COMPARATIVE EVALUATION OF MARGINAL AND INTERNAL ADAPTATION OF CLASS II ZIRCONIA CERAMIC INLAYS Vs FELDSPATHIC CERAMIC INLAYS WITH AND WITHOUT A RESIN BASE AND DIFFERENT INTERFACE TREATMENTS - AN IN VITRO SCANNING ELECTRON MICROSCOPIC STUDY

Dissertation submitted to

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DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation titled **"COMPARATIVE EVALUATION OF MARGINAL AND INTERNAL ADAPTATION OF CLASS II ZIRCONIA CERAMIC INLAYS Vs FELDSPATHIC CERAMIC INLAYS WITH AND WITHOUT A RESIN BASE AND DIFFERENT INTERFACE TREATMENTS - AN IN VITRO SCANNING ELECTRON MICROSCOPIC STUDY"** is a bonafide and genuine research work carried out by me under the guidance of **Dr. M. Rajasekaran, M.D.S., Professor**, Department of Conservative Dentistry and Endodontics, Ragas Dental College and Hospital, Chennai.

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Place: Chennai

CERTIFICATE

This is to certify that this dissertation titled **"COMPARATIVE EVALUATION OF MARGINAL AND INTERNAL ADAPTATION OF CLASS II ZIRCONIA CERAMIC INLAYS Vs FELDSPATHIC CERAMIC INLAYS WITH AND WITHOUT A RESIN BASE AND DIFFERENT INTERFACE TREATMENTS- AN IN VITRO SCANNING ELECTRON MICROSCOPIC STUDY"** is a bonafide record work done by **Dr. SRIDEVI SHALINI SAICHANDRAN** under our guidance during her postgraduate study period between 2014 - 2017.

This dissertation is submitted to **THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY**, in partial fulfillment for the degree of **MASTER OF DENTAL SURGERY – CONSERVATIVE DENTISTRY AND ENDODONTICS, BRANCH IV**. It has not been submitted (partial or full) for the award of any other degree or diploma.

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LIST OF ABBREVIATIONS

S.NO	ABBREVIATIONS	EXPANSION
1.	CAD/CAM	Computer aided designing/computer aided machining
2.	Y-TZP	Yttria tetragonal zirconia polycrystalline ceramics
3.	SEM	Scanning electron microscope
4.	y-PSZ	yttrium-Oxide Partially Stabilised Zirconia (Ceramill Amann Girrbach)
5.	Post hoc Tukey HSD test	Post hoc Tukey Honestly significant difference test
6.	p <0.001**	Significant at 1 level (Highly Significant)
7.	RCT	Resin Coating Technique
8.	MDP	10-methacryloyloxydecyl dihydrogen phosphate

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Introduction

INTRODUCTION

A dental restoration is done to restore function, integrity and regain the structural loss of tooth tissues and to bring back the normal shape, appearance, aesthetics and to hinder the progression of dental caries preventing its spread to the dental pulp.

The decision-making process of what to restore with majorly; depends on the lesion size, aetiology, aesthetics, occlusion, endodontic and periodontal considerations, number of teeth affected, patient compliance, habits, preferences and the dentist's own competence and underlying beliefs about restorative treatment.[61] Direct restorations can be done in traditional Class I, II, III, IV, V situations and where single step quick setting restorations are required. But in case of large cavities and/or failed direct restorations with multiple missing cusps; anterior teeth with large interproximal cavities involving incisal edges requiring replacement; large rehabilitation cases requiring the recreation of multiple occlusal surfaces; an indirect restoration is the best treatment of choice. The materials available for indirect restorations were Gold, noble metals, Porcelain fused to metal and all ceramics.[43]

Amalgam and cast gold restorations have been the gold standard for posterior proximal restorations due to their durability and long term success in clinical studies. An aesthetic alternative has always been preferred by the patients and the emergence of composites and ceramics were a boon.[31]

Post-operative sensitivity and polymerization shrinkage were the main problems faced in direct composites or indirect composite restorations used in large class II proximal restorations.[64]

Indirect Class II inlay restorations fabricated with Ceramics are a definite alternative to posterior metal restorations. They are mainly used in compromised posterior teeth where the buccal and lingual walls are intact which strengthen and conserve tooth structure by mechanical bonding to the tooth.[31] Improved aesthetics of ceramic materials, bonding techniques and accessibility of newer technology has reinstated the use of Ceramic inlays.[10]

Today, material choices for posterior ceramic inlays include use of a higher-strength ceramic material, or alternatively a high-strength ceramic core material which may be veneered with a more translucent aesthetic veneer. The development of higher strength ceramics was required with modern technology and in 1970 Francois Duret pioneered the use of computer aided design/ computer aided milling (CAD/CAM) in dentistry. This allowed the inlays to be machined from pre-fired ceramic blocks in the dental office.[31]

The newer addition of material which are available as blocks for milling or hot pressing are the Yttria Tetragonal Zirconia Polycrystalline – based monolithic ceramics (Y-TZP) and the feldspathic porcelains reinforced with leucite or lithium disilicate with higher strength, fracture resistance and better aesthetics.[50]

Any indirect restoration requires a cement for the prepared teeth to retain them. This cement can largely influence the performance of the restoration as a whole.[71] Two broad categories of available cements are water based cements and resin-based cements. The choice depends on the type of material selected for the indirect restoration and the clinical requirements, such as setting characteristics, film thickness, setting rates and adhesion to the underlying tooth. There are a few non-resin cements that can be used with all ceramic restorations, but they may reduce the overall strength of the restoration owing to their lack of adhesion to the ceramic and the tooth. All-ceramic restorations rely on technique-sensitive resin-based cements and adhesives to hold them in place and to seal the tooth against leakage.[71]

An indirect inlay restoration has a key advantage of precision and control over the final morphology and occlusion of the restoration which indeed requires a tapered preparation design and sometimes increased tooth tissue loss.[49] A dentin seal is necessary in such indirect restorations during the temporary phase which can be facilitated using a flowable composite.[54] The flowable composite as a base not only ensures a dentin seal but also helps in blocking out undercuts, reducing microleakage, even to reduce sensitivity during re-exposure and cleaning of dentin surface after temporary restoration removal. It also helps as a stress absorber between the ceramic inlay restoration and tooth interface.[54]

This interface between the resinous base and luting composite or between luting composite and inlay brings about the micro-mechanical retention and the copolymerisation, which is key in adhesion of the restoration. A pre-treatment of the cavity along with the base and the under surface of the inlay restoration following the removal of the temporary cement and before luting the indirect restoration either using pumice, soft air abrasion or sandblasting helps in cleaning and chemo-mechanical activation of the composite base which in turn helps in improving the micro-mechanical retention and adhesion of the restoration.[54]

Despite the misconception that inadequacies of fit of ceramic inlays can be compensated by the presence of composite luting cement at the margins of a restoration, it has been shown that an accurately fitting restoration is vital for long-term success in a clinical situation. The marginal and internal gap sizes usually influence the longevity, wear, discolouration, leakage, degradation of the luting agent and the ability of the restoration to withstand loading.[10]

Various methods to measure the gap between the restoration and the tooth are the non-invasive and invasive techniques. Groten et al reported, that the accuracy of Scanning Electron Microscope (SEM) was better in providing more appropriate and realistic observations than a light microscope.[47]

The high range of magnification and depth of focus makes SEM an useful tool for studying both the adaptation of restorations to cavity margins and the surface characteristics of the restorations.[55] It is useful in identifying the location of marginal defects, whether on the inlay-cement interface, the cement-tooth interface or within the cement layer itself. This degree of precision is not possible using clinical examination alone.[10]

The more accurately the casting fits the prepared tooth, the more difficult it is for cement to escape from the inner surface of the restoration and the surface of the prepared tooth. The adverse effects of viscous luting cements, variations in marginal designs, magnitudes of seating force, cements and different seating aid materials may complicate restoration seating during cementation.[16]

Hence the aim of this study was to compare and evaluate the marginal and internal adaptation of Class II Zirconia ceramic inlays and Feldspathic ceramic inlays with and without a resin base and different interface treatments with Scanning Electron Microscope SEM.

Aim and Objectives

AIM AND OBJECTIVES

AIM OF THE STUDY:

The aim of this in vitro study is to evaluate and compare the marginal adaptation and internal adaptation of Class II Zirconia ceramic inlays to Feldspathic ceramic inlays with and without a resin base and different interface treatments with SEM.

OBJECTIVE OF THE STUDY:

This in vitro study compares

1. The marginal adaptation of the zirconia ceramic inlays with and without base and feldspathic ceramic inlays with and without base in the
   - occlusal junction between the restoration and tooth interface and
   - proximal cervical area junction between the restoration and the cervical dentin.
2. The evaluation of internal adaptation was done along
   - the pulpal floor and distal wall line angle [occlusal dentin], along
   - the pulpal floor and axial wall line angle [axial dentin] and along
   - the axial wall and gingival seat line angle [cervical dentin] between the zirconia ceramic inlays with and without base and feldspathic ceramic inlays with and without base.

Review of Literature

REVIEW OF LITERATURE

Matty F Abate et al (1989)[1] evaluated the marginal fit of four ceramic crown systems 1) metal ceramic crowns with metal margins 2) metal ceramic crowns with a porcelain facial margins, 3) cerestore crowns 4) dicor crowns. Measurements of the marginal adaptation were recorded from the facial and lingual margins by using a video enhanced microscope with digital micrometer and image intensification in a high-resolution television screen. Results indicate that all 4 crown systems yielded comparable and acceptable marginal fit.

