"COMPARATIVE EVALUATION OF INFLUENCE OF CERAMIC FIRING ON INTERNAL FIT AND MARGINAL ADAPTATION OF SINGLE METAL CERAMIC CROWN RESTORATION FABRICATED BY CONVENTIONAL CASTING AND DIRECT METAL LASER SINTERING METHOD: AN IN VIVO STUDY"

BY

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Dissertation

Submitted to
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In

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(BRANCH – I)

Under the guidance of

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MY GUIDE

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No endeavor can start, continue and complete without the blessings of ***LORD GANESHA.*** *I thank him for blessing me with the strength and patience to complete the task entrusted to me.*

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"The task of the excellent teacher is to stimulate "apparently ordinary" people to unusual effort. The tough problem is not in identifying winners: it is in making winners out of ordinary people."

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DR. HARSHALI B. LOHAR

LIST OF ABBREVIATIONS USED IN THE STUDY

DMLS	-	Direst Metal Laser Sintering
CAD/CAM	-	Computer-aided design / Computer-aided manufacturing
SLM	-	Selective laser melting
Ni-Cr	-	Nickel-chromium
Co-Cr	-	Cobalt-chromium
Mm	-	Millimeter
N	-	Newton
µm	-	Micron
ISO	-	International Organization for Standardization
TSM	-	Triple scan method
SRT	-	Silicone replica technique
CSM	-	Cross-sectional method
OCT	-	Optical coherence tomography
MCT	-	Micro-computed tomography
CNCM	-	Computer numerical control milling
GML	-	Geometric Modelling Library

ABSTRACT

STATEMENT OF PROBLEM

Metal ceramic restoration is the most widely selected material for production of complete coverage restoration and fixed dental prosthesis. For of fixed prosthodontics, internal gap and marginal gap are two of the most crucial factors for determining the long-term prognosis of a prosthesis. The fit of metal ceramic restoration not only depends on the precision of the production method but also on the subsequent fabrication procedures such as firing process.

Nowadays the new digital systems are being commonly used for fabrication of metal ceramic crown to overcome the constraints with conventional casting technique. The effect of ceramic firing on clinical marginal and internal fit of restorations fabricated by laser sintering method is unknown.

PURPOSE

The purpose of this study was to evaluate and compare the effect of ceramic firing on the Clinical Internal fit and Marginal adaptation of metal coping fabricated by Direct Metal Laser Sintering method, with that of metal coping prepared by Conventional Casting method.

MATERIALS AND METHODS

40 subjects requiring premolar single crown restoration were randomly selected in this study and assigned in 2 groups of 20 subjects each. For all the subjects tooth preparation was done with shoulder finish line on all sides of the teeth and minimum occlusal reduction 2 mm and axial reduction 1.5 mm was maintained. Impression was made with monophase impression material and custom tray.

20 copings were fabricated by casting method and other 20 copings were fabricated by direct metal laser sintering method. Ceramic veneering was done by following equal number of firing cycles for all the 40 metal copings.

Silicone replica method was used to measure the internal fit and marginal adaptation. The replica was made onto the prepared tooth twice, that is before and after ceramic veneering. Digital stereomicroscope at 10X magnification was used to record measurements at 10 predefined points for each silicone replica sample and statistical analysis for the same was performed.

RESULTS

The results obtained for the marginal fit and internal adaptation of single crown metal ceramic restoration fabricated by DMLS method and Casting method showed statistically significant difference between both fabrication methods. The results also showed that the restoration fabricated by DMLS method were more precise than casting method. Also, ceramic firing process had significant influence on the marginal fit and internal adaptation of restoration fabricated by DMLS method and Casting method, with minimum difference in fit of restoration fabricated by DMLS method after ceramic firing.

CONCLUSIONS

Study concluded that ceramic firing process had significant influence on internal fit and marginal adaption of metal ceramic restoration, however the influence was minute for restorations fabricated by DMLS method when compared with restorations fabricated by traditional casting method. Restorations fabricated by DMLS method exhibited significantly superior internal adaptation and marginal fit in comparison with restorations fabricated by traditional casting method.

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INTRODUCTION

The principle goal of present-day dentistry is to render functional and aesthetic restoration to the patient.[1] To fulfil the aesthetic, mechanical and biological necessities of the patient an accurate fit is significant for a dental prosthesis. [2] Metal ceramic restoration is the most widely selected material for production of complete coverage restoration and fixed dental prosthesis.[3]

For fixed prosthodontics, “internal gap and marginal gap” are two of the most crucial factors in determining long-term prognosis of a prosthesis. [2] Holmes et al defined “marginal fit of a crown as the measurement perpendicular from axial wall of prepared tooth to the intaglio surface of coping at the margins, while internal fit is the perpendicular measurement all around tooth preparation except at the margins”.[4]

Clinical prognosis of any restorations is mainly relying on optimal adaptation between restoration and tooth structure. For long-term favourable outcome of metal-ceramic restorations one of the main critical technical aspect is optimal marginal adaptation. [5] Poor marginal adaptation can result in plaque retention, microleakage, cement dissolution and deterioration and following leakage of microorganisms and oral fluid through the gap, which in due course leads to pulpal inflammation, caries, and periodontal degradation. [6] When the internal fit is poor for a restoration it can result in increased cement thickness and can have impact on the stability of dental restorations.

Fabrication of fixed prosthesis is a multistep procedure hence minimization of gap or error needs to be done by decreasing error at each step during its fabrication. The traditional method for manufacturing the metal substratum is lost-wax casting process of metal alloys. Although through research is done on this method, it is a complex procedure requiring excellent technical expertise. [7]

"Direct Metal Laser-sintering (DMLS)", rapid prototyping systems, is a new additive fabrication technology in prosthetic dentistry and may take place of casting method. Working principle of DMLS is based on fabrication of 3-dimensional metallic frameworks from CAD software by using extreme elevated-temperature laser which merges small metal particles layer by layer. When the laser is applied to the metal particles, they melt, and the framework is gradually formed in layers by repeating this process. Thermal contraction of metal fragments is deceased as island scanning transmitting of laser beams is done for different sites at the same time. [8]

Although milling systems are widely used, milling method for hard base metal alloys causes loss of sharpness of milling equipment, increased price, and decreased production time. Worn out milling tool may have adverse impact on precision of restoration. [9]

Frequently used dental alloys are "nickel-chromium and cobalt-chromium". To improve castability of Ni-Cr metal alloy, beryllium (Be) is incorporated as it decreases the alloy's melting temperature. Nonetheless, Ni alloy containing beryllium releases Ni ion in an acidic environment, and the released Ni ions may cause allergic and toxic reactions. For removable partial and fixed prosthesis frameworks Co-Cr dental alloys have been used predominantly, as Co provides hardness and Cr prevents corrosion and improving mechanical properties. For patients with allergic reaction to Ni-based dental alloys, dental prosthesis is made using Co-Cr based dental alloys. Co-Cr metal substructure can be produced by casting and laser sintering method. For patients with allergic reaction to Ni-based dental alloys, dental prosthesis is made using Co-Cr based dental alloys. [1]

The fit of ceramo-metal restoration not only depends on the precision of production method but also it depends on subsequent fabrication procedures. After fabrication process, metal substructure undergoes various firing cycles, which includes oxidation, opaque porcelain, dentin porcelain, enamel porcelain and glaze porcelain firing. [8]

After the application of veneering porcelain, adaptation of metal coping may differ because of alloy type, ceramic shrinkage during firing and different thermal expansion coefficient of alloy and ceramic. [1]

In the available literature there are very few studies which are assessing the clinical internal and marginal fit of the metal copings produced by Direct metal laser sintering method.

Thus, the purpose of the present study is to compare the effect of ceramic firing on the Clinical Internal fit and Marginal adaptation of metal coping fabricated by Direct Metal Laser Sintering method, with that of metal coping prepared by Conventional casting method.

NEED FOR STUDY

Single crown restorations constitute the most part of fixed prosthodontic treatment. [10] It improves patient's aesthetics, speech and most importantly the ability to masticate. The most crucial factor for clinical prognosis of teeth undergone endodontic treatment is conservation of sound tooth structure. Root canal treated teeth with full coverage crown have higher long-term survival rate than those without full coverage crown [11].

Clinical survival of any restoration mainly relies on optimal adaptation between tooth structure and restoration. [6] As poor adaptation of the restoration leads to microleakage and plaque retention which is detrimental for tooth and periodontium (inflammation). [12]

The fit of metal ceramic restoration is not only dependant on precision of the production method but also dependant on the following fabrication procedures which involves ceramic firing process. [1]

At present there are various techniques available at our disposal for manufacturing single crown restoration. The introduction of digital technology has greatly changed the accuracy of prosthesis, while traditional techniques, still in use have also shown to produce acceptable prosthesis with regards to fit. The latest technology in prosthetic dentistry is Direct Metal Laser-sintering (DMLS). [13] DMLS is specially used for fabrication of metal restorations / metal framework.

Therefore, the present study was conducted to study the effect of ceramic firing cycle on the on the clinical internal fit and marginal adaptation of metal coping fabricated by DMLS method, with that of metal coping prepared using Conventional Casting method.

HYPOTHESIS

NULL HYPOTHESIS:

There is no influence of ceramic firing on clinical internal fit and marginal adaptation of single metal ceramic crown restoration fabricated by conventional casting method and direct metal laser sintering method.

RESEARCH HYPOTHESIS:

There is influence of ceramic firing on clinical internal fit and marginal adaptation of single metal ceramic crown restoration fabricated by conventional casting method and direct metal laser sintering method.

AIM OF THE STUDY

To evaluate and compare influence of ceramic firing on clinical internal fit and marginal adaptation of single metal ceramic crown restoration fabricated by conventional casting method and direct metal laser sintering method.

OBJECTIVES OF THE STUDY

1. To evaluate influence of ceramic firing on clinical internal fit and marginal adaptation of single metal ceramic crown restoration fabricated by conventional casting method.

2. To evaluate influence of ceramic firing on clinical internal fit and marginal adaptation of single metal ceramic crown restoration fabricated by direct metal laser sintering method.

3. To compare influence of ceramic firing on clinical internal fit and marginal adaptation of single metal ceramic crown restoration fabricated by conventional casting method and direct metal laser sintering method.

REVIEW OF LITERATURE

Shillingberg et al in 1973 discussed the design for tooth preparation and marginal distortion for porcelain fused metal full coverage prostheses. He stated that metal copings which at the time of try-in were fitting, apparently do not fit as well after veneering of ceramic, due to the possibility of general metal warpage. Typically, the buccal margin seems to be subjected to distortion as the width of the metal is restrained because of esthetics. The primary reason for marginal distortion is shrinkage of porcelain, hence increasing metal thickness seems to be the solution for minimizing distortion. He advocated use of shoulder margin finish line, with or without a bevel to reduce marginal distortion as this preparation creates the additional space for metal without invading the space necessary for the porcelain veneer. [14]

David V. Bridger et al in 1981 evaluated the effect of the firing cycle of porcelain on distortion of porcelain fused-metal fixed partial dentures. The study concluded that distortion occurs because of alterations in the metal in addition to the shrinkage of fired porcelain. The highest distortional changes occurred during the degassing cycle and last glaze firing cycle. Author also concluded that distortion caused by ceramic veneering and firing cycles is reversible, as there is elastic rebound when porcelain is removed from framework. Author inferred that distortion is clinically crucial as it may cause marginal openings and microleakage. [15]

Buchanan et al in 1981 evaluated the effect of multiple firing cycle on distortion of margin in two porcelain fused metal systems. Eight precious metal alloy copings and eight nonprecious metal alloy copings were cast. Image analyser was used for measuring marginal gap. Measurements were recorded at the three different locations after the oxidization, metal-conditioning, opaque-application, ceramic-addition, and glazing stage. Application of metal conditioner increased the marginal gap for both the nonprecious and the precious metal alloy. The results showed that subsequent firing procedures first increased marginal gap and then decreased marginal gap in comparison with the metal conditioning procedures. [16]

Ivy Schwartz et al in 1986 [17] found that various methods have been recommended and could be used to refine the marginal fit and seating of prosthesis:

i. The margins of the wax pattern can be over-waxed
ii. Wax can be removed from the inside of the prepared wax pattern
iii. The cast restoration can be internally relieved by:
    a. Electrochemical milling (deplating, striping)
    b. Acid etching (aqua regia),
    c. Sandblasting
iv. Occlusal venting can be done so that excess cement can come out.
v. Devices can be used to maintain and measure seating forces.
vi. Vibration during cementation.
vii. Die spacer application to the die for internal relief of wax, before fabrication of wax pattern.

