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Comparison Of Marginal Accuracy And Internal Fit Of Cast Nickle Chromium And Metal Laser Sintered Crowns – An In Vitro Study

[1]Dr. Priyanka Konin, Senior Lecturer, Department of Prosthodontics, Crown, Bridge & Implant logy, AME'S Dental College, Raichur, Karnataka

[2]Dr. Arvind Moldi, Professor & HOD, Department of Prosthodontics, Crown, Bridge & Implant logy, HKES's S. Nijalingappa Institute of Dental Science and Research, Kalaburagi, Karnataka

[3]Dr. Karishma Mayer, Private Practitioner, Maharashtra

[4]Dr. Aradhana Rathod, Private Practitioner

[5]Dr. Ajay Singh, Private Practitioner

[6]Dr. Manju George, Post Graduate Student, Department of Prosthodontics, Crown, Bridge & Implant logy, HKES's S. Nijalingappa Institute of Dental Science and Research, Kalaburagi, Karnataka

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Corresponding Author: Dr. Manju George, Post Graduate Student, Department of Prosthodontics, Crown, Bridge & Implant logy, HKES's S. Nijalingappa Institute of Dental Science and Research, Kalaburagi, Karnataka**Type Of Publication:** Original Research Paper

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Abstract

Objective: This in vitro study was conducted with an objective to evaluate and compare the marginal accuracy and internal fit of crowns fabricated by Direct Metal Laser Sintering, Induction casting and Centrifugal casting. Material and Method: An acrylic resin analog of the right maxillary first molar was prepared with a total convergence angle of 6 degrees and an occlusal reduction of 1.5 mm, 0.8 mm shoulder finish line. Thirty impressions of the analog tooth were obtained from the definitive die by using a light viscosity and putty vinyl polysiloxane. n=10 for each group. Twenty impressions were poured with type IV die stone for casting. The remaining impressions were poured with type IV die stone for the CAD/CAM group. 2 coats of die spacer was applied within 1 mm of the margin with a brush system for the casting group. Wax pattern were fabricated for induction and centrifugal group and casting was done using induction casting machine and centrifugal gas torch method and for direct metal laser

sintering group the dies were scanned and the design was fed to the EOS Sintering machine for fabrication. Each coping was luted to the original stone die with zinc phosphate cement and firm finger pressure for 5 minutes until the hydraulic pressure was relieved. They were sectioned longitudinally in a mesiodistal direction with a diamond disc. Sectioned specimens were polished using silicon carbide water proof abrasive paper to remove the metal particles that adhered in the cement region. The marginal gap and internal gap at the occlusal fossa area was estimated by measuring the cement thickness using Stereomicroscope. Results: DMLS had a significantly smaller marginal and internal gap than induction and centrifugal group. No significant difference exists in marginal and internal gap between induction and centrifugal group Conclusion: Under the limitation of this in-vitro study the marginal and internal gap of DMLS group are better than centrifugal and induction casting group. Keywords: Marginal Fit, Internal Fit, CAD/CAM, Direct Metal Laser Sintered Crowns, Margins. Introduction Marginal fit of castings is one factor that leads directly or indirectly to secondary dental caries, adverse pulpal reactions, and periodontal disease.1 There has been substantial disagreement about the acceptable marginal gap for dental crowns and fixed partial dentures. McLean and Von Frauhofer2 stated that a gap of 120 μm is tolerable, and that marginal discrepancies of less than 80 μm are difficult to detect under clinical conditions. Kashanietal3 considered that marginal openings greater than 100 μm were unacceptable, whereas Blackman et al4 reported that an acceptable gap should be no more than50 μm. Traditional method of fabrication of dental restoration is lost wax technique. Although the "lost wax" process has been used since ancient times, it has become common practice in dentistry after it was introduced by Taggart in 1907.5 The advent of CAD/CAM has enabled the dentists and laboratories to harness the power of computers to design and fabricate esthetic and durable restorations.6 When CAD/CAM burst onto the restorative dentistry scene a few years ago it brought with it a new range of exciting features; precision fit, reduced marginal adjustments. Direct metal laser-sintering (DMLS) is a well-known method for e-Manufacturing, the fast, flexible and cost-effective production directly from 3D CAD data. Using the conventional casting production process, a dental technician can currently produce only about 20 dental frames per day. Laser-sintering is a significantly superior method: one fully-automated laser-sintering system can produce approximately 450 high-quality units of dental crowns and bridges within 24 hours. The technological center piece of this is the EOSINT M 270 – the only system of its kind that produces cost effective, high-quality dental prostheses using Direct Metal Laser-Sintering (DMLS). In order to be able to manufacture dental prostheses using this additive layer manufacturing method, the 3D-CAD data is sliced into layers. Using these as a model, the desired geometry is produced in layers by selectively fusing cobalt chromium powder using a laser. DMLS is believed to produce high quality dental restoration which is cost effective. Therefore this study was carried out to evaluate the marginal integrity and internal fit of metal laser sintering crown and cast nickel chromium crown. The null hypothesis was that the fabrication method would have no effect on the marginal accuracy and internal fit. Materials and Methods Materials used 1. Auto polymerizing acrylic resin material (Dental products of India, Mumbai, India) 2. Vinyl polysiloxane impression material (Aquasil soft putty/light set, DENTSPLY, Germany) 3. Tray adhesive (DENTSPLY, De Trey GmgH Konstanz, Germany) 4.

