH THREE DIFFERENT LUTING CEMENTS – AN IN-VITRO STUDY

Dentistry

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ABSTRACT

Introduction: There can be multiple opinions when it comes to the marginal fit of crowns post-treatment. Even though if it's under occlusion there can be certain criteria from patient's point of view in esthetic manner and certain points need to be taken care during lab procedures depending upon the type of metal and their process of preparation. **Materials and Methodology:-**Multiple materials relating to direct metal laser sintered cobalt chromium related crowns were used to get a result based on aim as To evaluate and compare the marginal fit for Co-Cr Crowns fabricated using direct metal laser sintering (DMLS) technique for the following 3 margin preparation designs. **Results:-**With RMGIC and Zinc Polycarboxylate,In chamfer design overall marginal discrepancy in each cement between pre and post values was highly significant ($p<0.001$).In deep Chamfer design overall marginal discrepancy in each cement between pre and post values was highly significant ($p<0.001$).In Shoulder design, marginal discrepancy in each cement between pre and post values was highly significant ($p<0.001$).In Resin Cements In chamfer design line, mean difference between resin and RMGIC was found to be of statistical significance ($p<0.05$) with lesser marginal discrepancy in resin cement, Whereas In Deep chamfer finish line, mean difference between resin and RMGIC was not found to be of statistical significance ($p>0.05$). **Conclusion:** The present study concludes that the direct metal laser sintered cobalt–chromium crowns showed no significant difference in the marginal fit of all the three groups before cementation,. This signifies the role of cementation and necessary alterations required in the cementation process.

KEYWORDS

Marginal fit, cobalt chromium crowns, direct metal laser sintering (DMLS), margin preparation designs, cementation, luting cements

INTRODUCTION

Prosthodontics is the dental specialty related to the diagnosis, treatment planning, rehabilitation, and maintenance of the oral function, comfort, appearance and health of patients with clinical conditions associated with missing or deficient teeth and/or maxillofacial tissues using biocompatible substitutes. Various branches of prosthodontics are related to removable prostheses, fixed prosthesis, implant prostheses, and maxillofacial prosthesis.[1] Fixed prosthodontics is the art and science of restoring damaged teeth and of replacing missing teeth with prostheses that are fixed in the mouth. The scope of fixed prosthodontic treatment can differ from restoring a single tooth to full mouth rehabilitation. Fixed prosthodontic treatment often offers great comfort for both the patient as well as dentist. It can convert an unhealthy, destructive dentition with defective function into a comfortable, healthy occlusion greatly enhancing the aesthetics of patient.[2]

The aim of Fixed Partial Denture to restore function and aesthetics of lost intra-oral structures without affecting the oral and general health of the patients[3] Porcelain fused to metal crowns a consists of a thin metal coping bonded onto abutment teeth and a fused ceramic layer on top.[4] Most commonly used alloys for fabricating metal copings are Nickel-Chromium (Ni-Cr) and Cobalt-Chromium (Co- Cr) for metal ceramic restorations.[4,5] Beryllium (Be) has been added to the Ni-Cr alloy in order to improve castability and to reduce the alloy's melting temperature.[6] However, a Be-containing Ni alloy releases Ni ions in an acidic environment,[7] which causes allergic and toxic reactions. When compared to Ni-Cr based alloys Co-Cr comparatively have fewer side effects than Ni-Cr based alloys, they are an alternative source for patients with allergies.[9] The titanium is used as an substitute to chrome-type alloys for metal ceramic restorations because of its high strength and rigidity, low density and light weight, ability to withstand high temperatures and resistance to corrosion, low cost and mechanical properties that resemble those of hard and extra- hard casting golds.[10,11]

Long-term clinical success of fixed prosthodontic and cast restorations is influenced by many factors, preparation design, oral hygiene/ microflora, mechanical forces, and restorative materials. However, key factor to success is the choice of a proper luting agent and the cementation procedure. Hence, the rationale of this in vitro study is to evaluate and compare the marginal fit of cobalt chromium crowns fabricated with a new laser melting procedure for three different margin preparation design before and after cementation with three different luting cements.