Holmes et al in1989 described the terminology “fit”. He found that the methods used for measuring the adaptation of the restoration differ considerably in the available literature. The fit can be measured at numerous different sites between restoration and tooth. Holmes et al have co-related measurements of discrepancy at different points as they would be geometrically associated to each other. He concluded that “internal gap is the distance perpendicular from axial wall of tooth to the intaglio surface of the coping, whereas the similar measurement at the finish line is the marginal gap". He also stated that the vertical marginal discrepancy is the vertical misfit calculated along the path of removal of casting and the horizontal marginal discrepancy is measured perpendicular to the path of removal of coping. [4]

Hildebrand et al in 1989 reviewed correlation between hypersensitive reactions and dental alloys such as chromium (Cr), nickel (Ni), cobalt (Co). He discussed that allergic reactions associated to dental treatment may have different origins such as, pharmaceuticals, synthetic dental materials and alloys. Dental alloys routinely used for dental prosthesis constitute nickel, cobalt and/or chromium. Ni-Cr alloys constitute generally 69-81% nickel, in comparison Co-Cr alloys generally constitutes less than 1% nickel. Although considered as not easily oxidizable, these alloys might corrode in biological environment. It is possible that unanticipated reaction which is toxic or allergic nature is because of the release of Ni, Co and Cr from dental restorations. Nickel metal-induced contact dermatitis in humans is most common reaction than all the other available metals together. Chromium takes the second place, whereas Cobalt comes in the third place. [18]

Campbell et al in 1992 studied the distortion in metal ceramic alloys because of thermal cycling. He discovered that significant distortion occurred during oxidation stage which is the first firing cycle and the application of dentin and enamel porcelain did not exhibit distortion. In this study he inferred that there is significant decrease in distortion when the initial firing cycle is completed prior to the cold working of the specimens. [19]

S. Black et al in 1993 developed a system to measure the amount of force generated by a dentist when cementing restoration clinically, as the total of force applied for restoration cementation has effect on its clinical adaptation. The system was compared with a laboratory load cell by recording the force applications by a number of dentists. The system was designed based upon a commercially available small-scale load cell (length 3.8 mm and diameter 12.7 mm). The load cell measured the applied force which was positioned in a finger stall. The results stated that for first few seconds dentists generally apply 60 N force for cementation of metal crown, followed by application of 20-30 N steady force, whereas for porcelain crowns lower forces are applied. [20]

Samet et al in 1995 described the “computer-aided design and manufacture” system for the production of metal substructure for the porcelain-fused-to-metal prosthesis. In this article he explained the different stages of production: digitizing stage, mathematical processing stage, and milling stage, with focus on the system's ability to produce metal substructure for single-unit as well as multiple-unit prosthesis. He conducted a pilot study to evaluate the marginal adaptation of metal copings produced by the Titan system. However, in this pilot study marginal fit ranged from 111 to 270 µm, the clinical accepted marginal fit of conventional cast crowns ranges from 28 to 120 µm. He inferred that the main plus points of this system are its simplicity and reproducibility.[21]

M. Laurent et al in 2008 tested the accuracy of the silicone replica method in a clinical assessment of the fit of cast restorations and evaluated precision of the measurements in a cervical, axial and occlusal position.

The study found that the measurement of a silicone replica which mimics the cement space between tooth and restoration, permits comparison of adaptation whatever the silicone used. This technique when used with appropriate materials allows precise prediction of the true size of the cement thickness in vivo, after cementation. This method could also be used for the measurement of any location (cervical, axial or occlusal). [22]

Quante et al in 2008 published first article evaluating marginal and internal adaptation of metal ceramic restoration manufactured by novel laser melting technology. He also compared alloy type utilized for coping fabrication, a base metal alloy (cobalt–chromium alloy) and a noble metal alloy (gold platinum alloy). The method used was silicone replica method, to gauge marginal and internal accuracy at the time prior to ceramic veneering and firing cycles, while the subsequent measurement was taken after the ceramic firing. Before cementation third measurement was made in patient mouth. The results concluded that the fit of the crowns made with laser melting technology was within clinically acceptable range, regardless of the alloy type. [23]

Akova et al in 2008 assessed the shear bond strength of base metal dental alloys to dental porcelain. The control group used was cast Ni–Cr alloy and the experimental groups were laser-sintered and cast Co–Cr alloys. Ten specimens from each group were used for bond strength comparison. Shear bond strength was measured by a custom-fabricated stainless-steel device. The results revealed that differences between conventionally cast base metal alloys (Ni–Cr and Co–Cr) group and the laser-sintered Co–Cr alloy group was statistically insignificant. Hence, the author inferred that the new laser-sintering technique for Co–Cr alloy appears propitious for dental applications. [24]

Ucar et al in 2009 evaluated and compared the internal fit of Co-Cr crowns prepared by the conventional and laser sintering and Ni-Cr crown prepared by conventional methods. 12 copings of each were made from a stainless-steel die and the fit of the crown was evaluated using two methods. First weighing of the light body silicone used to simulate cement was done and second measuring the gap width for longitudinally sectioned specimens at 5 predetermined positions using an optical microscope was performed. For internal gap widths between three groups there was no remarkable difference. [25]

Tara et al in 2011 conducted a study to evaluate clinical prognosis of metal-ceramic crowns manufactured by use of laser-sintering technology. Sixty single-unit posterior metal-ceramic crowns were cemented in patients with glass-ionomer cement. Yearly clinical follow-up was done. During the surveillance duration of 47 months, there was biological failure of one crown, one crown decemented and one tooth had undergone endodontic treatment due to caries. During the surveillance duration other technical problems didn’t occur, e.g. veneering ceramic chipping.

The study conferred optimistic clinical outcome of posterior single-unit metal-ceramic crowns manufactured by use of laser-sintering technology. [26]

Qiu et al in 2011 evaluated the influence of ceramic-firing process on surface properties and corrosive nature of a commercially available cobalt–chromium (Co–Cr) alloy and 2 nickel–chromium (Ni–Cr) alloys [Beryllium (Be)-containing and beryllium-free]. The surface hardness and composition, microstructure, metal-ion release of cast alloy specimens and electrochemical corrosion properties of specimens were examined, for influence of firing process. Significant increased resistance to corrosion was seen with Co–Cr alloy than the other Ni–Cr alloys.

After ceramic firing the resistance to corrosion of beryllium free Ni–Cr alloy reduced significantly, however the firing cycles had nonsignificant impact on the corrosive nature of the Co–Cr alloy and the beryllium containing Ni–Cr alloy. [27]

Bhaskaran et al in 2013 measured the internal and marginal gap of cobalt chromium copings prepared from DMLS, 3D Print resin pattern and traditional wax pattern - ten copings were fabricated from each technique. All the samples were cemented on a model using pressure indicator paste and vertical marginal gap was evaluated at 8 predetermined positions. Then the copings were separated and sectioned along the midline. This sectioned coping was again cemented on the same master model and evaluated for internal gaps at four predetermined positions. Both measurements were recorded using a video measuring system. The copings produced by DMLS method showed statistically significant minimal value followed by 3D Printing. The measurements for internal gap were maximum and statistically significant for inlay casting wax. [2]

Nawafleh et al in 2013 assessed the precision and reliability of different methods used pertaining to marginal fit of indirect restoration. A variety of testing parameters and methods are used for this purpose which includes mainly “Direct-view technique”, “Cross-sectioning technique”, “Replica technique”, “Profile projector”, “Digimatic micrometer”, and “Micro-CT”.

He stated that making the measurement in vivo or in vitro, before or after cementation, before or after veneering, on a chamfer or shoulder finish line, and total measurements for each sample affect the marginal adaptation.[28]

Tamac et al in 2014 compared the clinical internal and marginal adaptation of ceramo-metal crowns manufactured with three techniques: direct metal laser sintering (DMLS), CAD/CAM milling (CCM), and conventional casting (TC). Twenty crowns were fabricated in each group for 42 patients. The method used to record “marginal gap and internal adaptation” was silicone replica technique. It was measured at 3 regions: occlusal surface, axial wall, and occluso-axial angle surface before luting the crowns.

For all three groups the difference in values at margin, axial wall region measurements were statistically insignificant. However, at the occluso-axial region and the occlusal surface values for DMLS group were higher in comparison with groups CCM and TC. [12]

Lin Wu et al in 2014 conducted a study to “assess the mechanical characteristics of a cobalt-chromium (Co-Cr) dental alloy prepared by selective laser melting (SLM) and to establish the correlation between its microstructure and mechanical properties”. Author conferred that the metal substructure produced by SLM method had layer with elemental interpenetration between porcelain and alloy, which improves bonding interface. [29]

Koutsoukis et al in 2015 published a review on “structure and properties of Selective Laser Melting Technique for Co-Cr Dental Alloys”. He reported that SLM technique can create very complex structures with great accuracy over the milling technique, accuracy of which is constrained by the cutting tools, or over the casting technique, which is sensitive to internal porosity and possible distortion of cast structures, which may need further correction through cutting and welding. [30]

Jong-Kyoung Park et al in 2015 evaluated and compared the marginal and internal discrepancy of metal copings produced from three different fabrication methods, by computer-aided milling, casting method and direct metal laser sintering (DMLS) systems.

The study concluded that although the discrepancy varied with fabrication methods, the internal and marginal discrepancy of copings produced by DMLS and computer-aided milling fell within the clinical acceptance (<120µm). The study showed superiority of digital systems over the traditional casting method, but still the scope for improvement in digital systems is warranted. [31]

An in vivo study was conducted by **Zhuoli Huang et al in 2015** comparing marginal and internal fit of SLM (Selective Laser Sintering) ceramo-metal restorations with two lost-wax cast ceramo-metal restorations. He also assessed the influence of type of tooth on the marginal and internal fit of these crowns.

In this study total 330 metal castings were produced with cast Co-Cr alloy, cast Co-Cr alloy and SLM Co-Cr (n=110). “Marginal and internal gaps” of copings were recorded using “replica technique”. The replicas were sectioned and stereomicroscope at ×30 magnification was used to examine the “marginal and internal gap” width of each cross section.

The study concluded that marginal fit of SLM Co-Cr ceramo-metal restorations was similar compared to the cast Au-Pt ceramo-metal restorations and was superior in comparison to cast Co-Cr metal ceramic restoration. The axial fit difference between the three groups was insignificant but the occlusal fit of SLM Co-Cr restoration was less precise compared to the 2 cast ceramo-metal restorations. The tooth type had no influence on marginal and internal fit. [32]

Kane et al in 2015 conducted an in-vitro study to evaluate impact of marginal preparation design on the marginal and internal fit of Co-Cr copings produced by CAD/CAM. Master dies were fabricated from ivorine teeth, maxillary two central incisors and two molars. One of each was prepared with chamfer (0.8 mm) and rounded shoulder (1.2 mm) marginal design. These prepared teeth were replicated to fabricated epoxy dies; total 40 dies were fabricated.

Laser scanner was used to obtain a 3-dimensional model. Cobalt-chromium copings of 0.4mm thickness were manufactured for each epoxy die using CAD/CAM system. Polyvinyl siloxane material of light body consistency was applied on the inside of each coping and placed on the die. Copings were separated from the dies, after the material was polymerized leaving the polyvinyl siloxane layer intact on the die. Then these dies along with the silicone layer were scanned. The software superposed the 2 scans, and the internal fit and the marginal discrepancy were measured at multiple sites.

Author concluded that for the chamfer marginal design significantly less mean marginal discrepancy was seen in comparison with the shoulder design. [30]

Necati Kaleli et al in 2016 conducted in vitro study assessing the marginal fit after fabrication of the metal substructure, porcelain veneering, and cementation of ceramo-metal restorations fabricated with four different methods - direct metal laser sintering (DMLS), the conventional lost-wax technique, Laser CUSING and milling. Laser CUSING is a newly introduced selective laser melting system in which thermal contraction of metal is less. Alterations in metal substructure marginal adaptation during the subsequent fabrication stages and accuracy of fabrication methods were assessed.

The study concluded that the marginal adaptation with Laser CUSING method is quite precise. Whereas higher marginal discrepancy was seen after porcelain veneering and cementation. [8]

Kocaagaoglu et al in 2016 compared marginal fit, occlusal and axial discrepancies in single-unit metal ceramic restorations fabricated with four distinct techniques, casting (C), laser sintering (LS), "hard metal milling (HM)", and "soft metal milling (SM)". Using silicone replica technique, the discrepancies of the copings were evaluated prior to ceramic veneering and after ceramic veneering. The result showed that ceramo-metal restorations manufactured with Hard Metal milling and newly introduced Soft Metal milling techniques exhibited superior marginal adaptations when compared with those produced with the Laser Sintering or Casting technique. [1]

Lövgren et al in 2016 conducted an in vitro study to examine 3 different production methods with consideration to marginal and internal fit, surface roughness, and retention of Co-Cr alloy single-crown copings. Three different fabrication techniques, i.e. laser- sintering, milling, and lost wax, were used to produce 12 cobalt-chromium alloy copings for each group. The surface topography of 2 copings from each group was analysed using interferometry. Replica method used 10 copings from each group to evaluate marginal and internal fit. Uni-axial tensile force pull-off test was to assess the retention for the copings

Co-Cr crown copings fabricated using laser-sintering technology showed improved surface roughness and superior internal and marginal fit in comparison with copings fabricated by milling or milled wax/lost wax technique. [34]

Kaleli et al in 2017 conducted a study to compare bond strength of cobalt-chromium (Co-Cr) metal frameworks to porcelain fabricated by four different techniques, the “conventional casting technique”, “milling”, “metal laser sintering (DMLS)”, and “laser cusing”.