Blair K.F et al (1993)[11] studied the microleakage associated with several luting agents for ceramic inlays. One hundred twenty Class V inlays (occlusal margins in enamel and gingival margins in dentin) were luted in extracted teeth using zinc phosphate cement, two resin cements without a bonding agent, and two resin cements with three dentin bonding agents. This study suggests that the use of a dentin bonding agent with a resin cement will reduce microleakage in cast glass-ceramic restorations.

Sjogren et al (1995)[60] the marginal and internal fit of four different types of ceramic inlays cerec, celay, empress, and vita in-ceram spinell was determined after they had been luted on extracted premolars. There was no statistically significant difference either in the proximal fit or in the gingiva-proximal fit between the four inlay systems studied, with the exception of the cerec inlays made for preparations with sharp proximal boxes, which had wider marginal gaps. The best internal fit was recorded for the celay inlays, whereas there was no significant difference in the internal fit between the other systems. For the cerec inlays the u-shaped proximal box shaping improved the marginal accuracy all around the restoration.

Bergman M.A et al (1999)[10] reviewed the clinical performance of ceramic inlays. Ceramic inlays perform better when compared with aesthetic intracoronal restorations. However, their high cost and extreme technique sensitivity would appear to restrict their use to certain limited clinical situations.

Addi simon et al (2002)[59] determined the fit of ceramic inlays manufactured using CAD/CAM-system (Denzir) and of two types of laboratory made heat pressed ceramics (IPS Empress and Opc). Extracted human premolars were prepared to receive mesio-occluso-distal (MOD) ceramic inlays, for which 10 Denzir, 10 IPS Empress, and 10 Opc inlays were fabricated. The Denzir restorations were produced by the manufacturer of the CAD/CAM-system, and the IPS Empress and Opc by student Dental technicians. Before luting the internal fit on the die stone models and on the premolars was determined using replicas. After luting on the premolars with a resin composite the marginal and internal fit were measured. The values were analysed and the results showed that after luting there were no significant differences between IPS Empress and Denzir, whereas the marginal gap width was significantly wider for Opc than for IPS Empress and Denzir. The internal fit was significantly wider for Opc than for IPS Empress, whereas there were no significant differences between IPS Empress and Denzir or between Opc and Denzir.

Mou et al (2002)[46] evaluated the influence of different convergence angles and tooth preparation heights on the internal adaptation of cerec crowns. Tooth preparations were made on typodont teeth with different combinations of convergence angles and occlusal-cervical heights: group I = 20° angle, 6 mm height; group II = 20° angle, 4 mm height; group III = 12° angle, 6 mm height; and group IV = 12° angle, 4 mm height. Three-way analysis of variance was used. Cerec crowns with a 12° convergence angle demonstrated the best internal fit. The difference between the 2 convergence types was within the range of the scanning error (25 µm) produced by the cerec camera. The study confirmed that there was little difference in the internal fit of cerec crowns prepared with convergence angles of 12° and 20.

Blatz M.B et al (2003)[12] reviewed resin ceramic bonding. The few available studies on resin bonding to zirconium oxide ceramics suggest the use of resin cements that contain special adhesive monomers. The rapidly increasing popularity of all-ceramic systems requires further research.

Dietschi D et al (2003)[20] compared the marginal and internal adaptation of class II fine hybrid composite inlays (Herculite, Kerr) made with or without composite bases, having different physical properties. Freshly extracted human molars were used for this study. The base extended up to the cervical margins on both sides and was made from Revolution (Kerr), Tetric flow (Vivadent), Dyract (Detrey-Dentsply) or Prodigy (Kerr), respectively. Before, during and after mechanical loading (1 million cycles, with a force varying from 50 to 100 N), the proximal margins of the inlay were assessed by scanning electron microscopy. Experimental data were analysed using non-parametric tests. The final percentages of marginal tooth fracture varied from 30.7% (no base) to 37.6% (Dyract). In dentin, percentages of marginal opening varied from 9.2% (Tetric Flow) to 30.1% (Prodigy), however, without significant difference between base products. Mean values of opened internal interface with dentin varied from 11.06% (Tetric Flow) to 28.15% (Prodigy). The results regarding dentin adaptation confirmed that the physical properties of a base can influence composite inlay adaptation and that the medium-rigid flowable composite Tetric Flow is a potential material to displace, in a coronal position,

Mota C.S et al (2003)[45] studied the microleakage in ceramic inlays using different resin cements with margins in enamel and cementum/dentine interface. Dye leakage at the margins in enamel was statistically lower than at cementum/dentine interface. Relyx ARC performed better than resin cement and composite restorations. Both material and substrate interface influenced microleakage of the ceramic inlays.

Ausiello et al (2004)[9] investigated the effect of differences in the resin-cement elastic modulus on stress-transmission to ceramic or resin-based composite inlay-restored class II mod cavities during vertical occlusal loading. Three finite-element (fe) models of class II mod cavity restorations in an upper premolar were produced. Model A represented a glass–ceramic inlay in combination with an adhesive and a high young's modulus resin-cement. Model B represented the same glass–ceramic inlay in combination with the same adhesive and a low young's modulus resin-cement. Model C represented a heat-cured resin composite inlay in combination with the same adhesive and the same low Young's modulus resin cement. Occlusal vertical loading of 400 n was simulated on the fe models of the restored teeth. Ansys FE software was used to compute the local von mises stresses. In the ceramic-inlay models, the greatest von mises stress was observed on the lateral walls, vestibular and lingual, of the cavity. Indirect resin-composite inlays performed better in terms of stress dissipation. Glass–ceramic inlays transferred stresses to the dental walls and, depending on its rigidity, to the resin-cement and the adhesive layers.

Liu PR et al (2005)[37] overviewed the development of various CAD/CAM systems. Operational components, methodologies, and restorative materials used with common CAD/CAM systems are discussed. Research data and clinical studies are presented to substantiate the clinical performance of these systems. The study concluded that CAD/CAM systems have dramatically enhanced dentistry by providing high-quality restorations. The evolution of current systems and the introduction of new systems demonstrate increasing user friendliness, expanded capabilities, and improved quality, and range in complexity and application. New materials also are more esthetic, wear more nearly like enamel, and are strong enough for full crowns and bridges. Dental CAD/CAM technology is successful today because of the vision of many great pioneers as Duret concluded in his article in 1991, the systems will continue to improve in versatility, accuracy, and cost effectiveness, and will be a part of routine dental practice.

Karakaya S et al (2005)[34] Investigated the internal adaptation of a ceramic (ceramco II) and Two composite resin inlay materials (Surefil and 3M Filtek Z 250™) using silicon replica technique as an Indicator. Forty-five standard MOD cavities were prepared into brass moulds. Inlays were prepared with indirect methods and replicas of the prepared cavities and inlays were produced with a Polyvinyl siloxane material (Elite H-D). Two parallel slices (mesio-distally) were obtained from the replicas with a sharp blade. Thickness between cavity and inlay was measured at seven points. The results showed that in the surefil and ceramco II groups, the sizes of the contraction gaps at mesial and distal gingival floors were greater than that of the occlusal marginal walls. In comparison of gap formation at occlusal regions, while the 3M composite group showed highest gap values, the ceramco II group revealed the lowest. At the gingival floors, gap formation of ceramco II group was the highest. Neither group showed any statistical difference between gap values of their self-occlusal and gingival floors. In conclusion, the results showed that ceramic inlays did not confer any big advantage for internal adaptation over the composite inlays.

Bortolotto et al (2007)[13] evaluated the marginal adaptation of cerec ceramic inlays, cerec composite inlays and direct composite restorations in unbeveled proximal slot cavities under artificial aging conditions. Two groups of each restoration type were prepared, one group with a self-etch adhesive, the other group with H_3PO_4 enamel etching before the self-etch adhesive application. Replicas were generated before and after long-term thermo-mechanical loading and analyzed using SEM. The study showed results were statistically significant difference before and after loading with respect to the percentages of "continuous margins", the direct composite filling with H_3PO_4 enamel etching giving the lowest percentages of "continuous margins" after loading. The highest percentage was attained by composite inlays without H_3PO_4 enamel etching. These results were not significantly different from ceramic inlays after stressing. The study concluded that polymerization shrinkage is still one critical property of composite restorative materials. The marginal adaptation of indirect adhesive proximal slot restorations without enamel bevels both fabricated out of composite and ceramic is better than that of directly placed.

Sadeghi M (2007)[53] evaluated the influence of fluid composites as gingival layer on microleakage of class II packable, microhybrid, and fiber-reinforced composite restorations with the margins below the cemento-enamel junction (CEJ). 45 sound premolars extracted for orthodontic reasons were selected. Class II cavities were prepared on the mesial and distal aspects with the gingival margin placed 1 mm below the CEJ, making 90 slot cavities. Teeth were randomly assigned into 3 groups (n=15). In each group, one side of each tooth was restored incrementally with respective packable, microhybrid, and fiber-reinforced composites; whereas, on the other side, fluid composite was placed as a 1 mm thickness gingival increment before restoration with the same composites. The teeth were stored for one week in distilled water at 37ºC, thermo-cycled (5-55ºC, x 1500), and immersed in 0.5% basic fuchsine for 24 hours. Dye penetration was evaluated using a stereomicroscope at 10X magnification. The data were analysed statistically showed that the fluid composite significantly decreased the microleakage at gingival margins of Class II composite restorations.