Type IV die stone (Neelkanth Healthcare Pvt. Ltd., Rajasthan, India) 5. Die spacer (Heart-Man Colour Spacer, CS-1000) 6. Wax separator (GC Sep; GC Corporation) 7. Inlay wax (Blue inlay, Kerr Corp) 8. Three millimeter round wax sprues 9. Dental investment material (BEGO Wilhelm-HerbstStraBe, Germany) 10. Zinc phosphate cement (Harvard) 11. Nickel chromium alloy 12. Cobolt chromium alloy Equipments used 1. Diamond rotary cutting instruments 2. Aerotar hand piece 3. Induction casting machine 4. Centrifugal casting machine 5. Laser sintering machine (EOS) 6. Stereomicroscope (Vardhan, India, Model M300) Methodology An acrylic resin analog of the right maxillary first molar was prepared with a round-end diamond rotary cutting instrument (MANI, dia burs, Suzhou Welcome Dental Instrument Co., Ltd) in an airotar hand piece (NSK). The total convergence angle was 6 degrees. An occlusal reduction of 1.5 mm was accomplished to produce a complete crown preparation. The definitive die had a 0.8 mm shoulder finish line. A flat-end diamond rotary cutting instrument, 1.6 mm in diameter, at the tip (MANI, diamond burs, Suzhou Welcome Dental Instrument Co., Ltd.) was used for the shoulder margin. Thirty impressions of the analog tooth were obtained from the definitive die by using a putty and light viscosity vinyl polysiloxane (Aquasil soft putty/light set, dentsply, Germany). Twenty impressions were selected and poured with type IV die stone (Neelkanth Healthcare Pvt. Ltd, Rajasthan, India) for casting. The remaining impressions were poured with type IV die stone for the CAD/CAM group. The dies were kept dry for at least 2 days before further processing. For the cast group, 2 coats of die spacer (Heart-Man Colour Spacer, CS-1000) were applied within 1 mm of the margin with a brush system and according to the manufacturer's instruction the bottles were kept closed between applications, and the brush was cleaned frequently with thinner. The mean thickness of 2 coats of die spacers used in this experiment was approximately 25 µm according to a previous study1 . All stone dies were sealed with a die hardener (Stone die and plaster hardener resin; George Taub and Fusion Co), and a wax separator (GC Sep; GC Corporation) was applied. Inlay wax (Blue inlay, Kerr Corp) was used to produce wax patterns. Dip method was used to fabricate wax pattern. When the pattern had cooled, the marginal excess was carved and the margin was burnished with the beavertail burnisher. The margin was examined with a stereomicroscope (Vardhan, India, Model M300) at × 40 magnifications. The thickness of the crown was confirmed with a thickness gauge (Iwanson crown wax caliper; Surgidental instruments, Deer Park, NY). Three millimeter round wax sprues were attached to the distopalatal cusp. The wax patterns were invested with a phosphate based investment (BEGO Wilhelm-Herbst StraBe, Germany) for nickel chromium casting at a 38mL/160g (water/powder) mixing ratio. Wax elimination was achieved by heating the mold to 850°C at 6°C/minute according to the manufacturer's instructions. After casting, the investment on the crowns was removed by using airborne-particle abrasion with 50µm aluminum oxide particles (Basic master; Renfert GmbH, Hilzingen, Germany) at a pressure of 0.3 MPa and with an ultrasonic cleaner. The casting sprues adjacent to the crown were removed by using a low speed hand piece with a disc. For direct metal laser sintered crowns, the die was sprayed with a contrast spray and was scanned using 3M ESP and a design module, The simulated die spacer was programmed at 25 µm, starting 1 mm from the margin. Data was sent for production of the frameworks with the Co–Cr powder in a laser sintering machine. Each crown was luted to the original stone die with zinc phosphate cement (Harvard) and firm finger pressure for 5 minutes until the hydraulic pressure was relieved. They were sectioned longitudinally in mesiodistal directions with a diamond disc. Sectioned specimens were polished using abrasive paper to remove the metal particles that adhered in the cement region. The marginal gap and internal gap at the occlusal fossa area was estimated by measuring the cement thickness using Stereomicroscope (Vardhan, India, Model M300). Each point was measured 3 times by a single investigator and the mean value was determined. p-value were obtained using one-way ANOVA test. A students 't' test was used to determine the differences between the three groups DMLS, Induction and Centrifugal group. Statistical Analysis The mean and standard deviation were calculated for internal fit and marginal accuracy for all the three groups. All p-value were obtained using one-way ANOVA test. Three groups compared by student 't' test. Results The mean marginal gap was 59.82 ± 5.21µm in Direct Metal Laser Sintering group, 116.13 ± 7.88µm in Induction casting group and 116.87 ± 7.46µm in Centrifugal casting group respectively. The mean marginal gap in Direct Metal Laser Sintering group was significantly better than induction and centrifugal group. The mean internal gap was 118.69 ± 20.23µm in Direct Metal Laser Sintering group, 136.94 ± 13.50 µm in induction casting group and 133.77 ± 10.63µm in centrifugal casting group respectively. Internal gap was significantly better for the direct