Universal testing machine was used to measure debonding strength at a crosshead speed of 1.5 mm/min. The bonding strength values showed significant difference only between laser cusing method and the lost-wax method, however metal ceramic frameworks produced by laser cusing method showed superior bond strength values. Bond strength value for all the specimens was more than 25 MPa, which is a critical value determined by International Organization for Standardization (ISO). Author concluded that direct process powder-bed method and DMLS method were found to be acceptable in correspondence to the ISO standard 9693-1. [35]

Revilla-León et al in 2017 published a review on “Additive Manufacturing technologies used for 3D Metal printing in dentistry”. Author emphasised on the advantages of additive manufacturing technologies such as reduced manufacturing time and costs, human errors minimization and prevention of possible defects in the cast objects in comparison to “conventional casting method”s. This review gives us an overview of latest additive manufacturing technologies used for fabrication of metal framework in dentistry in terms of its working mechanisms and possible drawbacks. [36]

Son et al in 2019 compared five techniques used for assessment marginal and internal fit of fixed prostheses. The five types of methods used for assessment were TSM- triple scan method, SRT - silicone replica technique, CSM - cross-sectional method, OCT - optical coherence tomography and MCT - micro-computed tomography. In this study author observed that in SRT and CSM groups “marginal and internal fit” was similar, whereas for MCT and OCT groups “marginal and internal fit “was similar. Overall, the values for all the five methods were within the clinical permissible range. Hence author inferred that the inexpensive and comparatively easy to use SRT method can be used an alternative for CSM method. [37]

Zuskova et al in 2019 investigated and compared the effect of CAD/CAM technology on the overall adaptation of metal copings. For scanning and designing the restoration identical CAD technology was used. Total 20 frameworks were prepared with two different manufacturing techniques (“computer numerical control milling” [CNCM] and “direct metal laser sintering” [DMLS]) - ten specimens in each group. all twenty specimens were scanned and digitized by the DS30 scanner. The adaptation discrepancies for the restorations were analysed in three dimensions by Geometric Modelling Library (GML). The DMLS group showed less variation from the average than milled group. A minute variation of 0.04 μm was detected between the two groups. Within the constraints of this study, author inferred that the variation between overall fit of CNCM and DMLS restorations was negligible. [38]

Gholamrezaei et al in 2020 assessed the marginal and internal fit of Co-Cr copings produced using the selective laser melting (SLM) and traditional casting method with the help of a profilometer. The copings produced using both techniques were seated on the model, and a profilometer was used to measure vertical marginal discrepancy. Whereas for the internal fit assessment light body addition silicone was coated inside the copings and seated on the model, which represents the luting cement. Silicone material was separated after polymerization from coping carefully and its weight was measured. The study concluded that the copings produced by SLM technique exhibited a lower vertical marginal discrepancy in comparison to the casting group. Nonetheless, in terms of internal fit there no significant difference between the two groups. [39]

MATERIALS AND METHOD

SOURCE OF DATA/ LABORATORY DETAILS:

- The in-vivo study was conducted the Department of Prosthodontics and Crown and Bridge, KAHER VK Institute of Dental Sciences, Belagavi.
- DMLS Metal Copings were procured from Dentcare Laboratory, Kerala.
- Measurements were performed at Praj Metallurgical Laboratory, Pune.

DATA COLLECTION

SAMPLE SIZE

40 Subjects divided into 2 equal groups

Group A - 20 subjects who will receive metal-ceramic crown fabricated by "conventional casting method"

Group B – 20 subjects who will receive metal-ceramic crown fabricated by "direct metal laser sintering method"

INCLUSION CRITERIA :

1. Non-vital endodontically treated teeth.
2. Maxillary/ Mandibular premolar teeth.
3. Teeth with a healthy periodontium.

EXCLUSION CRITERIA:

1. Teeth with gingival recession.
2. Teeth with periodontitis.
3. Teeth with developmental anomalies.
4. Hypocalcified teeth.

The methodology used in this study is described in the following order:

1. **List of materials used for the study:**
2. **Armamentarium and equipment used in the study.**
3. **Method followed**
    a) Preparation of teeth
    b) Impression making and die preparation
    c) Preparation of copings
    d) Silicone replica fabrication
    e) Ceramic veneering
    f) Measurement of marginal and internal fit using digital stereomicroscope

Table 1 : List of materials used for the study (Fig. 1)

Sr No.	Material	Manufacturer
1	Light Body PVS Impression Material	3M ESPETM, Seefeld,Germany
2	Putty PVS Impression Material	3M ESPETM, Seefeld,Germany
3	Co-Cr Metal Alloy Pellets	Girobond NBS , Amann Girrbach, Germany
4	Veneering Ceramic	VITA VMK® 95
5	Auto polymerizing acrylic resin	DPI, India
6	Tray Adhesive	3M ESPE, USA
7	Inlay wax	Bego, Germany
8	Die stone	Pearlstone Die Stone Class IV
9	Die lubricant	Picosilk-Renfert, Germany
10	Die Spacer	Die master, Renfert
11	Phosphate bonded investment material	BEGO, Germany
12	BP blade	Hindustan Surgicals, India
13	Debubblizer	Waxit, Germany
14	Sprue Wax	Renfert, Germany
15	Pindex Pins and Sleeves	Renfert, Germany

Table 2: Armamentarium and equipment used in the study (Fig. 2)

Sr No.	Material	Manufacturer
1	Mouth mirror, Probe, Explorer, Tweezer	G.D.C. India
2	Bur set	SHOFU Inc.
3	Kidney tray, Dentulous stock tray	G.D.C. India
4	Air-rotor hand piece	NSK, Japan
5	Gingival retraction Cord	Ultrapack E^{TM}, Ultardent
6	PKT Instrument Set	Visa Stainless Steel, Germany
7	Metal Casting Ring	Keystone Industries, Germany
8	Induction casting machine	Fornax, Bego
9	Phosphate bonded investment material	Bego Miditherm-26150
10	Automatic Mixer	Easy Mix -26090
11	Sandblasting Unit	BegoDuostar Z2-26115
12	Pindex Machine	Renfert Top Spin:Ref nr:1850000
13	Ceramic Furnace	Vita Vacumat 40 T
14	Direst metal laser sintering machine	EOSINT M270
15	Digital Stereomicroscope	XTL 3400E, wuzhou New Found Co. Ltd., China

I. Methodology

- A total of 40 subjects, with endodontically treated Maxillary / Mandibular premolar requiring Single crown restoration were selected in this study. They were grouped into 2 equal groups by simple randomization.
- Out of the 40, 20 subjects received cast metal-ceramic crown and other 20 subjects received DMLS metal-ceramic crown.
- The selection of subjects was done according to the inclusion and exclusion criteria.
- Before selection radiographic and clinical assessment of the all the participants was done, and after selection oral prophylaxis was carried out and diagnostic impressions were made for all.
- **Preparation Of Teeth :**

Depth orientation grooves were placed using depth orientation burs (bur nr: 122) on the occlusal, buccal and lingual aspects of the tooth. The buccal preparation was done first using a tapered flat bur (bur nr: 101, 201) the lingual surface was also prepared using the same followed by the preparation of the occlusal aspects using round inverted cone bur (bur nr: 265R) and double cone bur (bur nr: 148).

Tooth preparation was done with shoulder finish line on all sides of the teeth and minimum occlusal reduction 2 mm and axial reduction 1.5 mm was maintained (Fig. 4). Finally, the preparation was finished using finishing burs (bur nr: SF201, SF101, SF265R)

- **Impression making and Die Preparation :**

  Impression was made using Monophase Polyether impression material (3M ESPETM, Seefeld, Germany) and custom tray with a 2mm wax spacer (Fig. 5). Custom tray coated with tray adhesive (3M ESPE, USA) was used to make impression. Gingival retraction cord was used for tissue displacement.

  Type IV Dental stone (Pearlstone) was mixed as instructed by manufacturer and impression was poured to fabricate a master cast (Fig. 6). Die preparation was done for each of the casts using two-pour technique and Pindex system (Renfert Top Spin) (Fig. 7). Die ditching was carried out and the prepared die was used for fabrication of the metal copings (Fig. 8).

- After making impression temporary restoration was luted onto the prepared tooth.

- **Preparation Of Copings :**

  20 crowns were fabricated by casting method and other 20 by direct metal laser sintering method.

  For conventional casting a single coat of die spacer of 20μm thickness was applied on the prepared die on all surfaces except the margins (Fig. 9). The die was then painted with a layer of die lubricant which helps prevent the wax from sticking. A PKT instrument was used for the wax (BEGO, Inlay wax) build up on the labial, lingual and proximal surfaces of the die. The thickness of each pattern was standardized to 0.5mm (Fig. 10). After the fabrication the thicknesses at various points were checked using a wax gauge and adjustments made accordingly (Fig. 11). Posphate bonded invest material was used investing the wax pattern and casting was done using cobalt-chromium alloy (Girobond® NBS, Amann Girrbach) in the casting machine (BegoFornax T-26300). (Fig. 12, 13)

For Direct metal laser sintered coping dies were scanned with laboratory scanner. Using a CAD software program, the coping was designed from the scanned image maintaining an internal space of 20 μm and 0.5mm thickness. The data was saved as an STL file. This STL file was used to fabricate coping with the help of EOSINT M270 DMLS machine. (Fig. 14)

- **Silicone Replica Fabrication** (Fig. 18) :

Light Body Impression Material was mixed as instructed by manufacturer and applied on the internal surface of metal coping and then seated onto prepared tooth surface with firm axial finger pressure.

After the material was polymerized, it was gently removed from tooth surface. The light body is a thin fragile layer within the casting hence putty was introduced into the internal surface of casting to reinforce the layer of light body. After the putty has set, light body and putty are pulled out of casting as one. This represents a smaller replica of the prepared tooth.

Like this silicone replicas were collected and labelled for all the metal copings.

- **Ceramic Veneering :**

  VITA VMK® 95 veneering ceramics was used for the two groups of metal copings. (Fig. 15)

  First oxidization process was done, after which opaque porcelain was applied to all metal copings and left to dry. First firing cycle temperature was 500°C to 960°C for 20 minutes. It was followed by veneering of dentin porcelain and enamel porcelain materials and firing for 25 minutes at 500°C to 930°C in a ceramic furnace (Vita Vacumat 40 T) (Fig. 16). Diamond rotary instrument with water coolant was used to remove surface irregularities, and in the end glaze porcelain material was applied and fired once for 12 minutes at 500°C to 920°C. (Fig. 17)

- The number of firing cycles were equal for all the 40 metal copings

- After completion of ceramic veneering silicone replicas were again fabricated by the same method mentioned previously.
- After adjusting the occlusion, fabricated prosthesis was cemented and patient was informed about post insertion information.
- **Measurement of marginal and internal fit using digital stereomicroscope :**

  The collected silicone replica was sectioned in two planes along bucco-lingual and mesio-distal directions using a Stanley's knife (Fig. 19). Each section was examined under Stereo microscope (XTL 3400E, wuzhou New Found Co. Ltd., China) (Fig. 20) at 10X magnification. Digital images were captured and examined by image analysis system (MVIG 2005, Chroma systems Pvt. Ltd., India) (Fig. 21).

Measurements were recorded at 10 predefined points for each silicone replica sample out of which, marginal fit was measured at 4 points and internal fit at 6 points and statistical analysis for the values obtained was performed.