Roland frankenberger et al (2008)[23] evaluated the marginal integrity of IPS empress inlays luted with different adhesives and cements before and after thermo-mechanical loading (TML). Mod cavities with one proximal box beneath the cemento-enamel junction were prepared in 72 extracted human third molars. IPS empress inlays were luted with nine combinations of adhesive and luting composite or self-etch cement alone: prime & bond (Nt) dual-cure + calibra (pc), xp bond/sca+ calibra (xc), xp bond/sca light-cured + calibra (xl), syntac +variolink ii (sv), multilink primer + multilink (ml), adhesse dc+variolink ii (av), ed primer + panavia f 2.0 (ep), relyx unicem (ru), and maxcem (mc). Marginal quality was analyzed under an SEM using epoxy resin replicas before and after thermo-mechanical loading. The study showed that all systems involving the etch-and-rinse approach resulted in significantly higher percentages of gap-free margins in enamel than all other luting systems. Between the luting systems xc, xl, sv, ml, av, ed,ep, and ru, no significant differences were computed. The study showed that etch-and-rinse adhesives combined with conventional luting resin composites reveal the best prognosis for adhesive luting of glass ceramic inlays.

Silva et al (2009)[58] evaluated the performance of Ceramco inlays and onlays over 40 months. The ceramic restorations did not show alterations that could result in their replacement, although there was a moderate failure in the marginal adaptation.

Yüksel E et al (2011)[67] studied the effects of both marginal fit and cementing with different luting agents on the microleakage of all-ceramic crown systems. Group1: CAD/CAM-fabricated ZrO_2, Group 2: Heat-pressed lithium disilicate, and Group 3: Cast Cr-Co copings as the control group. Marginal discrepancy and cement type both had significant effects on microleakage. Lower levels of microleakage were recorded with self-adhesive resin cement, while CAD/CAM-fabricated ZrO_2 copings showed smaller marginal discrepancy and less microleakage in comparison to cast Cr-Co.

Medina AD et al (2012)[42] evaluated the influence of material combinations used in the resin coating technique (rct) on the marginal adaptation of indirect restorations with gingival margins in enamel (em) and cement (cm). Eighty third-molars were used. Two cavities were prepared in each tooth. The cavities were distributed into 16 groups. The fillings were performed with the sinfony-system (3M/ESPE). After 24 h, the teeth were submitted to thermocycling (2,000 cycles, 5° to 55°c) and load-cycling (50,000 cycles, 50 n). Finally, the caries-detector (kuraray) was applied to the restoration margins. Images from the proximal margin were evaluated using the image-tool 3.0 software. The results were submitted to ANOVA and Tukey's test. The highest percentages of marginal gap on em or cm were found in the groups that did not use a liner. The article concluded that the most appropriate rct combinations were the groups that used a liner.

Rocca GT et al (2012)[51] evaluated the influence of different composite bases and surface treatments on marginal and internal adaptation of class II indirect composite restorations, after simulated occlusal loading. Thirty-two class II inlay cavities were prepared on human third molars, with margins located in cementum. A 1-mm composite base extending up to the cervical margins was applied on all dentin surfaces in the experimental groups. Impressions were made and composite inlays fabricated. Tooth–restoration margins were analyzed by SEM before and after loading. Internal adaptation was also evaluated after test completion. No debonding occurred between the base and composite luting. A significant, negative influence of cyclic loading was observed. The results of the study supported the use of flowable or restorative composites as base/liner underneath large class II restorations.

Colpani JT et al (2013)[17] measured the marginal and internal adaptation of different prosthetic crowns infrastructures (IS) and analysed two types of methodologies (replica and weight technique) used to evaluate the adaptation of indirect restorations. In this study, Ceramic IS were fabricated using CAD/CAM technology and slip-casting technique, and metal IS were produced by casting

(n = 10). For each experimental group, the adaptation was evaluated with the replica (RT) and the weight technique (WT), using an impression material (low viscosity silicon) to simulate the luting agent. Cross-sectional images of the silicon replica were obtained and analysed with Image J software to measure the low viscosity silicon layer thickness at pre-determined points. The results showed that all IS evaluated showed clinically acceptable internal and marginal adaptation. Metal IS showed the best adaptation, irrespective of the measuring technique (RT and WT). The IS produced by CAD–CAM showed greater gap values at the occlusal area than at other evaluated regions. The IS produced by the dental laboratory technician showed similar gap values at all evaluated regions. There is no correlation between RT and WT.

Hopp D Christa et al (2013)[31] reviewed ceramic inlays in posterior teeth which includes history of ceramic restorations, indications and contraindications. It also discussed the potential for tooth wear, recommended preparation design considerations, fabrication methods and material choices. The review concludes with a section on luting considerations, and offers the clinician specific recommendations for luting procedures.

Roland frankenberger et al (2013)[24] evaluated the marginal quality and resin–resin transition of milled CAD/CAM glass–ceramic inlays in deep proximal cavities with and without 3-mm proximal box elevation (PBE) using resin composites before and after thermomechanical loading. The mod cavities with one proximal box were prepared in 48 extracted human third molars. Proximal boxes ending in dentin were elevated for 3 mm with different resin composites (relyx unicem, g-cem, and maxcem elite as self-adhesive resin cements and clearfil majesty posterior as restorative resin composite in one or three layers bonded with adhesive) or left untreated. IPS empress CAD inlays were luted with syntac and variolink. Marginal quality as well as the PBE–ceramic interface was analyzed under an SEM using epoxy resin replicas before and after thermomechanical loading. Bonding glass–ceramic directly to dentin showed the highest amounts of gap-free margins in dentin. Bonded resin composite applied in three layers achieved 84% gap-free margins in dentin; PBE with self-adhesive resin cements exhibited significantly more gaps in dentin. The study concluded that with a meticulous layering technique and bonded resin composite, PBE may be an alternative to ceramic bonding to dentin. Self-adhesive resin cements seem not suitable for this indication. Clinical relevance for deep proximal boxes ending in dentin, a PBE may be an alternative to conventional techniques.

Zaruba M et al (2013)[68] evaluated the effect of a proximal margin elevation technique on marginal adaptation of ceramic inlays. Class II mod-cavities were prepared in 40 human molars and randomly distributed to four groups. In group EN (positive control) proximal margins were located in enamel, 1 mm above the cemento-enamel junction, while 2 mm below in groups DE-1in, DE-2in and DE. The groups DE-1in, DE-2in and DE simulated subgingival location of the cervical margin. In group DE-1in one 3 mm and in group DE-2 in two 1.5 mm composite layers (tetric) were placed for margin elevation of the proximal cavities using Syntac classic as an adhesive. The proximal cavities of group DE remained untreated and served as a negative control. In all groups, ceramic inlays were adhesively inserted. Replicas were taken before and after thermomechanical loading. Marginal integrity was evaluated with scanning electron microscopy. Percentage of continuous margin was compared between groups before and after cycling using ANOVA and Scheffé Post-hoc test. The result showed that after thermomechanical loading, no significant differences were observed between the different groups with respect to the interface composite-inlay and tooth-composite with margins in dentin. Margin elevation technique by placement of a composite filling in the proximal box before insertion of a ceramic inlay results in marginal integrities not different from margins of ceramic inlays placed in dentin.

Guess PC et al (2014)[27] evaluate the marginal and internal fit of heat-pressed and CAD/CAM fabricated all-ceramic onlays before and after luting as well as after thermomechanical fatigue. Seventy-two caries-free, extracted human mandibular molars were randomly divided into three groups (n = 24/group).

All teeth received an onlay preparation with a mesio-occlusal–distal inlay cavity and an occlusal reduction of all cusps. Teeth were restored with heat-pressed IPS-e.max-Press* (IP, *Ivoclar-Vivadent) and Vita-PM9 (VP, Vita-Zahnfabrik) as well as CAD/CAM fabricated IPS-e. max-CAD* (IC, Cerec 3D/InLab/Sirona) all ceramic materials. After cementation with a dual-polymerising resin cement (VariolinkII*), all restorations were subjected to mouth-motion fatigue (98 N, 1.2 million cycles; 5ºC/55ºC).Marginal fit discrepancies were examined on epoxy replicas before and after luting as well as after fatigue at 200 X magnification. Internal fit was evaluated by multiple sectioning technique. The results showed that mean marginal gap values of the investigated onlays before and after luting as well as after fatigue were within the clinically acceptable range. Marginal fit was not affected by the investigated heat-press versus CAD/CAM fabrication technique. Press fabrication resulted in a superior internal fit of onlays as compared to the CAD/CAM technique.

Huang Z et al (2014)[32] compared the marginal and internal fit of single-unit crowns fabricated using a selective laser melting (SLM)procedure with two CAD/CAM grinding procedures, and evaluated the influence of tooth type on the parameters measured. A total of 270 crowns were evaluated, including 90SLM metal-ceramic crowns (group B), 90 zirconium-oxide-based ceramic crowns (group L), and 90 lithium disilicate ceramic crowns (group C). The marginal and internal gaps of the crowns were recorded using a replica technique with a silicone indicator paste stabilized with a light-body silicone. The gap replica specimens were sectioned buccolingually and mesiodistally and then examined using a stereomicroscope at 30 X magnification. Ten reference points were measured on each anterior and premolar specimen, and 20 reference points were measured on each molar specimen. The results were statistically analysed and concluded that SLM system demonstrated better marginal and internal fit compared to the two CAD/CAM grinding systems examined. Tooth type did not significantly influence the marginal or internal fit.