The aim of this study is to evaluate and compare the marginal fit for Co-Cr Crowns fabricated using direct metal laser sintering (DMLS) technique for the following 3 margin preparation designs i.e. chamfer, deep chamfer and shoulder; before and after cementation with Adhesive resin ,Resin modified GIC and zinc poly-carboxylate as luting cements.

MATERIAL AND METHODS

In this study, we have evaluated and compared the marginal fit of direct metal laser sintered cobalt chromium crowns on three different margin preparation designs namely chamfer, deep chamfer, and shoulder with Adhesive resin, Resin modified GIC and zinc polycarboxylate as luting cements. The following methodology was cleared by the Institutional Ethical Clearance Committee.

The Material Used Were: Ivorine teeth,Diamond burs, Nickel-chromium alloy, Type IV dental stone, Polyvinyl siloxane impression material, Pattern resin, Phosphate bonded investment material, Sprue wax, Debublizer, Crucible former, Casting ring, Casting ring liner, StarbondCoS Powder 30, Opaquer porcelain, 3C – Bond,Enamel & Dentin porcelain, Glaze porcelain, Adhesive resin, zinc polycarboxylate

Equipment Used For The Study: Dental scanning machine, Laser melting machine, Pre-heating furnace, Induction casting machine, Vacuum mix, Micro sandblaster, Porcelain furnace, Cementation apparatus, Optical stereomicroscope

The inclusion criteria for this study require that impressions be free of defects, and preparations must feature distinct, regular, and smooth margin designs. Additionally, copings should fit well over the die, and crowns must have an accurate fit. The die itself should have no surface irregularities, and the crowns must exhibit a polished surface with an accurate fit. Conversely, the exclusion criteria stipulate that impressions with any defects will be disqualified, as will preparations that have indistinct, irregular, or rough margin designs. Copings that do not fit adequately over the die, as well as crowns with inadequate fit, will also be excluded. Furthermore, dies exhibiting surface irregularities and crowns with unfinished surfaces or inaccurate fits will not be considered for this study.

The sequence of clinical and laboratory steps undertaken in this study is as follows. First, master dies for the chamfer, deep chamfer, and shoulder margin designs were fabricated. Next, each master die was duplicated 20 times using Type IV dental stone. Following this, copings were fabricated using the Direct Metal Laser Sintering (DMLS) technique for each of the three margin designs. After the copings were created, they underwent ceramic firing. The marginal fit of the crowns was then measured before cementation, followed by the cementation of the crowns. Finally, the marginal fit of the crowns was measured again after cementation to assess any changes.

The scanner used for this study has a scan volume of 62 mm x 46 mm x 46 mm, with an average scan time of 1.40 minutes for a single crown. It is a non-contact, optical scanner that utilizes fringe projection triangulation technology, ensuring high accuracy in measurements. The dimensions of the scanner are as follows: it measures 545 mm in width, 800 mm in height, and 465 mm in depth, with a total weight of 45 kg. For its electrical specifications, the scanner operates on a line voltage of 100-240 volts, with a frequency of 50 Hz and a power requirement of 250 watts.

The EOSINT system utilized in this study has the following specifications: it measures 2,000 mm in width, 1,050 mm in height, and 1,940 mm in depth, with an approximate weight of 1,130 kg. The system is equipped with a Yb-fibre laser with a power output of 200 W, allowing for a scan speed of up to 7.0 m/s. It requires a compressed air supply of 7,000 hPa and a flow rate of 20 m^3/h. In terms of power consumption, the system has a maximum requirement of 8.5 kW, with typical usage around 2.4 kW.

Statistical analysis was performed using S.P.S.S. Version 17 software. The difference in marginal discrepancy before and after cementation in the three groups was analyzed using a paired t-test. Differences in marginal discrepancies in between the three groups before cementation and differences in marginal discrepancies in between the three groups after cementation were compared using Tukey Post-hoc analysis for multiple comparisons.