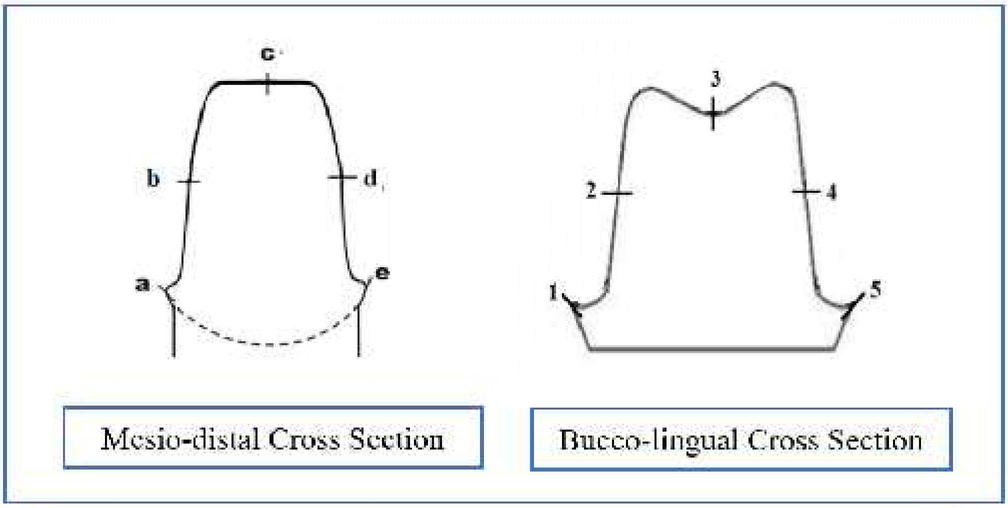


Fig 1: Reference points for measurements

SCHEMATIC REPRESENTATION

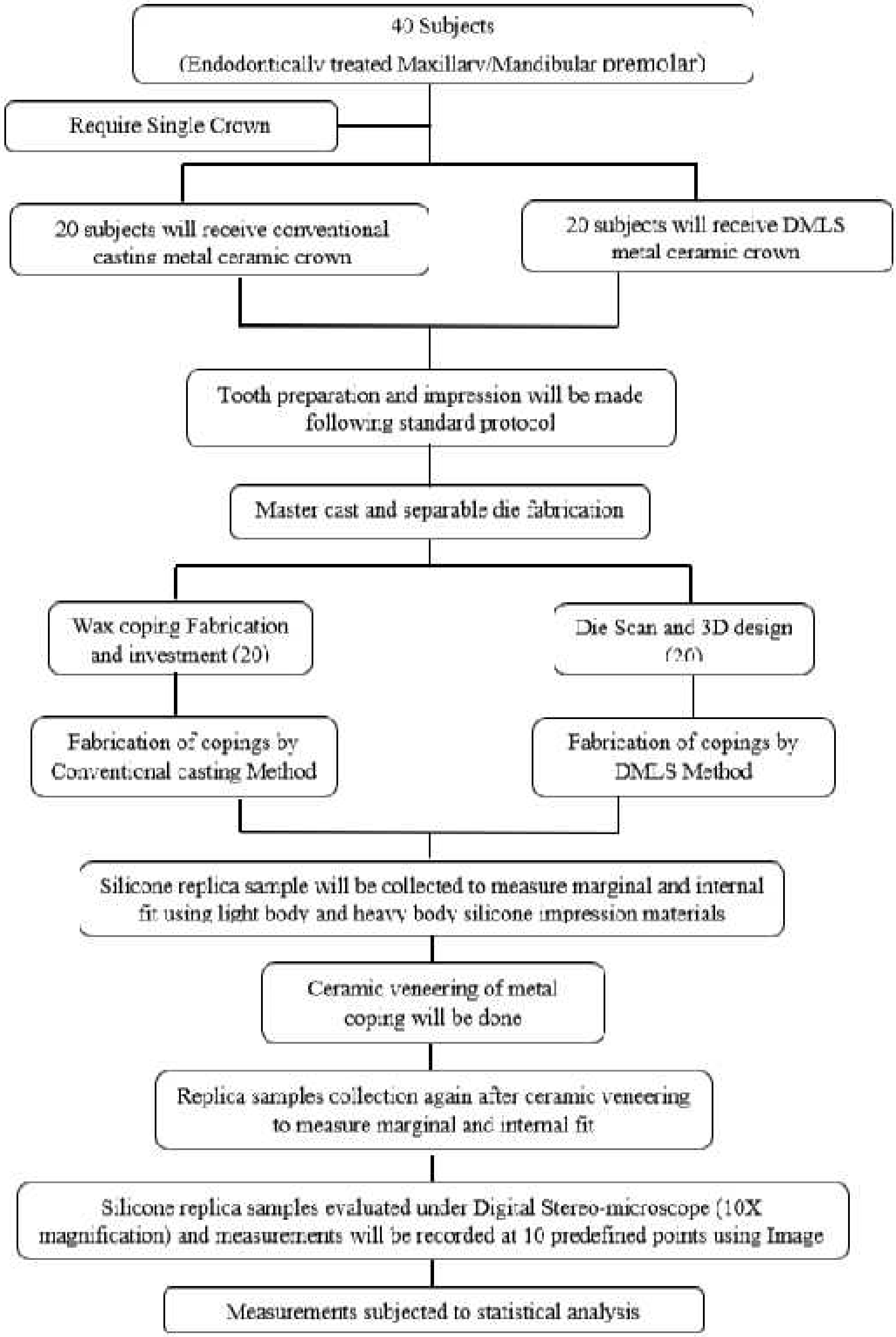


Fig 2: Materials used for the study

Fig 3: Armamentarium used in the study

Fig 4: Intra-oral view of Premolar Tooth Preparation

Fig 5: Impression made using Monophase Impression Material

Fig 6: Die Stone Cast

Fig 7: Pindex System (Renfert Top Spin)

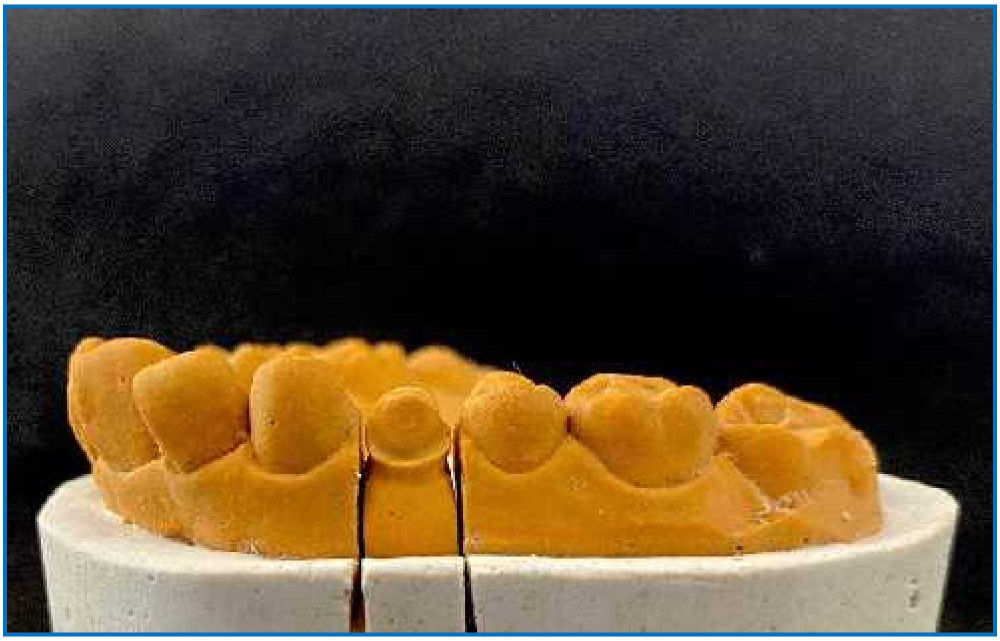


Fig 8: Die Cutting and Ditching

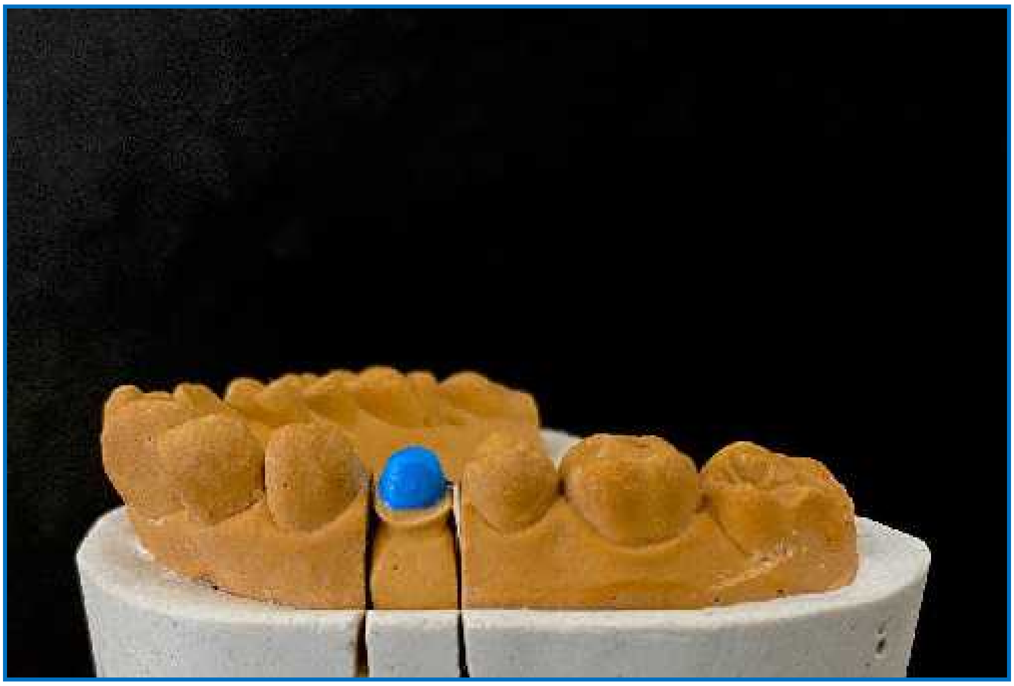


Fig 9: Die spacer application

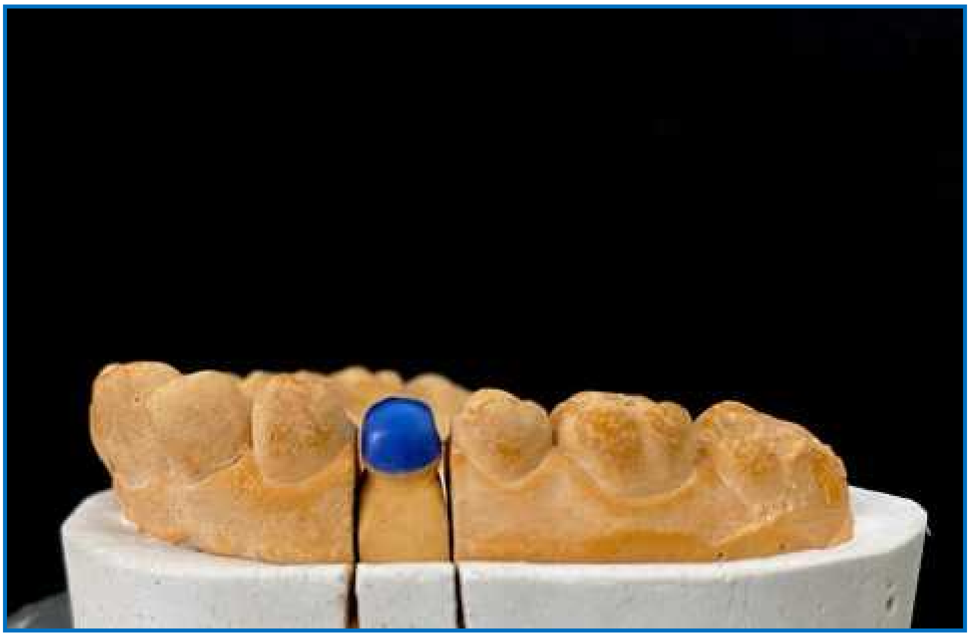


Fig 10: Wax Pattern for the Conventional Casting Method

Fig11: Assessing the thickness of wax pattern

Fig 12: Casting Machine (BegoFornax T-26300)