Zaruba M et al (2014)[69] evaluated the effect of a minimally invasive mod preparation on the marginal adaptation of ceramic and composite inlays with the aim of saving sound dental substance. Class II mod cavities were prepared in50 extracted human molars and randomly allocated to five groups. In all groups, the mesial proximal box margins were located in the dentin, 1 mm below the cemento-enamel junction (CEJ), while the distal box margins were 1 mm above the CEJ. In groups A and B, conventional standard preparations with a divergent angle of = 6° were prepared. In groups C, D, and E, minimally invasive standard preparations with a convergent angle of = 10° were prepared. In groups A and D, composite inlays and, in groups B and C, ceramic inlays were fabricated and adhesively inserted. In group E, a direct composite filling using the incremental technique was placed. Replicas were taken before and after thermomechanical. Marginal integrity was evaluated by SEM. The percentage of continuous margins in the different locations was compared between and within groups before and after cycling, using ANOVA and Scheffé Post hoc test. Results showed that after thermomechanical loading, no significant differences were observed between the different groups with respect to the interface of luting composite-inlay.

Evanthia A et al (2015)[5] evaluated the internal adaptation of pressed and milled ceramic crowns made from digital impressions. Thirty polyvinyl siloxane (PVS) impressions and 30 Lava COS impressions made of a prepared dentoform tooth (master die) were fabricated. Thirty crowns were pressed in lithium disilicate (IPS e. max Press), and 30 crowns were milled from lithium disilicate blocks (IPS e. max CAD) (15/impression technique) with the E4D scanner and milling engine. The master die and the intaglio of the crowns were digitized with a 3-dimensional laser coordinate measurement machine. The digital master die and intaglio of each crown were merged. The distance between the die and the intaglio surface of the crown was measured at 3 standardized points. The results revealed that the internal gap obtained from the Lava/press was significantly greater than that obtained from the other groups ($p<.001$), while no significant differences were found among PVS/press, PVS/CAD/CAM and Lava/CAD/CAM.

Durand LB et al (2015)[21] determined the effect of cavity depth, ceramic thickness and resin bases with different elastic modulus on von mises stress patterns of ceramic inlays. 3D geometric models were developed and the differences between the models were: depth of pulpal wall, ceramic thickness, and presence of composite bases with different thickness and elastic modulus. A load of 100 N was applied. The stress distribution pattern was analyzed with von mises stress diagrams. The highest von mises stress value was found on models with 1-mm-thick composite resin base and 1-mm-thick ceramic inlay. Intermediate values occurred on models with 2-mm-thick composite resin base and 1-mmthick ceramic inlay and 1-mm-thick composite resin base and 2-mm-thick ceramic inlay. Lowest values were observed on models restored exclusively with ceramic inlay. It was found that thicker inlays distribute stress more favorably and bases with low elastic modulus increase stress concentrations on the internal surface of the ceramic inlay. The increase of ceramic thickness tends to present more favorable stress distribution, especially when bonded directly onto the cavity without the use of supporting materials.

Guven Sedat et al (2015)[28] examined the influence of two ceramic inlay materials with different cavity designs on stresses in the inlay. Finite-element analysis and three-dimensional modelling were used to examine the stress in ceramic inlays resulting from a 250 N point load on occlusal surfaces. The adhesion properties and von mises stress values in the enamel, dentin, ceramic materials and cement linings were simulated. Two ceramic inlay materials: porcelain ceramic and zirconia ceramic, as well as two cavity corner designs: rectangular and rounded, were evaluated. The obtained von mises stress results indicated that the maximum and minimum forces were concentrated in the enamel and dentin, respectively. The stress values in the dentin and inlay material were similar in the porcelain ceramic and zirconia ceramic groups. However, in the enamel, the stress values in the zirconia ceramic group were significantly lower than those in the porcelain ceramic group. Additionally, cavities with rounded corners were subject to significantly less stress compared to those with rectangular corners. The study confirmed that, the zirconia ceramic inlay demonstrated better performance under applied stress, based on the reduced stress values in the tooth structure.

Irina ilgenstein et al (2015)[33] investigated the influence of proximal box elevation (PBE) with composite resin when applied to deep proximal defects in root-filled molars with MOD cavities, which were subsequently restored with CAD/CAM ceramic or composite restorations. Root canal treatment was performed on 48 human mandibular molars. Standardized MOD cavities were prepared with the distal box located 2 mm below the CEJ. The teeth were randomly assigned to one of four experimental groups. In groups G1 and G2, the distal proximal box was elevated up to the level of the CEJ with composite resin (PBE). No elevation was performed in the remaining two groups (G3, G4). CAD/CAM restorations were fabricated with feldspathic ceramic in groups G1 and G3 or with resin nano-ceramic blocks in groups G2 and G4. Replicas were taken before and after thermomechanical loading. Following TML, load was applied until failure. Fracture analysis was performed under a stereomicroscope. Marginal quality before and after TML was evaluated using scanning electron microscopy. The results showed lower percentages of continuous margins in groups G1–G3 compared with pre-TML assessments. For group G4-lav, the marginal quality after TML was significantly better than in any other group. The highest mean fracture value was recorded for group G4. No significant difference was found for this value between the groups with PBE compared with the groups without PBE, regardless of the material used. The specimens restored with ceramic onlays exhibited fractures that were mainly restricted to the restoration while, in teeth restored with composite onlays, the percentage of catastrophic failures (fractures beyond bone level) was increased. The study concluded that PBE had no impact on either the marginal integrity or the fracture behavior of root canal-treated mandibular molars restored with feldspathic ceramic onlays.

Rocca et al (2015)[52] presented an evidence-based update of clinical protocols and procedures for cavity preparation and restoration selection for bonded inlays and onlays. In cases of severe bruxism or tooth fragilization, CAD/CAM composite resins or pressed CAD/CAM lithium disilicate glass ceramics are often recommended, although this choice relies mainly on scarce *in vitro* research as there is still a lack of medium- to long-term clinical evidence. The decision about whether or not to cover a cusp can only be made after a multifactorial analysis, which includes cavity dimensions and the resulting tooth biomechanical status, as well as occlusal and esthetic factors. The clinical Impact of the modern treatment concepts such as – dual bonding (db)/immediate dentin sealing (ids), cavity design optimization (cdo), and cervical margins relocation (cmr) – should be followed. Despite the wide choice of restorative materials (composite resin or ceramic) and techniques (classical or CAD/CAM), the cavity for an indirect restoration should meet five objective criteria such as detailed sharp margins, absence of undercuts, accessibility of subgingival margins, absence of contact between the cavity and the adjacent teeth, and adequate inter-occlusal space, before the impression.

Sandoval MJ et al (2015)[54] evaluated the influence of different composite bases and surface treatments on marginal and internal adaptation of class II cerec CAD/CAM ceramic inlays, before and after simulated occlusal loading. Thirty-two IPS empress cad class II inlays (MO or DO) were placed on third molars, with margins 1 mm below the cementum-enamel junction (CEJ), following different cavity treatments. The restorations were then luted with premise. All specimens were submitted to 1,000,000 cycles with a 100-n eccentric load. There were no significant differences among groups. The results of the present study support the use of flowable or restorative composites as a liner underneath ceramic CAD/CAM inlays, producing marginal and internal adaptation which is not different from restorations placed directly on dentin. Soft air abrasion proved not to be different from sandblasting for treating cavities before cementation.

Susana morimoto et al (2016)[44] evaluated the fracture strength of teeth restored with bonded ceramic inlays and overlays compared to sound teeth. Thirty sound human maxillary premolars were assigned to 3 groups: 1- sound/unprepared (control); 2- inlays and 3- overlays. The inlay cavity design was class II mod preparation with an occlusal width of 1/2 of the inter cuspal distance. The overlay cavity design was similar to that of the inlay group, except for buccal and palatal cusp coverage the inlay and overlay groups were restored with feldspathic porcelain bonded with adhesive cement. The specimens were subjected to a compressive load until fracture. The results showed that there were no statistically significant differences among the groups. For Inlays and overlays, the predominant fracture mode involved fragments of one cusp (70% of simple fractures). The fracture strength of teeth restored with inlay and overlay ceramics with cusp coverage was similar to that of intact teeth.

Materials and Methods

MATERIALS AND METHODS

Armamentarium used - Materials

- 40 extracted natural teeth (lower mandibular molars)
- 0.1% thymol solution
- Addition silicone impression material (Aquasil – putty index)
- Tooth coloured self-cure acrylic resin powder and liquid monomer
- SSW-FG-169L, SSW-FG-271(SS White), 8862 (MANI) burs, diamond discs
- Gingival Margin Trimmers – mesial and distal
- High speed Airotor handpiece
- Micromotor handpiece and unit
- Flowable composite – (Tetric – N – Flow - Ivoclar)
- Zirconia blank – yttrium-Oxide Partially Stabilised Zirconia (y-PSZ) (Ceramill Amann Girrbach)
- Feldspathic porcelain reinforced with lithium disilicate ceramic ingot – (IPS Emax Press – IVOCLAR)
- Sandblasting (aluminium oxide powder - 27µm)
- Soft air abrasion (sodium bicarbonate powder - 100µm)
- 5% Hydrofluoric acid tube (Ivoclar)
- Silane coupling agent (Monobond – S - Ivoclar)
- 37% Orthophosphoric acid (d-tech)
- Dentin bonding agent (Pearl Bond) and applicator tips

- Dual cure Resin cement – base and catalyst (Variolink – N – Ivoclar)
- Dental surveyor -with 5 kg stone
- Mixing pad and Agate spatula
- Chip blower and cotton
- Clear acrylic resin powder and monomer liquid
- Light curing unit (3M ESPE)
- Ultrasonic cleaner
- Steam Cleaner
- Scanning Electron Microscope along with gold sputtering machine (Variable pressure – SEM - S – 3400 N – HITACHI)

INCLUSION CRITERIA

- Extracted lower first and second mandibular molars with proper coronal anatomy, all four walls of the teeth intact, complete root formation, absence of dental caries

EXCLUSION CRITERIA

- Teeth with attrition, loss of buccal or lingual walls, grossly decayed, fractured teeth, abrasion, cracked teeth, lower mandibular third molars

METHODOLOGY

40 extracted lower human mandibular molar teeth (figure 1) which were extracted due to periodontal problems were selected and cleaned and stored in 0.1% thymol solution at $4^{o}C$. All the teeth were then embedded using tooth coloured self-curing acrylic resin (figure 2), using a putty index made out of addition silicone impression material (figure 11).