RESULTS

In chamfer design, the marginal discrepancy in resin cements, RMGIC & Zinc polycarboxylate cements increased after cementation (mean difference 39.53, 44.37 and 45.73 respectively) and this difference in overall marginal discrepancy in each cement between pre and post values was highly significant ($p<0.001$) as seen in table 1-5. In deep chamfer design, marginal discrepancy in resin cements, RMGIC & Zinc polycarboxylate cements increased after cementation (mean difference 31.96, 35.09 and 36.8 respectively) and this difference in overall marginal discrepancy in each cement between pre and post values was highly significant ($p<0.001$). In shoulder design, marginal discrepancy in resin cements, RMGIC & Zinc polycarboxylate cements increased after cementation (mean difference 57.66, 25.04 and 45.89 respectively) and this difference in overall marginal discrepancy in each cement between pre and post values was highly significant ($p<0.001$).

As seen in tables 1-5, the comparison of change (pre to post) in overall marginal discrepancy among different finish lines within each cement. :- In resin cements, change in marginal discrepancy in chamfer line, deep chamfer line and shoulder line were 39.53, 31.96 & 45.56 respectively and the overall difference between the three groups was highly statistical significant ($p<0.001$). In RMGIC, change in marginal discrepancy in chamfer line, deep chamfer line and shoulder line were 44.37, 35.09 & 50.91 respectively and the difference between the three groups was highly statistical significant ($p<0.001$). In zinc polycarboxylate cements, change in marginal discrepancy in chamfer line, deep chamfer line and shoulder line were 48.62, 40.54 & 54.68 respectively and the difference between the three groups was found to be highly statistical significant ($p<0.001$). In Zinc Polycarboxylate cement group , mean difference between chamfer and deep chamfer was found to be of statistical significance ($p<0.05$) with lesser marginal discrepancy in deep chamfer finish line. In chamfer design, change in marginal discrepancy in resin cements, RMGIC and Zinc polycarboxylate were 39.53, 44.37 & 48.62 respectively and the difference between the three groups was highly statistical significant ($p<0.001$) as seen in table 1-5.

In RMGIC, change in marginal discrepancy in chamfer line, deep chamfer line and shoulder line were 31.96, 35.0 & 40.54 respectively and the difference between the three groups was highly statistical significant ($p<0.001$). In resin cements, change in marginal discrepancy in chamfer line, deep chamfer line and shoulder line were 45.56, 50.91 & 54.68 respectively and the difference between the three groups was found to be of highly statistical significance ($p<0.001$). In chamfer design line, mean difference between resin and RMGIC was found to be of statistical significance ($p<0.05$) with lesser marginal discrepancy in resin cement, Whereas In Deep chamfer finish line, mean difference between resin and RMGIC was not found to be of statistical significance ($p>0.05$) with lesser marginal discrepancy in resin cement, Also In shoulder finish line design, mean difference between resin and RMGIC was not found to be of statistical significance ($p>0.05$) with lesser marginal discrepancy in resin cement as seen in table 1-5.

DISCUSSION

Metal ceramic restorations are still the most widely used type of indirect restorative system. Porcelain remains the material of choice for esthetic veneering of teeth, metal or high-strength ceramic copings. It has proven to be highly biocompatible, which favours a healthy gingival response. Conventional restorative techniques used for fixed restorations require the use of impression materials for making an impression with proper contours and finish lines of the preparation which is followed by pouring of stone models and dies prior to laboratory fabrication of definitive fixed restoration.

In present study, we have used three margin preparation designs i.e. chamfer, deep chamfer and shoulder; as they provide adequate bulk for material in case of metal ceramic restorations. Different methods have been used to check the marginal gap between finish line of preparation and margin of the restoration. Rinke-et al[12] utilized a stereomicroscope combined with a computer system to evaluate marginal gaps. Pelekanos-et al[13] mentioned several methods to measure marginal fit, including the use of low viscosity impression materials, profilometry, optical microscopy, and stereomicroscopy. Other methods include direct view technique, cross-sectioning technique, replica technique, use of Micro-CT and Scanning Electron Microscope etc. McLean and von Fraunhofer in their studies reported that the maximum clinically acceptable marginal opening was found to be 120 µm.[14] In present study non-parametric tests One-way ANOVA and paired sample t-test were applied for statistical analysis. In present study, cements used are Adhesive resin, resin modified GIC and zinc polycarboxylate as luting agent ,because of its favorable clinical performance. Self-adhesive resin cement is the newest type of cement to be introduced for luting dental restorations. Adhesive luting agents have been shown to be less soluble, biocompatible and bacteriostatic [15] A recent report demonstrated that RMGIC acid–base and visible light polymerization reactions inhibit one another during the early phases of setting, which may explain the low retentive strength of RMGIC.[16]