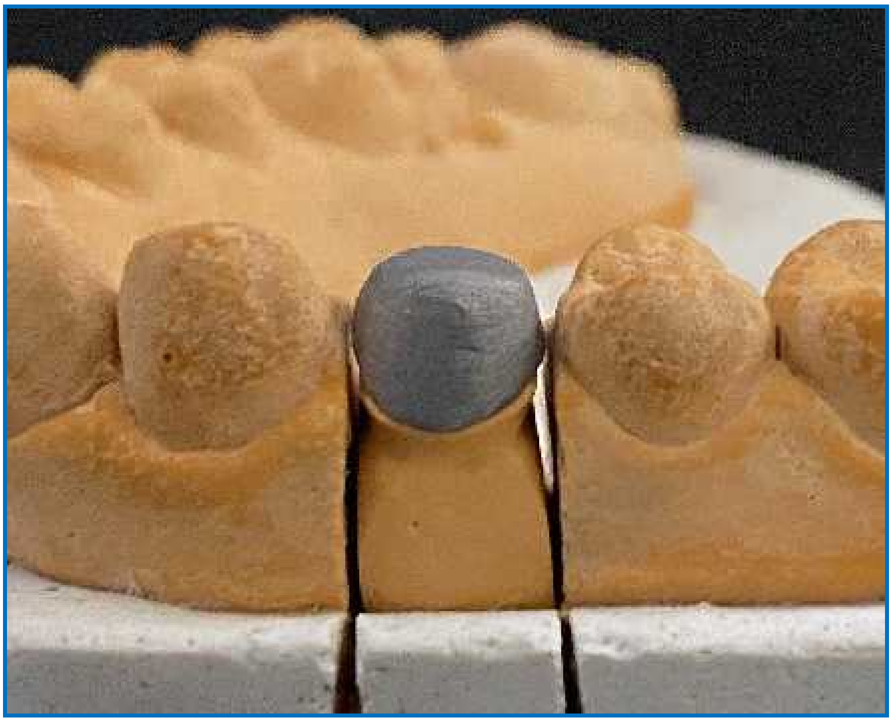


Fig 13: Metal Coping Fabricated by Conventional Casting Method

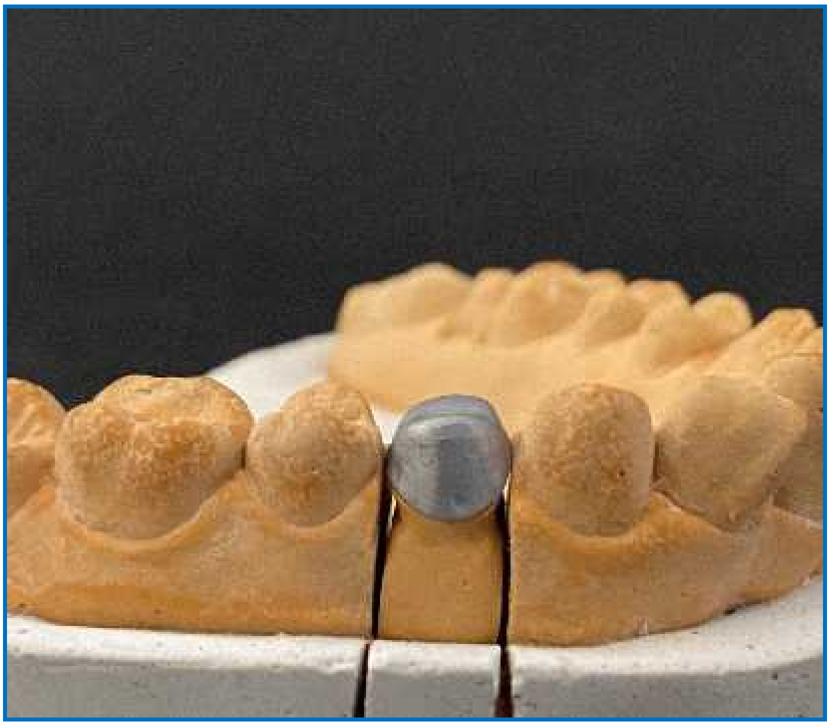


Fig 14: Metal Coping Fabricated by Direct Metal Laser Sintering method

Fig 15: VITA VMK® 95 veneering ceramic Powder

Fig 16: Ceramic furnace (Vita Vacumat 40 T)

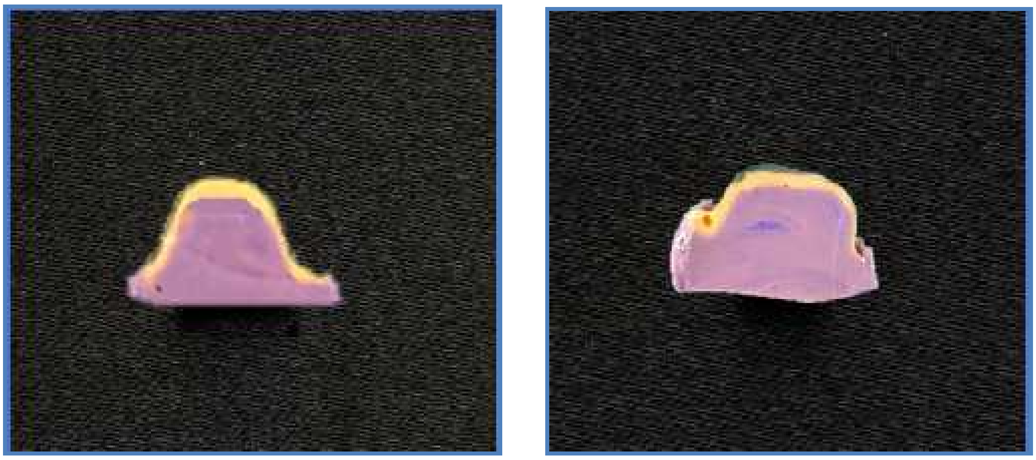
Fig 17: Restoration After Ceramic Veneering

Light Body Impression Material is mixed and applied on the internal surface of restoration

Restoration is seated onto the prepared tooth surface with firm axial finger pressure.

After the material was polymerized, it was gently removed from tooth surface. Putty was introduced into the internal surface of the casting to reinforce the layer of light body

Fig 18: Silicone Replica Fabrication



Bucco-lingual Cross section

Mesio-distal Cross section

Fig 19: Sectioned Silicone Replica along two planes

Fig 20: Digital Stereomicroscope (XTL 3400E, wuzhou New Found Co. Ltd., China)

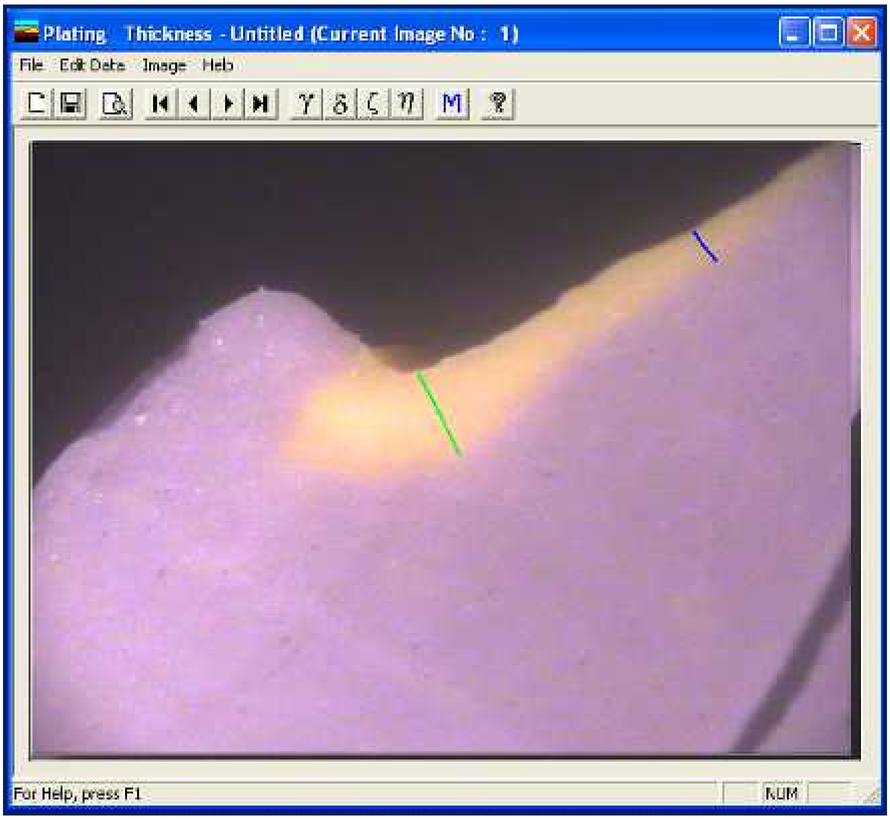


Fig 21: Measurements recorded using Image Analysis System

(MVIG 2005, Chroma systems Pvt. Ltd., India)

RESULTS

The measurements obtained from the in-vivo study, which evaluated and compared the influence of ceramic firing on internal fit and marginal adaptation of single metal ceramic crown restoration fabricated by conventional casting method and direct metal laser sintering method were subjected to statistical analysis to draw conclusion from the experimental data.

The samples were grouped as follows:

GROUP A: Conventional Casting Method (Control group)

GROUP B: Direct Metal Laser Sintering Method (Experimental Group)

The marginal gap and internal gap values obtained prior to ceramic firing and after ceramic firing in the two study groups were subjected to Kolmogorov Smirnov test for obtaining normality of values.

Since the marginal gap and internal gap values obtained prior to ceramic firing and after ceramic firing in the two study groups followed a normal distribution, the parametric tests were applied.

Descriptive statistical measures such as mean, standard deviation, percentage of change and standard error of means were computed and measured for both the study groups. The means of the marginal gap and internal gap (µm)between the two study groups were compared by independent t test and the means of the marginal gap and internal gap (µm)ceramic firing and after ceramic firing for eachgroup were subjected to dependent t test.

Table 3: Normality of marginal gap (µm)and internal gap (µm) values in Group A and Group B before and after ceramic firing by Kolmogorov Smirnov test

Variables	Time	Group A		Group B	
		Z-value	P-value	Z-value	P-value
Marginal Gap (µm)	Before ceramic firing	0.6870	0.7330	0.5130	0.9550
	After ceramic firing	0.9740	0.2990	0.5840	0.8850
	Diff.	0.5940	0.8720	0.8100	0.5270
Internal Gap (µm)	Before ceramic firing	0.8800	0.4210	0.7060	0.7020
	After ceramic firing	0.7710	0.5930	1.0080	0.2620
	Diff.	0.5960	0.8690	0.6710	0.7590

Note: The before and after marginal gap (µm)and internal gap (µm) values in group A and group B follow a normal distribution. Therefore, the parametric tests were applied

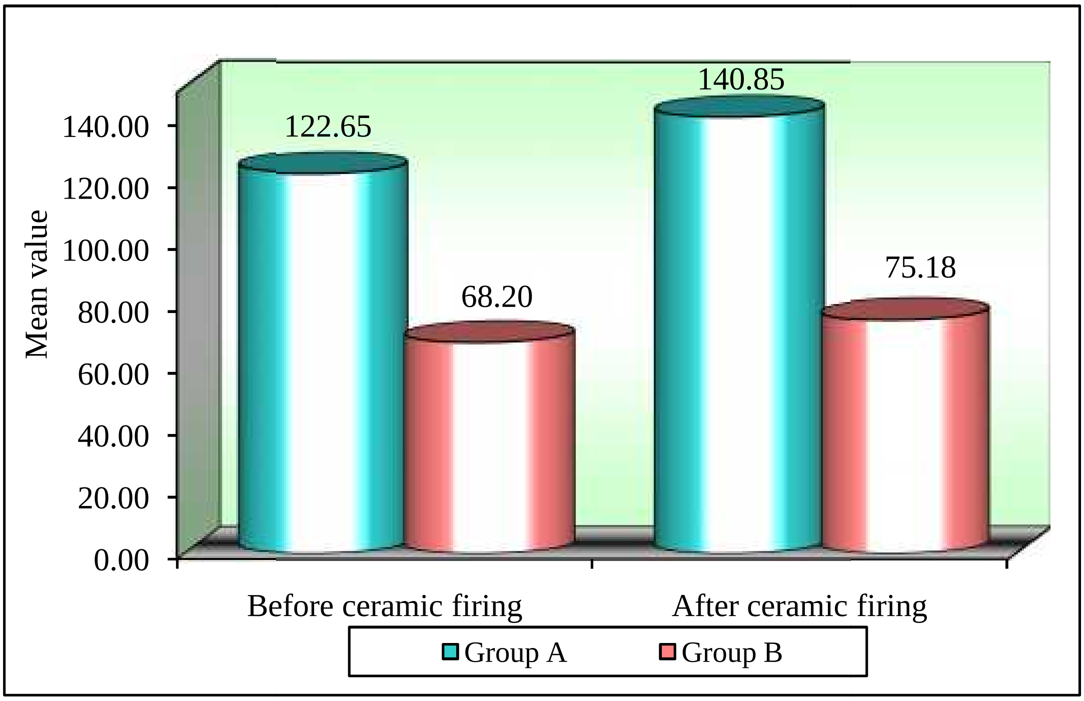
Table 4 : Statistical comparison mean values of marginal gap (μm) of two groups before and after ceramic firing by independent t test

Time	Groups	n	Mean	SD	SE	t-value	P-value
Before ceramic firing	Group A	20	122.65	4.71	1.05	47.9381	0.0001*
	Group B	20	68.20	1.90	0.43		
After ceramic firing	Group A	20	140.85	5.73	1.28	47.5891	0.0001*
	Group B	20	75.18	2.28	0.51		
Difference	Group A	20	18.21	4.06	0.91	12.2382	0.0001*
	Group B	20	6.98	0.59	0.13		

*p<0.05

Comparison of mean marginal gap (μm) values of the two study groups prior to ceramic firing and after ceramic firing was done with independent t test. Statistically significant difference (p=0.0001) between the groups was seen with the lowest mean marginal gap (μm) in group B (DMLS method) with mean value 68.20 μm and 75.18 μmprior to ceramic firing and after ceramic firing respectively and highest in group A (casting method) with mean value 122.65 μm and 140.85 μm respectively.