TOOTH PREPARATION:

Tooth preparation was done to all the 40 samples.(figure 8a) The cavity preparation was done based on the protocol given by ROCCA et al 2015 [51,52] and Class II mesio – occlusal preparations (figure 17) were done in all the 40 teeth with SSW-FG-169L, SSW-FG-271 (SS White) burs, 8862(Mani) diamond point (figure 7) and with the proximal margins 1mm below the cemento-enamel junction and with a tapered proximal box 4mm in width and 2 mm in depth at the bottom of the proximal box and with 5mm in width and 3 mm in depth in the occlusal isthmus. All the walls had a taper of about 10 degrees to 15 degrees of divergence.[54] The axio-pulpal line angles were rounded using gingival marginal trimmer (figure 8b). All line and point angles, internal and external, were rounded to avoid stress concentrations in the restoration and tooth, thereby reducing the potential for fractures.[74]

SAMPLE GROUPING:

The 40 teeth were randomly divided into two groups. The Group 1 had 20 teeth, which were further sub-divided into Group 1A (figure 3) and Group 1B (figure 4) of 10 teeth samples each. The Group 1A got Zirconia ceramic inlays [yttrium-Oxide Partially Stabilised Zirconia (y-PSZ) Ceramill Amann Girrbach] with flowable composite base Tetric – N – Flow - Ivoclar) (figure 9) whereas the other 10 teeth sample of Group 1B were made out of Zirconia Ceramic inlay alone [y-PSZ] without a base. Similarly, Group 2 had 20 teeth, which were further sub-divided into Group 2A (figure 5) and Group 2B (figure 6) of 10 teeth samples each. The Group 2A were made of Feldspathic ceramic inlays reinforced with lithium disilicate ceramic ingot [IPS Emax Press – IVOCLAR] with a flowable composite base (Tetric – N – Flow - Ivoclar) (figure 9) and the last 10 samples of the teeth of Group 2B were made only with of Feldspathic ceramic inlays reinforced with lithium disilicate ceramic ingots [IPS Emax Press – IVOCLAR] without a base.

PLACEMENT OF FLOWABLE COMPOSITE BASE:

Now the cavities of Group 1 A and 2 A which had to receive a flowable composite base (Tetric – N – Flow – Ivoclar)[20] (figure 9) underwent etching only on the pulpal floor, axial wall and not on the gingival seat as the base was not placed on the gingival seat area. Then, only the pulpal floor and axial wall was etched with 37% phosphoric acid (d-tech) (figure 16) for about

20 seconds and was rinsed with water and dried using cotton pellets and chip blower, while care was taken not to over dry the etched tooth surface. Now, the denting bonding agent (pearl bond) (figure 16) was applied only on the etched tooth surface with the help of an applicator tip and light cured (3M-ESPE) (figure 20) for about 40 secs as per the manufacturer's instructions. Now the flowable composite base (Tetric – N – Flow – Ivoclar) of about 1mm thickness (figure 10) is placed on the pulpal floor and the axial wall and light cured (3M-ESPE). Care to be taken that the flowable composite base does not cover the gingival seat area.[77]

The teeth in Group 1 B and 2 B did not have a base and served as a control in both the groups.

FABRICATION OF INLAY:

Now all the prepared Group 1 (y-PSZ) samples were subjected to direct optical scanning. The tooth surface to be scanned was coated with titanium dioxide powder and the measurements for the zirconia inlay was obtained by the scanner (figure 13) and the measurements was fed into the CAD/CAM machine with the help of the software. The CAD/CAM machine (figure 14) used the zirconia blanks (y-PSZ) to mill the ceramic inlay according to the measurements scanned and the final product obtained.

The Group 2 [IPS Emax Press – IVOCLAR] samples were replicated by making an impression (figure 12) using addition silicone impression material (Aquasil) (figure 11) and a master cast obtained with die stone. Now the Group 2 [IPS Emax Press – IVOCLAR] samples were manufactured by the conventional layering technique by hot pressing using feldspathic ceramic with the help of the master cast in a VITA ceramic furnace (figure 15).

SURFACE TREATMENTS:

The inner surface of the inlays of both the Groups 1 and 2 underwent sandblasting with aluminium oxide particles 27µm at 2 bar pressure and the class II cavity of all the teeth was subjected to soft air abrasion with 100µm of sodium bicarbonate particles at 3 bar pressure to increase the micro mechanical bonding of the luting cement.[41]

The cement serves as a bridge between the tooth and the restoration. While the bonding procedures ensure that the cement adheres well to the tooth, pre -treatment of the internal surface of the restoration ensures that the cement will adhere to the restoration as well. A good adhesion to the internal surface of the restoration requires (i) roughening of the internal surface of the restoration to increase the surface area for bonding and (ii) increasing the wettability of the cement to the restoration and forming chemical bonds between the ceramic, the fillers, and the cement. Depending on the restoration material, the first procedure is done through air abrasion, sandblasting, or etching with a hydrofluoric acid (for ceramic and composite restorations). The second procedure is achieved by applying a silane coupling agent on the etched porcelain or composite. The silane makes the ceramic chemically adhere to the resin cement through covalent and hydrogen bonds (Horn 1983). Silanating the internal surface of indirect restorations ensures that the fillers of the luting composite react and adhere with the restoration (Calamia and Simonsen 1985).[77]

LUTING OF INLAY WITH RESIN CEMENT WITH MECHANICAL LOADING:

All the 40 teeth with class II cavity is then acid etched with 37% phosphoric acid gel [d tech] (figure 18) for 20 secs and then rinsed with water and dried with cotton pellets. Then dentin bonding agent [pearl bond] (figure 19) was applied on the etched cavity surface with the help of an applicator tip and light cured for 40 secs (figure 20). Thus, the tooth of all the groups were prepared.

The Group 1 zirconia (y-PSZ) inlays were treated with silane coupling agent (Monobond – S – Ivoclar) (figure 22) and left uncured until the dual cure resin cement (Variolink – N – Ivoclar) (figure 16) base and catalyst paste were dispensed on the mixing pad in equal quantity and mixed using an Agate spatula and the cement was applied on the cavity surface (figure 23) and the zirconia (y-PSZ) inlay placed on the cavity. Then the sample was placed in a dental surveyor under 5 kg load simulating oral masticatory load (figure 25) and the excess cement removed and light curing done for 20 seconds from all the sides of the tooth.[18,25]

The inner surface of Group 2 feldspathic ceramic [IPS Emax Press – IVOCLAR] inlays were now treated with 5% hydrofluoric acid (Ivoclar) (figure 21) for 60 seconds and then rinsed with water and silane coupling agent (Monobond – S – Ivoclar) (figure 22) applied and left uncured. The dual cure resin cement (Variolink – N – Ivoclar) (figure 16) base and catalyst paste dispensed on a mixing pad equally and mixed with an agate spatula and loaded on the cavity (figure 23). The feldspathic ceramic [IPS Emax Press – IVOCLAR] inlay was then placed on the cavity and subjected to 5 kg load under a dental surveyor (figure 25) and excess cement was removed and light cured for 20 secs from all the sides.[18,25]

PREPARATION OF SAMPLE FOR ANALYSIS:

All the 40 luted samples (figure 24) were left for 24 hours for complete polymerisation and then all the samples were embedded in clear acrylic resin (figure 2) used with the help of a putty index (addition silicone impression material – Aquasil) (figure 11).

Now all the 40 samples were cut mesio – distally through and through the entire resin sample using diamond discs (figure 26). One half of the cut undamaged sample (lingual) was chosen for scanning electron microscopic analysis.

All the 40 samples were now subjected to cleaning (figure 28) in a steam cleaner (figure 27) and further cleaned with distilled water in an ultrasonic cleaner (figure 29) for 10 mins to ensure the cutting procedures have not let any microscopic particles on the sample so that the SEM analysis can be done without any hindrance and the samples placed in a sterile container until SEM analysis was done.

SCANNING ELECTRON MICROSCOPIC ANALYSIS:

All the samples are now analysed using Scanning electron microscope (figure 32) with magnifications 200 X and up to 500 X when required. All the 40 sliced samples of the four groups underwent gold sputtering (figure 31) in the gold sputtering machine (figure 30) for about 15 seconds to make the samples more electro-conductive underneath the SEM. The thickness of luting cement was measured and expressed in µmicrons in various points to ensure the marginal and internal adaptation. Then all samples were loaded in the SEM machine one by one.