metal laser sintering group than induction and centrifugal group. Comparison of three groups by students 't' test shows that there is a significant difference between the DMLS group and Induction group, and between DMLS and Centrifugal group. No significant difference was found in marginal and internal gap between Induction group and Centrifugal group. The mean marginal and internal gap is significantly better in DMLS than induction and centrifugal group. Discussion The success of a restoration is determined by a range of factors. Marginal fit is one of the most important criteria when evaluating the clinical acceptability of the crowns. Lack of adequate fit is potentially detrimental to both the tooth and supporting periodontal tissues due to cement solubility or plaque retention. According to a study evaluating the service life of crowns in a 15-year period7 , the primary reason for crown failure was caries, 36.8%; followed by uncemented crowns, 12.1%; and defective margins, 11.3%. Various determinants of marginal adaptation of cast restorations are geometry of tooth preparation, dental materials such as impression materials, wax, die stone and casting investment, cement film thickness. Cement film thickness is related to preparation dimensions, occlusal perforations, die spacing, internal relief of the crowns, type of finish line, and type of cement. Other factors include power-liquid (P/L) ratio, cementation pressure, temperature and rate of mixing the cement, the powder particle size, and the liquid composition.8 Many methods have been advocated to improve the marginal adaptation and seating of restorations, they are, over waxing the margins of the wax pattern, removing wax from the internal surface of the wax pattern, internal relief of the cast restoration by (a) sandblasting, (b) mechanical milling with burs, with and without disclosing wax, (c) acid etching (aqua regia), (d) electrochemical milling (stripping, deplating), occlusal venting for escape of excess cement, devices to apply and maintain seating forces, internal relief of wax by application of a die spacer to the die before fabrication of wax pattern.8 Laurent et al. 9 showed that in vitro studies present better quality of fit in a controlled laboratory environment with optimal circumstances, than in a clinical setting. However, the production procedures for dental restorations in the dental laboratory do affect the fit more than the study design 10. The main clinical and laboratory variables are impression making, master cast fabrication, die spacing, fitting procedures and cementation 11. Accordingly, future CAD/CAM techniques could minimize some of these risk factors proven in the DLMS group were few critical manual steps are present. However, the descriptive terminology defining the fit varies considerably among investigators. Moreover, the same term is used for different measurements, or different terms are used for the same measurement. In the present study, the marginal gap and internal gap was defined according to the terminology reported by Holmes et al12 . Two common methods of measuring the marginal gap are measurements of embedded and sectioned specimens and measurements of the specimens by direct visualization. The latter method is nondestructive and provides several measuring points. However, it is difficult to obtain accurate measurements and the internal fit cannot be measured. Therefore, the former method was used in this study. The report of this study rejects the null hypothesis that there would be no difference in the marginal and internal fit of crowns produced by DMLS group, the Induction casting group and centrifugal casting group. There has been substantial disagreement about the acceptable marginal gap for dental crowns and fixed partial dentures. McLean and vonFraunhofer4 concluded that for single tooth restorations to be clinically acceptable, the maximum marginal gap should be 120 µm (10-160µm). In the present study the mean marginal gaps in all the three groups are within an acceptable marginal gap of 120 µm with better marginal gap in DMLS group than in induction and centrifugal group. The few published studies on the fit of constructions fabricated in Co–Cr have demonstrated marginal discrepancies of 74–99 µm, with internal gaps ranging from 250 to 350 µm using laser melting technology on single crowns13. Bindl and Mormann14 reported internal gap widths of 81 µm to 136 µm for different all-ceramic CAD/CAM crown copings. Ortorp et al11in his study reported mean internal gap of 144 ± 67 for conventional lost wax group and mean internal gap of 151 ± 58 for DMLS group. In this present study the mean internal gap of 118 ± 69 in DLMS, 136.94 ± 13.50 in Induction group and 133.77 ± 10.63 in Centrifugal group which were within the range compared of previous studies. Further studies with a greater sample size are needed to get a definite conclusion about the marginal and internal fit by different fabrication methods. Conclusion Within the limitation of the present study following conclusion can be made, 1. DMLS had a significantly better marginal and internal gap than induction and centrifugal group 2. No significant difference exists in marginal and internal gap between induction and centrifugal group. References