Graph 1 : Comparison of mean values of marginal gap (µm) of two groups before and after ceramic firing



Graphical representation of comparison of mean marginal gap (µm) values of the two study groups before and after ceramic firing. Before and after ceramic firing, the lowest mean marginal gap (µm) is shown by Group B (DMLS method) with mean value 68.20 µm and 75.18 µm respectively and highest is shown by group A(casting method) with mean value 122.65 µm and 140.85 µm respectively.

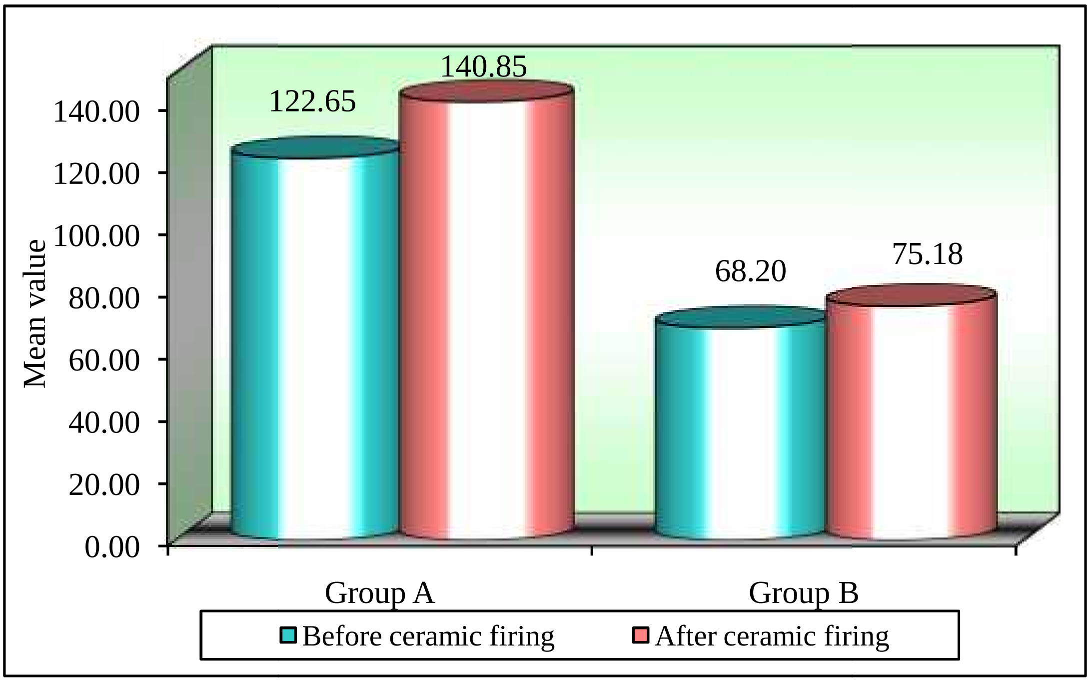
Table 5 : Statistical comparison of mean values of marginal gap (µm) before and after ceramic firing in each of the two groups by dependent t test

Groups	Time	Mean	Std.Dv.	Mean Diff.	SD Diff.	% of change	t-value	P-value
Group A	Before ceramic firing	122.65	4.71	-18.20	4.08	-14.83	-19.9530	0.0001*
	After ceramic firing	140.85	5.73					
Group B	Before ceramic firing	68.20	1.90	-6.98	0.60	-10.24	-52.0563	0.0001*
	After ceramic firing	75.18	2.28					

*p<0.05

Dependent t test showed statisticallysignificant difference in mean values of marginal gap (µm) before and after ceramic firing in each of the two groups. The lowest mean difference in marginal gap (6.98 µm) was seen in Group B after ceramic firing, whereas in group A mean difference in marginal gap was18.20 µm.

Graph 2 : Comparison of mean values of marginal gap (µm) before and after ceramic firing in each of the two groups.



Graphical representation of comparison of mean marginal gap (µm) values of the two study groups prior to ceramic firing and after ceramic firing. Before ceramic firinghighest values are shown by Group A (casting method) with mean value of 122.65 µmand lowest by Group B (DMLS method) with mean value of 68.20 µm. After ceramic firing, highest values are shown by Group A (casting method) with mean value of 140.85 µm and lowest by Group B (DMLS method) with mean value of 75.18 µm.the lowest mean marginal gap (µm).

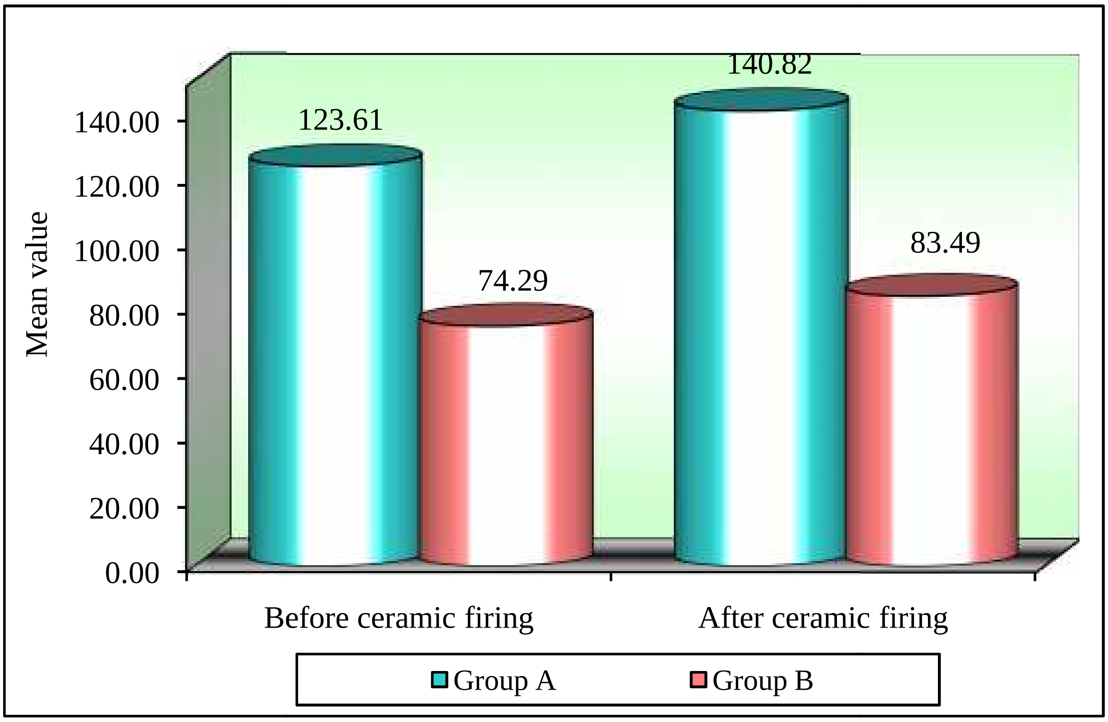
Table 6 : Statistical comparison of mean values ofinternal gap (μm) of two groups before and after ceramic firing by independent t test

Variable	Groups	n	Mean	SD	SE	t-value	P-value
Before ceramic firing	Group A	20	123.61	3.10	0.69	63.9703	0.0001*
	Group B	20	74.29	1.52	0.34		
After ceramic firing	Group A	20	140.82	4.97	1.11	48.4561	0.0001*
	Group B	20	83.49	1.81	0.40		
Difference ceramic firing	Group A	20	17.19	2.66	0.60	12.5146	0.0001*
	Group B	20	9.20	1.03	0.23		

*p<0.05

Comparison of mean internal gap (μm) values of the two study groups prior to ceramic firing and after ceramic firing was done with independent t test. Statistically significant difference (p=0.0001) between the groups. Lowestmean internal gap (μm)was seen in group B (DMLS method) with mean value 74.29 μm and 83.49 μmprior to ceramic firing and after ceramic firing respectively and highest in group A (casting method) with mean value 123.61 μm and 140.82 μm respectively.

Graph 3 :Comparison of mean values of internal gap (µm) of two groups before and after ceramic firing



Graphical representation of comparison of mean internal gap (µm) values of the two study groups prior to ceramic firing and after ceramic firing. Before and after ceramic firing, the lowest mean internal gap (µm) is shown by Group B (DMLS method) with mean value 74.29µm and 83.49µm respectively and highest is shown by group A(casting method) with mean value 123.61µm and 140.82µm respectively.

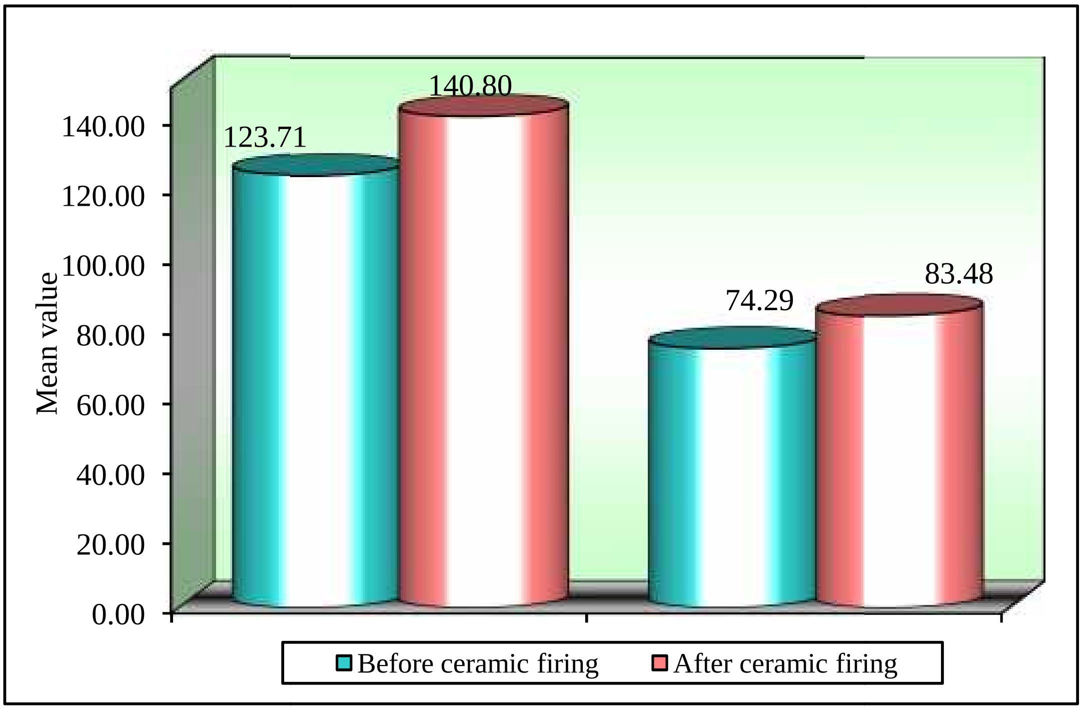
Table 7: Statistical comparison of mean values of internal gap (μm) before and after ceramic firing in each of the two groups by dependent t test

Groups	Time	Mean	Std.Dv.	Mean Diff.	SD Diff.	% of change	t-value	P-value
Group A	Before ceramic firing	123.61	3.10	-17.21	2.66	-13.92	-28.9299	0.0001*
	After ceramic firing	140.82	4.97					
Group B	Before ceramic firing	74.29	1.52	-9.20	1.02	-12.38	-52.0563	0.0001*
	After ceramic firing	83.49	1.81					

*p<0.05

Dependent t test showed statistically significant difference in mean values of internal gap (μm) prior to ceramic firing and after ceramic firing in each of the two groups. The lowest mean difference in internal gap (9.20 µm) was seen in Group B after ceramic firing, whereas in group A mean difference in internal gap was17.21 µm.

Graph 4 : Comparison of mean values of internal gap (µm) before and after ceramic firing in each of the two groups



Graphical representation of comparison of mean internal gap (µm) values of the two study groups prior to ceramic firing and after ceramic firing. Before ceramic firing highest values are shown by Group A (casting method) with mean value of 123.71 µm and lowest by Group B (DMLS method) with mean value of 74.29 µm. After ceramic firing, highest values are shown by Group A (casting method) with mean value of 140.80 µm and lowest by Group B (DMLS method) with mean value of 83.48 µm. the lowest mean internal gap (µm).