SEM evaluation of marginal adaptation of all the 40 samples were evaluated at two points –

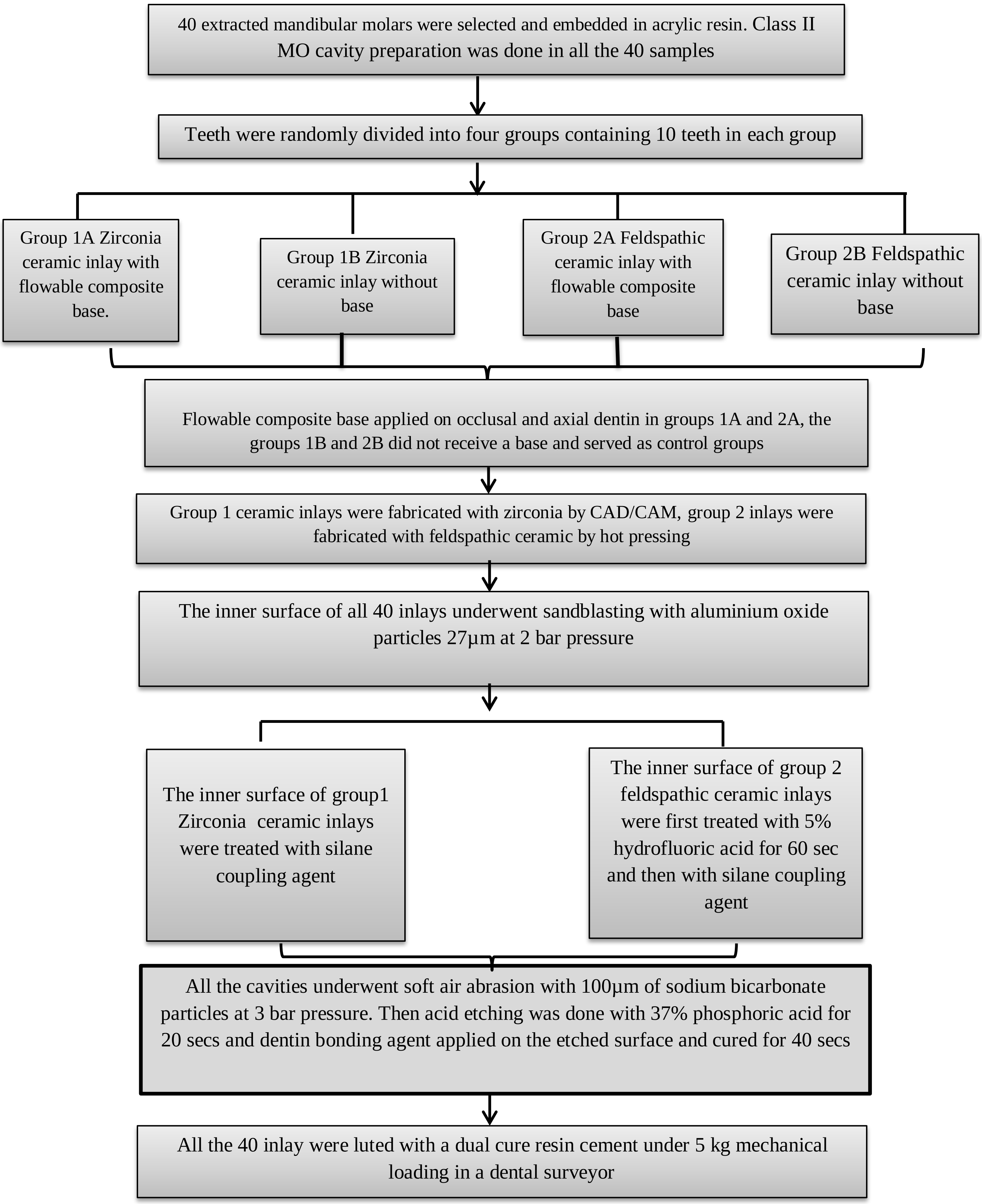
1. at the occlusal junction between the restoration and tooth interface where the luting cement thickness was measured in µm and
2. at the proximal box-cervical area junction between the restoration and the cervical dentin.

The internal adaptation of all the 40 sliced samples were evaluated by SEM at three areas namely

1. Pulpal floor and distal wall line angle and along the pulpal floor [occlusal dentin],
2. The pulpal floor and axial wall line angle and along the axial wall [axial dentin].
3. The axial wall and gingival seat line angle and along the gingival seat [cervical dentin].

The thickness of the luting cement in all the areas were measured and recorded between the restoration and tooth interface as in the Groups 1B zirconia ceramic inlay without base (figure 34) and in Group 2B feldspathic ceramic inlay without base (figure 36) whereas in the Group 1 A zirconia ceramic inlay with base (figure 33) and Group 2 A feldspathic ceramic inlay with base (figure 35) which consists of a flowable composite base, the interface between the flowable composite base and the tooth was considered as one whole interface and the amount of luting resin cement was measured from the flowable composite base to the restoration interface. All the measurements of the 40 sliced samples were then recorded and then tabulated.

METHODOLOGY- FLOWCHART



After polymerization for 24 hours, all the 40 samples were embedded in clear acrylic resin and cut mesio distally using diamond discs with a micromotor

↓

All samples underwent steam cleaning and ultrasonic cleaning for 10 mins

↓

Then the samples are subjected to SEM analysis to measure the marginal and internal adaptation of all the inlays.