Jorgensen-et al [17] showed that there was an improvement in the final seating of cemented crowns as the force was increased from 0.5 kg (5 N) to 10 kg (98 N), but that the increase in seating was very small beyond 5 kg (49 N). Hence in present study, load of 5 kg was applied with cementation apparatus for a period of 10 minutes. This exceeded the setting time of cements (as given by the manufacturer) to ensure complete setting of the luting agent before the load is removed, preventing any chance of rebound. In the present study, the measurement of post-cementation and pre-cementation marginal fit exhibited the mean marginal discrepancy among Group A, B and C of 39.53, 31.96 & 45.56 respectively with adhesive resin cement. The higher post- precementation marginal discrepancies were observed with shoulder and chamfer margin designs as compared to deep chamfer margin design. The results of the present study are in accordance with the study conducted by Rahshenas N et al [18], Shearer et al [19], Gonzalo, Esther, et al[20,] Rossetti, Paulo Henrique Orlato, et al,[21,] Yüksel, Ece, and Ali Zaimoğlu. [22,] Pathak, Sidhant, et al. [23,] Sorensen, John A. [24] Kious, Andrew R., Howard W. Roberts, and William W. Brackett. [25]

Based on statistical analysis and the stereomicroscopic analysis for the marginal fit, it can be stated that the data obtained supports the rejection of null hypothesis for comparison of marginal discrepancies of the Groups A, B and C after cementation, because significant differences were observed. However, there was no significant difference in marginal discrepancy values for Groups A, B and C before cementation; thus, the data do not support the rejection of null hypothesis for this variable. The marginal fit of direct metal laser sintered cobalt-chromium copings of all the three groups i.e. chamfer; deep chamfer and shoulder before and after the cementation process were found to be within the acceptable limit for clinical use. According to the findings of the present study, there was no significant difference between all three groups before the cementation process whereas Group B i.e. deep chamfer margin design when cemented with adhesive resin has a better marginal fit i.e. less marginal discrepancy after cementation compared to Group A i.e. chamfer and Group C i.e. shoulder margin design.

CONCLUSION

The present study concludes that the direct metal laser sintered cobalt–chromium crowns showed no significant difference in the marginal fit of all the three groups before cementation, however; a significant difference was observed in the marginal discrepancy after cementation with adhesive resin, resin-modified GIC, zinc polycarboxylate as luting agents. This signifies the role of cementation and necessary alterations required in the cementation process for decreasing the post cementation marginal discrepancies.

Tables:

Table 1: Intragroup Comparison Of Overall Pre And Post Values

Design	Cement	Pre	Post	Difference	p value
	Resin cement	34.36 ± 1.99	73.9 ± 0.88	39.53	p<0.001**
Group A (Chamfer)					
	RMGIC	34.47 ± 1.75	78.84 ± 2.6	44.37	p<0.001**
	ZPC	33.81 ± 0.81	82.44 ± 2.07	45.73	p<0.001**
Group B	Resin cement	35.13 ± 1.79	67.1 ± 4.37	31.96	p<0.001**
(Deep chamfer)	RMGIC	32.84 ± 1.48	67.94 ± 3.52	35.09	p<0.001**
	ZPC	36.4 ± 3.03	76.94± 3.01	36.8	p<0.001**
	Resin cement	38.96 ± 3.94	84.53 ± 2.76	57.66	p<0.001**
Group C (Shoulder)					
	RMGIC	35.18 ± 1.51	86.1 ± 2.76	25.04	p<0.001**
	ZPC	34.82 ± 1.79	89.51± 2.59	45.89	p<0.001**