DISCUSSION

Tooth loss results in reduced mastication ability, loss of neuromuscular control of mandible, reduced vertical occlusion dimension and attrition of anterior teeth. However, there is no clear correlation of the extent of tooth loss to severity of signs and symptoms of mandibular dysfunction. [40]

Masticatory efficiency is associated linearly with the teeth present in the oral cavity. In patients with extensive loss of posterior teeth, fixed or removable prosthesis can used for rehabilitation. Some patients seek removable options while others prefer fixed options, with an increased number opting for fixed partial dentures. [40]

In case of teeth undergone endodontic therapy, the tooth composition is compromised. The most important element in increasing clinical survival rate of teeth undergone endodontic treatment is conservation of sound tooth structure. Root canal treated teeth with full coverage restoration have higher long-term survival rate than those without full coverage restoration.[11]

A fixed prosthesis can either be a single crown restoration or a multi-unit prosthesis. According to GPT “a crown restoration is an artificial replacement which restores the lost tooth structure by covering part or all of the remaining structure”.[41]

Fixed partial dentures improve patient’s aesthetics, speech and most importantly the ability to masticate. It also lifts the individual’s standard of living and gives them the confidence to go about their day-to-day lives comfortably.

Fixed partial dentures are cast using alloys. Alloys are a combination of one or more metal elements which are soluble in each another in molten state. In combining different metals in varying ratios, it is viable to create boundless number of combinations. Alloys used for fabrication of dental prostheses are broadly classified into high noble, noble and base metal alloys. [42]

Gold was the most common alloy used owing to its high resistance to tarnish; corrosion and that it can withstand the fluctuating oral conditions. Given all its advantages gold is an expensive material and difficult to handle. Because of its high cost, low hardness, poor sag resistance and degree of thermal expansion incompatible with some high- expansion porcelain it eventually got replaced by base metal alloys. [42]

Most commonly used base metal-ceramic alloy are nickel based and cobalt based alloys. Alloys in both the types contain chromium as their second highest component and rely on it for corrosion resistance. Castability of base-metal dental alloys is proven to be better than noble-metal alloys.[43]

Nickel chromium alloys were routinely used in dental field for fabrication of fixed and removable metal prosthesis. It was observed though; Ni-Cr caused allergies in some individuals. Various case reports of nickel-based dental restoration resulting in hypersensitive reactions are present, with approximately 1% of men and 10% of women showing sensitivity reaction to nickel-based alloys [44]. Corrosion products of nickel-based metal alloys for example; nickel sulfide, nickel carbonyl and nickel subsulfide have also shown to produce carcinogenesis.[45]

So, as an alternative Cobalt–chromium alloys were the customarily used base-metal alloys for population with known allergy to nickel. Co-Cr alloys have shown to have high strength, heat-resistant, non-magnetic and have favourable resistance to tarnish, wear, and corrosion. They also possess excellent biocompatibility. The required strength and rigidity is chieved because of the high elastic modulus without the necessity for heavy cross-section, thus reducing weight of metal substructures and making the prosthesis lighter.[46]

Due to all these properties Co-Cr is slowly gaining popularity for fabrication of fixed partial denture. The ability to fabricate routinely sound, smooth, and well-fitting restoration requires stern adherence to particular fundamentals and everything that is done from the moment the wax pattern is prepared till the restoration is cemented onto the prepared tooth has a definite effect upon the ultimate clinical result.[47]

Utmost important element for the success, longevity and acceptance of a complete coverage restoration is its fit. The fit of a fixed dental restoration can be predominantly categorised as: Internal fit and Marginal Fit.

Holmes et al defined "marginal fit of a crown as the measurement perpendicular from axial wall of prepared tooth to intaglio surface of coping at the margins, while the internal fit is the perpendicular measurement all around tooth preparation except at the margins". [4]

The marginal fit of a prosthesis is vital as defective margins expose the luting material to the oral habitat leading to plaque accumulation and microleakage that is detrimental to tooth composition (secondary caries) and periodontium (inflammation). The internal fit of prosthesis is also vital as an increased gap between prosthesis and tooth will increase the thickness of the cement, thus influence mechanical stability of dental restorations. The luting cement space across the tooth surface and the internal surface of the restoration needs to be consistent throughout to ease placement without compromising resistance and retention.[12]

McLean et al conducted a 5-year in-vivo study of 1000 dental restorations and stated that 120 µm was the highest clinically admissible marginal opening.[48] However, marginal gap upto 100 µm was regarded as good and marginal gap between 200–300 µm was regarded as acceptable by Moldovan et al. [49]

Fixed partial denture fabrication procedure involves multiple steps. Conventional lost-wax technique requires a model of prepared tooth, onto which wax pattern of desired design is fabricated. Once the pattern is prepared it is then invested, cast and retrieved. Inlay wax has various immanent restrictive properties such as heat sensitivity, high elastic memory and high coefficient of thermal expansion.[50] Wax pattern distortion can occur due to release of internal stress which contributes to inimical effects on cast restoration.[2]

Nowadays the new digital systems are being commonly used for fabrication of metal ceramic crown to overcome the constraints with conventional casting technique. Use of digital system provides various advantages such as reduced labour and time, better quality, increased cost efficiency and new improved materials.[38]

The evolution of CAD-CAM facilitated a wide scope of fabrication methods including computer numerical control (CNC) milling which is a subtractive manufacturing procedure and DMLS systems which is an additive technique.[31]

Computer numeric controlled (CNC) milling is a commonly used subtractive process. Computer assisted machine (CAM) uses special tools which has sharp cutting edges [51]. Depending upon the number of milling axes present the milling process varies from simple to complicated. More the milling axes more compound structures can be fabricated [52]. The cutting tools cause strain to material surface, which creates microcracks and results in subsequent chipping. These cracks remain on and beneath the newly formed surface structure as a chipping residue. These intrinsic flaws are categorized as subsurface and surface damage, which severely affect mechanical functioning of the restoration under masticatory load [51].

New rapid prototyping additive technology in prosthetic dentistry is Direct Metal Laser-sintering (DMLS). It was created by Joe Beaman and Carl Deckard and in 1989 they patented it. The working principle is based on use of high powered laser (Na:YAG laser) beam, which is concentrated onto a powdered metal bed. The metal framework is gradually formed in solid thin layers (20–100 μm) until the 3D object is built. The fabrication chamber is completely sealed and temperature is maintained at just under melting temperature that of the sintered metal powder. [13]

Precision of ceramo-metal restoration is dependent on the precision of production method as much as following fabrication procedures. After the fabrication process, metal substructure undergoes various firing cycles, which includes oxidation, opaque porcelain, dentin porcelain and enamel porcelain and glaze porcelain firing.. [1]

Thus, the current study was devised and conducted to evaluate the influence of ceramic firing on the Clinical Internal fit and Marginal adaptation of metal coping fabricated by DMLS method, with that of metal coping prepared by traditional casting method.

According to the results of study null hypothesis was rejected. The marginal fit of restoration fabricated by both methods showed significant difference. Significantly lower marginal gap was exhibited by restoration fabricated by DMLS method in comparison with restoration fabricated by casting method.

The marginal discrepancy values for the DMLS group prior to ceramic firing and after ceramic firing were lower than 120 µm which is maximum clinically admissible marginal discrepancy according to Homes et al, whereas for the casting group the marginal discrepancy ranged from 116 µm to 136 µm. The reason for this can be that the casting procedure cannot be standardized because of its complex technical aspect [53] and DMLS entirely eliminates the errors associated with casting procedure such as distortion of wax pattern, thermal expansion of investment material and thermal contraction of metal alloy. [39]

This was in conformance with the study published by Xu et al, marginal discrepancy of Co-Cr copings manufactured using laser sintering method (102.86 µm) was lower than those of casting method (170.19 µm) [54]. However, in the present study the marginal discrepancy values are lower than those observed by Xu et al in his study.

The internal adaptation of restoration fabricated by both methods also showed significant difference at axial and occlusal region between both the groups. Restoration fabricated by casting method exhibited significantly inferior internal adaptation in comparison with the restoration fabricated by DMLS method.

Tamac et al performed similar study assessing clinical internal and marginal fit of metal ceramic restoration fabricated by DMLS method, traditional casting and CAD/CAM milling. In this study the internal gap for DMLS group was significantly higher than casting group which is in contrast with present research. Whereas marginal gap was within clinical admissible range for all three groups. [12]

For both the groups ceramic firing had a significant influence on marginal and internal fit. In the present research the marginal and internal discrepancy values before and after ceramic veneering differed for both groups. This finding is in accordance with study by conducted by Kim et al. [55] Buchanan et al reported that the elevated temperature used for firing cycles increases the discrepancy as the heat expansion coefficients of the metal and the porcelain are different. [16] Hung et al also observed that the thermal cycling increases the marginal discrepancy. [56]

The influence of ceramic firing in present research corresponds with a recent investigation by Hong et al in 2019. He inferred that metal substructure subjected to high-temperature conditions through firing cycles may be the root cause for distortion or dimensional, eventually reducing the marginal adaptation of ceramo-metal restorations. [57]

Kocaagaoglu et al conducted a similar study assessing impact of repeated ceramic firing on “marginal and internal adaptation” of ceramo-metal restoration fabricated by laser sintering, casting and “CAD/CAM milling method”. “Laser sintering and milling” had significantly better marginal fit than casting group. However, in this study, “marginal and internal adaptation” of the Co-Cr based ceramic copings were not affected by repeated ceramic firings which is in contrast with present research.[58]

The overall findings of the present research indicate that there is a statistically significant effect of ceramic firing on “marginal and internal adaptation” of the ceramo-metal single crown restoration. The present study provides a direct evidence that DMLS method of manufacturing produces metal ceramic single crown restoration with clinically admissible “marginal and internal adaptation”. Within the limitations of the present research there is a scope for improvement and further research can be done to demonstrate superiority of one method over the other.

SCOPE OF THE STUDY

1. A long-term clinical study can be performed to compare the clinical survival the single metal ceramic crown fabricated by DMLS and traditional casting method.
2. A study can be conducted evaluating which firing cycle has more influence on marginal adaptation and internal fit of single metal ceramic crown fabricated by DMLS and traditional casting method.
3. A study can be performed in which micro-CT can be used for assessing marginal adaptation and internal fit of single metal ceramic crown fabricated by DMLS and traditional casting method, as micro-CT has better accuracy in comparison with silicone replica method.

LIMITATION OF THE STUDY

1. Light body PVS material was injected into the metal coping and seated onto the prepared tooth under finger pressure, the force applied could not be standardized and may vary for each patient.
2. The tooth preparation could not be standardized for each subject and may result in veneering ceramic of different thickness.
3. The effect of thermal expansion of investment material can not be controlled for each metal coping as it might have impact on the accuracy of metal coping adaptation.

CLINICAL IMPLICATIONS

- In the present research, statistically significant difference was seen in marginal fit and internal adaptation of single crown restoration fabricated by DMLS method and traditional casting method. Restoration fabricated by DMLS method had better marginal fit and internal adaptation than those fabricated by casting method. Therefore, DMLS method of fabrication can be used successfully for metal ceramic restoration fabrication.
- As for the effect of ceramic firing, restoration fabricated by DMLS and casting method both showed statistical significance. Although, in DMLS group least changes in fit of restoration were seen before ceramic firing and after ceramic firing when compared with restoration fabricated by casting method.
- Overall restoration fabricated by DMLS method exhibited better accuracy which is of clinical significance. Improved adaptation of restoration will increase long-term clinical survival as it reduces microleakage, luting cement dissolution and plaque retention.

CONCLUSION

Within the limitation of this in -vivo study and from the results acquired following conclusions could be drawn:

1. The ceramic firing process had significant influence on internal fit and marginal adaption of metal ceramic restoration, however the influence was minute for restorations fabricated by DMLS method when compared with restorations fabricated by traditional casting method.
2. Restorations fabricated by DMLS method exhibited significantly superior internal adaptation and marginal fit in comparison with restorations fabricated by traditional casting method.

SUMMARY

The present study was conducted with the aim of evaluating and comparing the influence of ceramic firing on internal fit and marginal adaptation of single metal ceramic crown restoration fabricated by conventional casting method and direct metal laser sintering method.

A total of 40 subjects with endodontically treated maxillary / mandibular premolar requiring single crown restoration, attending to the Department of Prosthodontics and Crown and Bridge, K.L.E Vishwanath Katti Institute of Dental Sciences, Belagavi, were recruited in the study. They were divided into 2 groups, with 20 subjects in each group. One group received metal ceramic restoration fabricated by conventional casting method and the other group received metal ceramic restoration fabricated by Direct Metal Laser Sintering Method.

The null hypothesis stated that there is no influence of ceramic firing on internal fit and marginal adaptation of single metal ceramic crown restoration fabricated by conventional casting method and direct metal laser sintering method.