Figures

FIGURE 1: TEETH SPECIMEN

FIGURE 2: MATERIALS USED FOR MOUNTING AND EMBEDDING SAMPLES

FIGURE 3: EMBEDDED SAMPLES - GROUP 1A

FIGURE 4: EMBEDDED SAMPLES - GROUP 1B

FIGURE 5: EMBEDDED SAMPLES - GROUP 2A

FIGURE 6: EMBEDDED SAMPLES - GROUP 2B

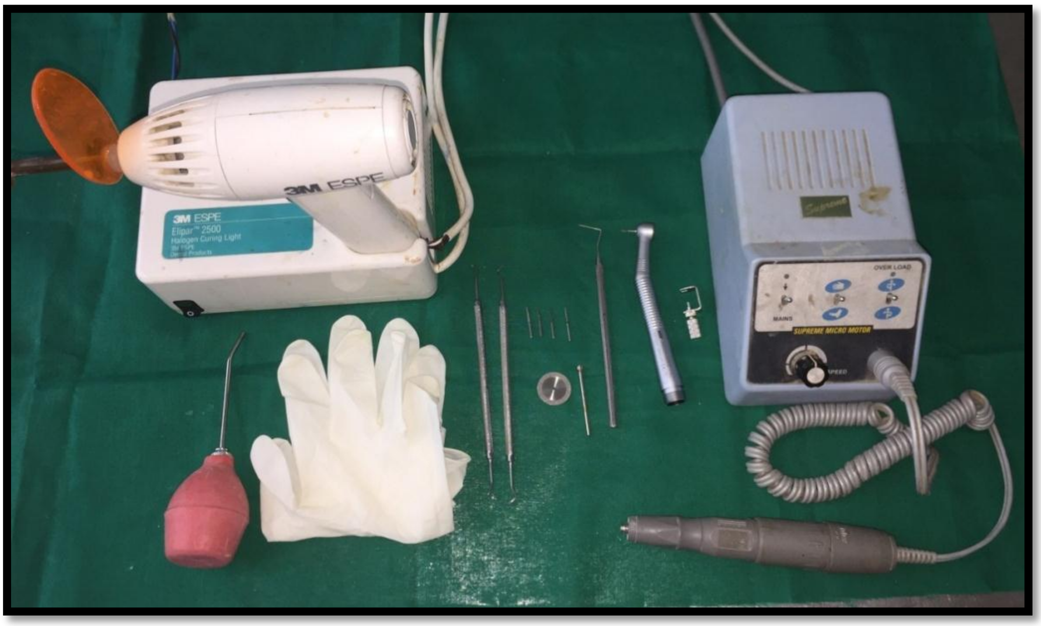


FIGURE 7: ARMAMENTARIUM

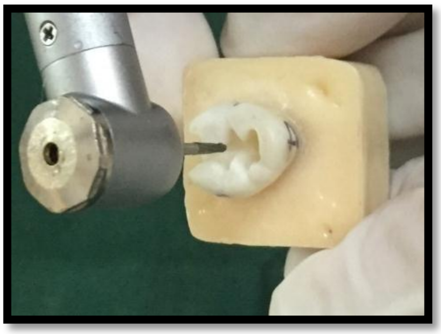


FIGURE 8 a: INLAY CAVITY PREPARATION

FIGURE 8 b – ROUNDENING OF PREPARATION OF AXIO-PULPAL LINE ANGLE WITH GMT

FIGURE 9: TETRIC-N- FLOW USED AS BASE

FIGURE 10: APPLICATION OF BASE

FIGURE 11: MATERIALS USED FOR IMPRESSION

FIGURE 12: IMPRESSION MAKING FOR GROUP 2

FIGURE 13: SCANNER MAP400

FIGURE 14: CERAMILL MACHINE

FIGURE 15: VITA CERAMIC FURNACE

FIGURE 16: MATERIALS USED FOR LUTING

FIGURE 17: PREPARED CAVITY

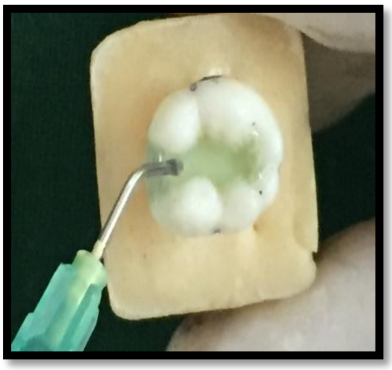


FIGURE 18: APPLICATION OF ETCHANT

FIGURE 19: APPLICATION OF BONDING AGENT

FIGURE 20: CURING

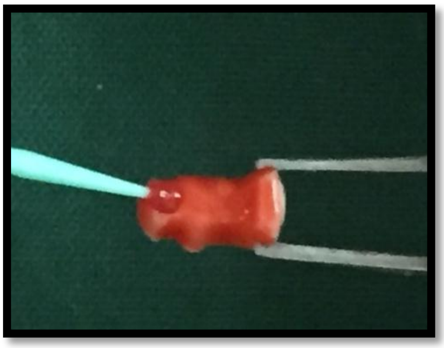


FIGURE 21: 5% HYDROFLUORIC ACID USED FOR GROUP 2

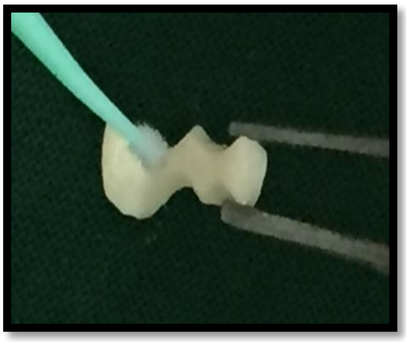


FIGURE 22: APPLICATION OF SILANE COUPLING AGENT FOR GROUP 1 AND 2

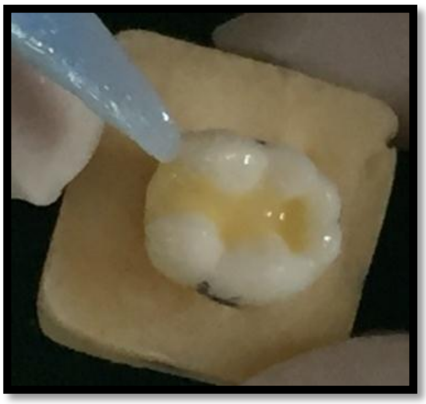


FIGURE 23: LUTING CEMENT

FIGURE 24: LUTED INLAY

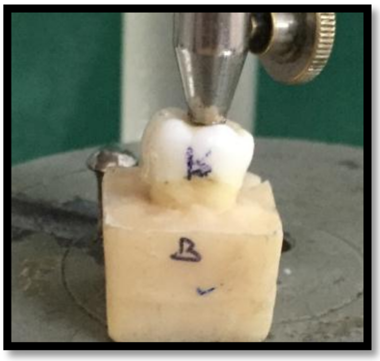


FIGURE 25: MECHANICAL LOADING

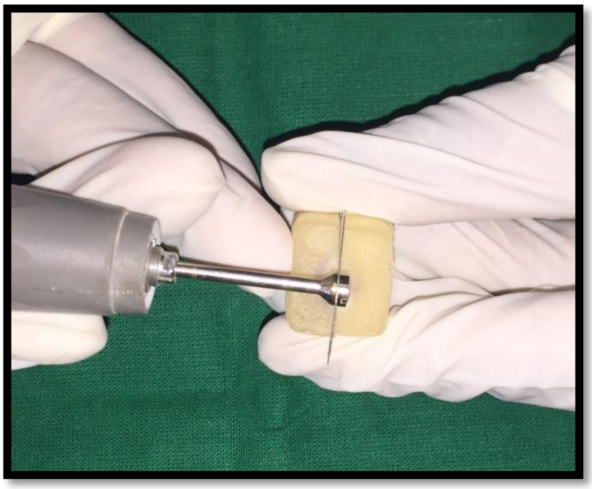


FIGURE 26: SECTIONING OF SPECIMEN

FIGURE 27: STEAM CLEANER

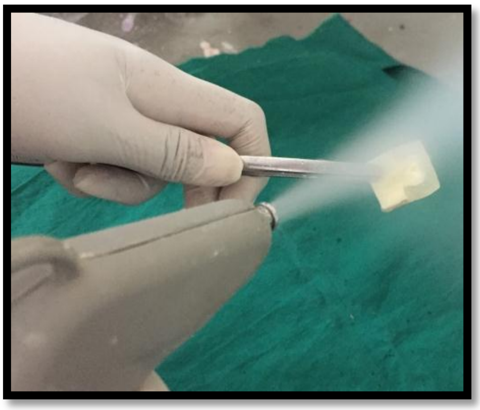


FIGURE 28: STEAM CLEANING

FIGURE 29: ULTRASONIC CLEANING

FIGURE 30: GOLD SPUTTERING MACHINE

FIGURE 31: GOLD SPUTTERED SPECIMENS

FIGURE 32: SCANNING ELETRON MICROSCOPE

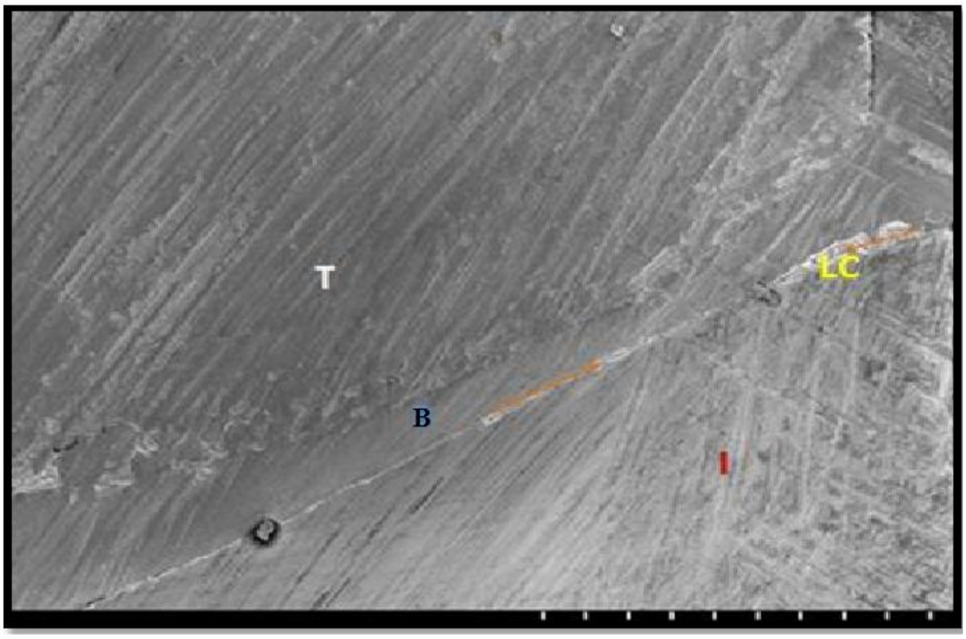


Figure: 33 – SEM image of group 1A Zirconia ceramic inlay with base
T – Tooth, B – Base, LC – Luting Cement, I – Inlay