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Figure 6: Stereomicroscopic image showing marginal gap under 40x magnification

Table I: Metal laser sintered group

Sl. No	Internal fit in µm	Marginal fit in µm
1	141.1	53.8
2	127.2	60.8
3	141.6	54.5
4	89.2	57.9
5	93.2	64
6	122.8	71.5
7	95.5	62.9
8	145.2	57.9
9	125.5	54
10	105.6	60.9

Table II: Induction casting group

Sl. No	Internal fit in µm	Marginal fit in µm
1	155.9	119.5
2	136.0	126.5
3	155.9	100.1
4	155.0	121.1
5	114.2	115.5
6	128.0	115.2
7	125.5	119.0
8	132.7	105.7
9	132.2	113.0
10	154.0	125.7

Table Iv: Mean And Standard Deviation (Sd) For Three Groups In µm

Sl. No	Internal fit in µm	Marginal fit in µm
1	152.2	126.5
2	135.5	115.6
3	120.7	126.5
4	127.5	102.4
5	132.5	112.9
6	125.9	112.0
7	132.5	113.6
8	152.2	121.1
9	137.5	125.5
10	121.2	112.6

Table V: Comparison By Student's T Test

	Metal laser sintered crowns		Induction casting		Centrifugal casting	
	MEAN	SD	MEAN	SD	MEAN	SD
Internal Fit	118.69	20.23	136.94	13.50	133.77	10.63
Marginal Fit	59.82	5.21	116.13	7.88	116.87	7.46

COMPARSION BETWEEN	T VALUE	
	INTERNAL FIT	MARGINAL FIT
Metal laser sintered crowns & Induction casting	7.39	58.75
Metal laser sintered crowns & centrifugal casting	6.49	61.74
& centrifugal casting 6.49 61.74 Induction casting & centrifugal casting	1.82	0.67