Silicone replica method was used to measure internal gap and the marginal gap. Silicone replica of the copings was made by injecting light body into the coping and seating on the tooth; this represents the cement space. After setting of the light body putty consistency polyvinylsiloxane was placed in the space to stabilize the light body and both pulled out of the casting together. The replicas were made before and after ceramic firing for each subject. The silicone replica was sectioned in two planes and the internal gap and the marginal gap was measured at 10 predetermined points using Digital Stereomicroscope.

The data obtained was subjected to statistical analysis using SPSS software version 20. The statistical analysis performed were independent t test for comparison of internal and marginal gap(µm) for the two groups and dependent t test for comparison of effect of ceramic firing on internal and marginal gap(µm) within the groups.

Within the limitation of the study, it was concluded that the metal coping produced with Direct metal laser sintering method showed significantly better internal fit and marginal adaptation in comparison with metal copings produced conventional casting method. The ceramic firing had more significant effect on the internal fit and marginal adaptation of metal copings produced conventional casting method in comparison with metal coping produced with Direct metal laser sintering method.

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ANNEXURE - I

Mean measurements of Marginal Gap for Conventional Casting Metal Coping:

	Sample Number	Marginal Gap Before Ceramic Firing	Marginal Gap After Ceramic Firing
Group A **Conventional Casting method**	1	117.9	133.7
	2	120.15	129.55
	3	120.93	144.65
	4	116.65	134.53
	5	128.78	146.15
	6	122.35	143
	7	116	133.08
	8	122.35	146.15
	9	120.15	130.3
	10	122.98	144.95
	11	124.9	144.23
	12	117.33	142
	13	123.05	138.58
	14	126.85	143.93
	15	123.23	141.13
	16	124.15	142.45
	17	119.73	141.3
	18	122.18	142.4
	19	136.28	150.9
	20	126.73	143.73

ANNEXURE - II

Mean measurements of Internal Gap for Conventional Casting Metal Coping:

	Sample Number	Internal Gap Before Ceramic Firing	Internal Gap After Ceramic Firing
Group A **Conventional Casting method**	1	119.82	139.57
	2	122.87	140.47
	3	126.47	147.15
	4	117.73	129.27
	5	125.37	141.75
	6	126.47	147.15
	7	122.82	139.25
	8	124.97	141.6
	9	123.03	136.3
	10	131.12	150.22
	11	125.48	143.18
	12	122.8	139.18
	13	123.05	143.88
	14	123.12	141.85
	15	123.93	144.67
	16	118.2	132.57
	17	120.02	134.63
	18	124.8	141.68
	19	125.63	140.08
	20	124.5	141.5

ANNEXURE - III

Mean measurements of Marginal Gap for DMLS Metal Coping:

	Sample Number	Marginal Gap Before Porcelain Firing	Marginal Gap After Porcelain Firing
Group B **Direct Metal Laser Sintering method**	1	70.9	78.45
	2	69.15	76.3
	3	70.93	79.15
	4	68.65	75.78
	5	67.53	74.9
	6	65.98	73.05
	7	67.1	73.58
	8	68.9	74.63
	9	71.13	78.38
	10	65.08	71.73
	11	65.5	72.5
	12	70.78	78.48
	13	69.8	77.08
	14	66.78	73.05
	15	66.3	72.78
	16	68.65	74.98
	17	67.6	74.93
	18	67.68	74.75
	19	66.2	72.48
	20	69.13	76.24

ANNEXURE - IV

Mean measurements of Internal Gap for DMLS Casting Metal Coping:

	Sample Number	Internal Gap Before Porcelain Firing	Internal Gap After Porcelain Firing
Group B **Direct Metal Laser Sintering method**	1	70.97	80.23
	2	74.03	84.63
	3	73.63	81.98
	4	70.9	78.27
	5	76.23	86.08
	6	73.02	82.3
	7	75.3	83.68
	8	74.28	84.87
	9	74	84.42
	10	72.4	82.93
	11	73.72	83.62
	12	74.72	83.67
	13	75.13	84.3
	14	75	84.87
	15	76.37	85.55
	16	74.87	84.23
	17	74.85	84.13
	18	75.3	83.68
	19	75.63	83.75
	20	75.4	82.35

ANNEXURE – IV

ETHICAL CLEARANCE CERTIFICATE

Research and Ethics Committee
KLE V K INSTITUTE OF DENTAL SCIENCES
KLE University

Accredited 'A' Grade by NAAC   Placed in Category 'A' by MHRD (GoI)

Nehru Nagar, Belagavi - 590 010, Karnataka State

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FAX: 0831-2470640   E-mail:principal@kledental-bgm.edu.in

Sl. No. : 1204

CERTIFICATE

This is to Certify that the synopsis titled Comparative Evaluation of Influence of Ceramic Firing on Internal fit & Marginal Adaptation of Single ~~Ferro~~ Metal Ceramic Crown Restoration Fabricated by Conventional Casting and Direct Metal laser Sintering Method - An In-Vivo Study *Submitted by Dr.* Harshali Baburao Lohar *P. G. Student / Staff, Guided by* Dr. Raghunath Patil *from Department of* Prosthodontics And Crown And Bridge *has been critically evaluated by committee members and granted ethical clearance to conduct the above mentioned study*

Date : 24/05/2019

Member Secretary
Research and Ethical Committee
KLEVK Institute of Dental Sciences
Belagavi

Chairman
Research and Ethical Committee
KLEVK Institute of Dental Sciences
Belagavi

ANNEXURE – IV

CONSENT FORM

DEPARTMENT OF PROSTHODONTICS AND CROWN AND BRIDGE

KLE V.K.INSTITUTE OF DENTAL SCIENCES

BELAGAVI.

Comparative evaluation of influence of ceramic firing on internal fit and marginal adaptation of single metal ceramic crown restoration fabricated by conventional casting and direct metal laser sintering method – An In-Vivo study

1. I, _________________________________, aged ___ years have been informed about my involvement in the study to be conducted by Dr. Harshali Lohar.
2. I agree to give my personal details like Name, Age, Gender and any other details if required for the study to the best of my knowledge.
3. I will co-operate with the dentist.
4. I will follow the instructions given by the dentist during study.
5. I permit the dentist to utilize the information given and results obtained from this study for presentation and publication without disclosing my identity.
6. I am aware that if prosthesis is faulty it will be refabricated without extra charges.
7. I will not claim any returns for co-operation in this study, even if it is being sponsored by any agency. I am participating with my own will and wish.

In my full consciousness and presence of mind, after understanding all the procedure and related complications if any, in my vernacular language, I am willing and give my consent to participate in this study.

Date:

Patient's name:

Patient's signature:

CONSENT FORM

DEPARTMENT OF PROSTHODONTICS AND CROWN AND BRIDGE

KLE V.K.INSTITUTE OF DENTAL SCIENCES

BELAGAVI.

Comparative evaluation of influence of ceramic firing on internal fit and marginal adaptation of single metal ceramic crown restoration fabricated by conventional casting and direct metal laser sintering method – An In-Vivo study

१. मी . . . . वय . . . . . सहभागी होत असलेल्या वरील सांशोधनाबद्दल मला समजत असलेल्या भाषेत सर्व माहिती दिली आहे .

२. मी माझी माहिती जसे कि नाव, वय , लिंग , पुर्व दंत उपचार माहिती आणि इतर लागणारी माहिती देण्यास तयार आहे.

३. मी दंतचिकित्सकाने दिलेल्या सूचनांचे पालन करेल आणि संशोधनात सहकार्य करेल.

४. मी दंतचिकित्सकास माझी ओळख न उघडता दिलेली माहिती आणि या अभ्यासातून मिळालेल्या परिणामांचा प्रकाशनासाठी वापर करण्यास परवानगी देत आहे .

५. मला पूर्वमाहिती आहे की जर प्रोस्थेसिस दोषपूर्ण असेल तर ते अतिरिक्त शुल्काशिवाय पुन्हा तयार केले जाईल.

६. जर एखाद्या एजेन्सीने मी दिलेली माहिती वापरली तरीही मी या अभ्यासात सहकार्य करण्यासाठी कोणत्याही परताव्याचा दावा करणार नाही.

७. मला संपूर्ण प्रक्रिया आणि उद्भवणाऱ्या अडचणींबद्दल माझ्या स्थानिक भाषेत माहिती समजली आहे . मी या अभ्यासात सहभागी होण्यासाठी सहमती देत आहे .

तारीख :

रुग्णाचे नाव : दंतवैद्यकाचे नाव :

स्वाक्षरी :

CONSENT FORM

DEPARTMENT OF PROSTHODONTICS AND CROWN AND BRIDGE

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BELAGAVI.

Comparative evaluation of influence of ceramic firing on internal fit and marginal adaptation of single metal ceramic crown restoration fabricated by conventional casting and direct metal laser sintering method – An In-Vivo study

೧. ನಾನು .... ವಯಸ್ಸಿನ .... ವ್ಯಕ್ತಿಯಾದ್ ನಾನು ತಿಳಿದಿರುವ ಭಾಷಯಲ್ಲಿಈ ಸಂಶೋಧನಯಲ್ಲಿ ಭಾಗವಹಿಸು ವದರ್ ಬಗ್ಗ ನನಗ ತಿಳಿಸಲಾಗಿದ.

೨. ನಾನು ಕಲವು ಖಾಸಗಿ ಮಾಹಿತಿಗಳಾದ್ ಹಸರು ವಯಸ್ಸು , ಲಿಂಗ ಹಲ್ಲಿನತಪಾಸಣಯ/ ಚಿಕಿತ್ಸಯ ಮಾಹಿತಿಯನ್ನು ಮತ್ತು ಅಧ್ಯಯನಕ್ಕಾಗಿ ಬೇಕಾದ್ ಯಲ್ಲ ವಿವರಗಳನ್ನು ಕೊಡಲು ತಯಾರಾಗಿರುತನ್ನ .

೩. ನನಗ ದಂತಚಿಕಿತ್ಸಕರು ತಿಳಿಸಿರುವ ಸೂಚನಯಂತ ಪಾಲನ ಮಾಡುತ್ತೇನ ಮತ್ತು ಸಂಶೋಧನಗ ಸಹಕಾರ್ಯ ಮಾಡುತ್ತೇನ .

೪. ನನಗ ನೋಡುವ ದಂತಚಿಕಿತ್ಸಕರು ನನ್ನಗುರುತನ್ನು ಯಾರಿಗೂ ತಿಳಿಸದೇ ಮತ್ತು ಅಭ್ಯಾಸ್ಕಾಗೀ ಆಗುವ ಪರಿಣಾಮಗಳ್ ಪ್ರಕಾಶನಮಾಡಲು ನನ್ನ ಅನುಮತಿಯನ್ನು ಕೂಡುತ್ತನ .

೫. ನನಗ ಮೊದಲೇ ಮಾಹಿತಿ ಇದ ಮತ್ತೊಮ್ಮ ಪ್ರೋಸ್ಥಸಿಸ್ ದೋಷವಾಗಿದ್ದರ ಅದರ ವಚ್ಚವನ್ನು ಭರಿಸದ ಮತ್ತೊಮ ತಯಾರಿ ಮಾಡಲು ಹೇಳ್ಬಹುದು .

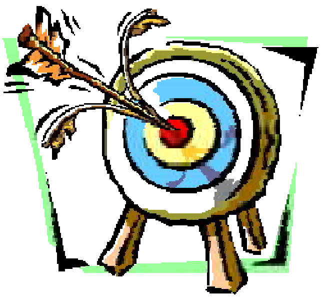
೬. ನನಗ ಸಂಪೂರ್ಣ ಚಿಕಿತ್ಸಯೀ ಮತ್ತು ಆಗುವ ಅಡಚಣಿ ಬಗ್ಗ ನನಗ ನಮ್ಮ್ ಭಾಷಯಲ್ಲಿ ಮಾಹಿತಿ ಇರುತ್ತದ . ನಾನು ಈ ಅಭ್ಯಾಸದಲ್ಲಿ ಸಹಭಾಗಿ ಆಗಲಿಕ್ಕ ನನ್ನ ಸಂಪೂರ್ಣ ಸಹಮತಿ ಕೂಡುತ್ತೇನ .

ದಿನಾಂಕ :

ರೋಗಿಗಳ ಹಸರು : ವೈದ್ಯರ ಹಸರು :

ಸಹಿ :

Introduction



Need For the Study

Hypothesis

Aim and Objectives

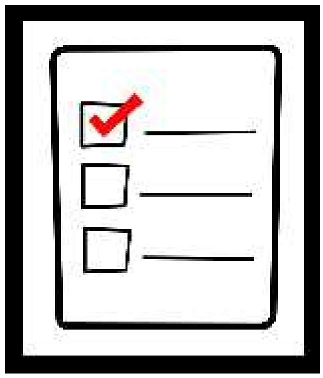
Review of Literature

Methodology

Results

Discussion

Scope of the Study



Limitations

Clinical Implication

Conclusion

Summary

Bibliography

Annexures