Paired t test; * indicates significant difference at p≤0.05. ** p<0.001 – indicated highly significant differences

Table 2: Overall Intergroup Comparison Of Change In Overall Marginal The Discrepancy Among Different Finish Lines Within Each Cement

Cement	Design	Mean	SD	F value	p value
Resin cement	Chamfer	39.53	2.36	F=15.286	p<0.001 **
	Deep Chamfer	31.96	4.54		
	Shoulder	45.56	5.32		
RMGIC	Chamfer	44.37	4.02	F = 29.634	p<0.001 **
	Deep Chamfer	35.09	3.53		
	Shoulder	50.91	4.0		
Zinc Polycarboxylate	Chamfer	48.62	2.3	F = 18.876	p<0.001 **
	Deep Chamfer	40.54	5.97		
	Shoulder	54.68	3.87		

One way ANOVA test* indicates significant difference at p≤0.05
** p<0.001 – indicated highly significant differences

Table 3: Pairwise Intergroup Comparison Of The Change In Overall Marginal The Discrepancy Among Different Finish Lines Within Each Cement Using Tukey's Post Hoc Test.

Resin Cement			
Group	Comparison Group	Mean Difference	p-value
Chamfer versus	Deep Chamfer	7.56	p =0.02*
	Shoulder	6.03	p =0.066
Deep Chamfer versus	Shoulder	13.6	p<0.001**
RMGIC			
Group	Comparison Group	Mean Difference	p value
Chamfer versus	Deep Chamfer	9.27	p =0.001*
	Shoulder	6.54	p =0.014*
Deep Chamfer versus	Shoulder	15.81	p<0.001**
Zinc Polycarboxylate			
Group	Comparison Group	Mean Difference	p value
Chamfer versus	Deep Chamfer	8.08	p =0.007*
	Shoulder	6.05	p =0.043*
Deep Chamfer versus	Shoulder	14.14	p<0.001**

One way ANOVA test. * Indicates significant difference at p≤0.05. ** p<0.001 – indicated highly significant differences

Table 4: Overall Intergroup Comparison Of The Change In Marginal Discrepancy Among Different Resin Cement Within Each Finish Line Design

Design	Cement	Mean	SD	F value	p value
Chamfer	Resin cement	39.53	2.38	F =14.406	p < 0.001*
	RMGIC	44.37	4.02		
	Zinc Polycarboxylate	48.62	2.30		
Deep Chamfer	Resin cement	31.96	4.54	F= 5.365	p = 0.016*
	RMGIC	35.0	3.53		
	Zinc Polycarboxylate	40.54	5.84		
Shoulder	Resin cement	45.56	5.32	F = 6.986	p = 0.006*
	RMGIC	50.91	4.0		
	Zinc Polycarboxylate	54.68	3.87		

One way ANOVA 'F' test* indicates significant difference at p≤0.05
** p<0.001 – indicated highly significant differences

Table 5: Pairwise Intergroup Comparison Of Change In Overall Marginal Discrepancy Among Different Resin Cements Within Each Finish Line Design Using Tukey's Post Hoc Test

Chamfer finish lines			
Group	Comparison Group	Mean Difference	p value
Resin cement versus	RMGIC	4.83	p =0.028*
	Zinc Polycarboxylate	9.09	p <0.001**
RMGIC versus	Zinc Polycarboxylate	4.25	p=0.045*
Deep Chamfer finish lines			
Group	Comparison Group	Mean Difference	p value
Resin cement versus	RMGIC	3.12	p =0.486
	Zinc Polycarboxylate	8.57	p =0.014*
RMGIC versus	Zinc Polycarboxylate	5.44	p= 0.115
Shoulder			
Group	Comparison Group	Mean Difference	p value
Resin cement versus	RMGIC	5.34	p = 0.102
	Zinc Polycarboxylate	9.11	p = 0.004*
RMGIC versus	Zinc Polycarboxylate	3.77	p= 0.270

One way ANOVA test. * Indicates significant difference at p≤0.05. ** p<0.001 – indicated highly significant differences

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