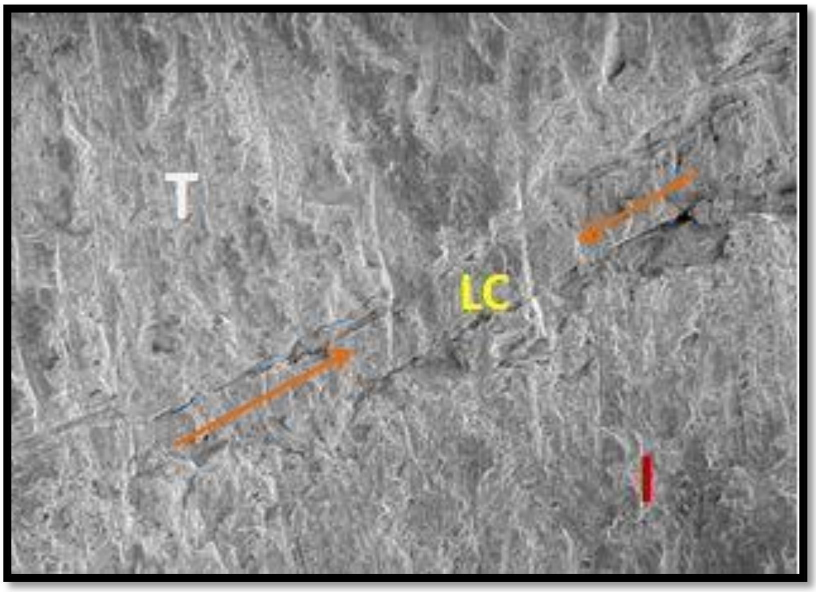


Figure 34 – SEM image of Group 1B Zirconia ceramic inlay without base

T – Tooth, LC – Luting Cement, I – Inlay

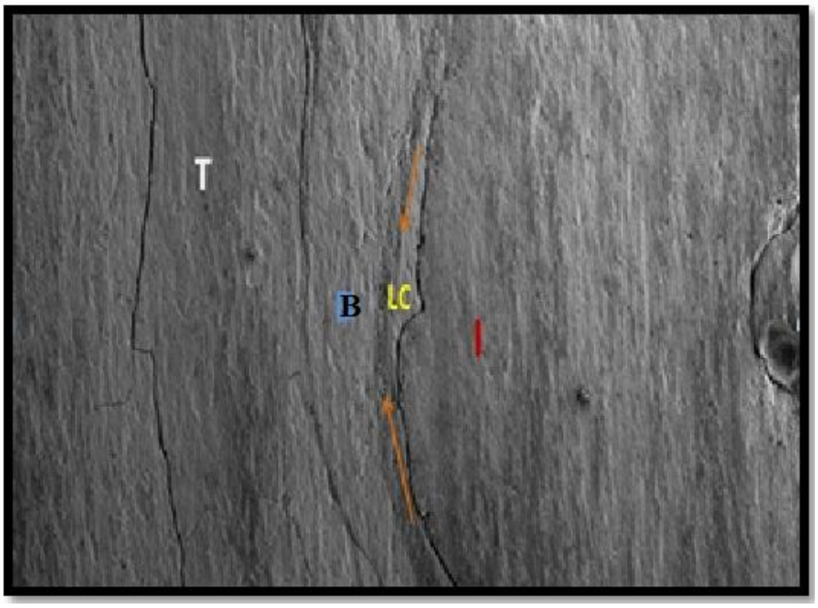


Figure 35 – SEM image of Group 2A Feldspathic ceramic inlay with base

T – Tooth, B – Base, LC – Luting Cement, I – Inlay

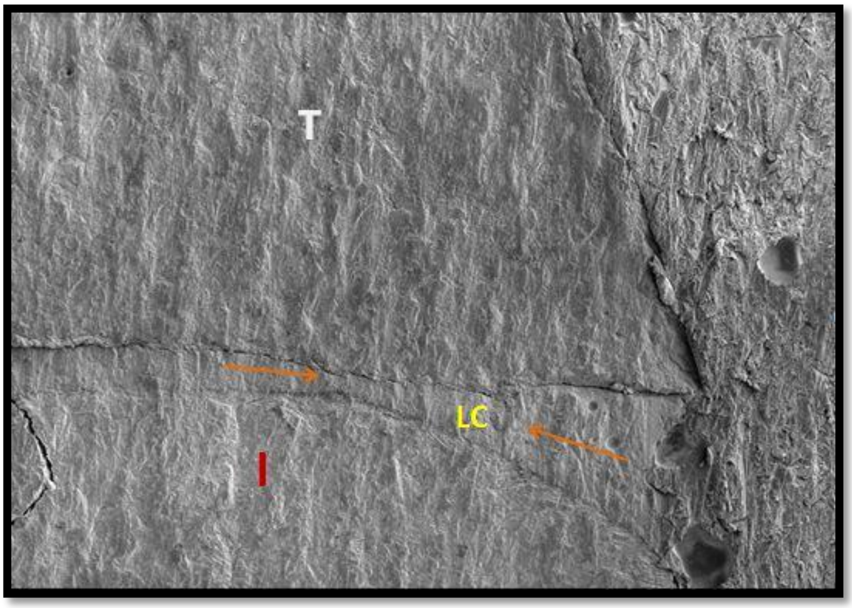


Figure 36 – SEM image of Group 2B Feldspathic ceramic inlay without base

T – Tooth, LC – Luting Cement, I – Inlay

Results

RESULTS

In this study, Scanning Electron Microscope was used to evaluate the marginal and internal adaptation of class II ceramic inlays fabricated with zirconia and feldspathic ceramic. All the values were tabulated and Statistical analysis was done using Software SPSS, Version 20.0. One-way analysis of variance (ANOVA) is used to study the overall variance within groups. It is the extension of the t-test done between groups to the situation in which more than two groups are compared simultaneously. However, it is not possible to identify the difference between the various subgroups with the help of the p values obtained from ANOVA. Therefore, a specific statistical test was used for intra group comparison. The Post hoc Tukey Test Honestly significant difference or HSD test is designed to perform a pairwise comparison of the means to identify the specific sub groups in which significant difference expression occurs.

Table 01 shows the SEM values of marginal adaptation measured in the occlusal and proximal areas in all the groups of the 40 samples expressed as µm.

Table 02 shows the SEM values of internal adaptation measured in occlusal, axial and cervical dentin area in all the groups of the 40 samples expressed as µm.

Table 03 shows the mean and standard deviation comparison of marginal adaptation in the occlusal area between all the four groups by one-way ANOVA. The mean for Group 1A (Zirconia with base) was 13.80±3.29, GROUP 1B (ZIRCONIA without base) was 16.20±3.97, GROUP 2A (Feldspathic ceramic with base) was 159.30±32.05, Group 2B (Feldspathic ceramic without base) was 163.90±35.74 and the p value was highly significant [p <0.001**]. (Graph 01)

Table 04 shows the pairwise comparison of marginal adaptation in the occlusal area between all the four groups by Post – Hoc tests – Tukey HSD where the p value between Group 1A and 1B was insignificant and Group 1A and Group 2A was highly significant [p <0.001**], Group 1A and group 2B was highly significant. The p value for Group 1B and Group 2A was highly significant and Group 1B and Group 2B was highly significant too. The p value for Group 2A and Group 2B was insignificant.

Table 05 shows the mean and standard deviation comparison of marginal adaptation in the proximal are between all the four groups by one-way ANOVA. The mean for Group 1A was 71.30±21.27, Group 1B was 76.80±15.06, Group 2A was 273.50±18.65 and Group 2B was 281.00±44.49. The p value was found to be highly significant [p <0.001**]. (Graph 02)

Table 06 shows the pairwise comparison of marginal adaptation in the proximal area between all the four groups by Post hoc tests- Tukey HSD where the p value for Group 1A and group 1B was insignificant, Group 1A and Group 2A is highly significant [$p < 0.001^{**}$], Group 1A and Group 2B was highly significant. The p value for Group 1B and Group 2A was highly significant, Group 1B and Group 2B was highly significant and Group 2A and Group 2B was insignificant.

Table 07 shows the mean and standard deviation comparison of internal adaptation in the occlusal dentin area between all the four groups by one-way ANOVA. The mean for Group 1A was 6.60±1.51, Group 1B was 15.20±1.75, Group 2A was 74.00±13.50, Group 2B was 125.00±14.34 and the p value was highly significant [$p < 0.001^{**}$]. (Graph 03)

Table 08 shows the pairwise comparison of internal adaptation in the occlusal dentin area with all the groups using Post hoc tests – Tukey HSD. The p value for Group 1A and Group 1B was insignificant, Group 1A and Group 2A was highly significant [$p < 0.001^{**}$] , Group 1A and Group 2B was highly significant. The Group 1B and Group 2A was highly significant, Group 1B and Group 2B was highly significant and Group 2A and Group 2B was highly significant.

Table 09 shows the mean and standard deviation comparison of internal adaptation in the axial dentin area between all the four groups by one-way ANOVA. The mean for Group 1A was 35.40±5.27, Group 1B was

52.10±7.55, Group 2A was 19.30±3.68, Group 2B was 56.60±7,18. The p value was highly significant [$p < 0.001^{**}$]. (Graph 04)

Table 10 shows the pairwise comparison of internal adaptation in the axial dentin area with all the groups using Post hoc tests – Tukey HSD. The p value for Group 1A and Group 1B was highly significant [$p < 0.001^{**}$], Group 1A and Group 2A was highly significant, Group 1A and Group 2B was highly significant, Group 1B and Group 2A was highly significant, Group 1B and Group 2B was insignificant and Group 2A and Group 2B was highly significant.

Table 11 shows the mean and standard deviation comparison of internal adaptation in the cervical dentin area between all the four groups by one-way ANOVA. The mean for Group 1A was 196.70±10.60, Group 1B was 199.90±28.47, Group 2A was 253.00±22.63, Group 2B was 263.00±50.78 and the p value was highly significant [$p < 0.001^{**}$]. (Graph 05)

Table 12 shows the pairwise comparison of internal adaptation in the cervical dentin area with all the groups using Post hoc tests – Tukey HSD. The p value for Group 1A and Group 1B was insignificant, Group 1A and Group 2A was highly significant [$p < 0.002^{**}$], Group 1A and Group 2B was highly significant [$p < 0.001^{**}$], Group 1B and Group 2A was highly significant [$p < 0.003^{**}$], Group 1B and Group 2B was highly significant [$p < 0.001^{**}$] and Group 2A and Group 2B was insignificant.

Tables and Graphs

TABLE 1: SEM VALUES OF MARGINAL ADAPTATION MEASURED IN OCCLUSAL AND PROXIMAL AREAS

Group	Sample	Occlusal Adaptation µm	Proximal Adaptation µm
1A	1	10	50
1A	2	11	51
1A	3	14	48
1A	4	10	53
1A	5	12	57
1A	6	16	87
1A	7	18	80
1A	8	12	98
1A	9	19	92
1A	10	16	97
1B	1	24	58
1B	2	18	84
1B	3	13	53
1B	4	17	74
1B	5	11	71
1B	6	18	63
1B	7	19	92
1B	8	15	91
1B	9	11	90
1B	10	16	92
2A	1	110	240

2A	2	153	280
2A	3	130	250
2A	4	140	280
2A	5	220	270
2A	6	200	300
2A	7	160	295
2A	8	170	280
2A	9	160	262
2A	10	150	278
2B	1	145	338
2B	2	157	320
2B	3	205	322
2B	4	100	330
2B	5	115	260
2B	6	164	240
2B	7	194	210
2B	8	185	270
2B	9	203	240
2B	10	171	280

Group 1A – Zirconia ceramic inlay with Base

Group 1B – Zirconia ceramic inlay without Base

Group 2A – Feldspathic ceramic inlay with Base

Group 2B – Feldspathic ceramic inlay without Base

TABLE 2: SEM VALUES OF INTERNAL ADAPTATION MEASURED IN OCCLUSAL, AXIAL AND CERVICAL DENTIN AREAS

Group	Sample	Occlusal Dentin µm	Axial Dentin µm	Cervical Dentin µm
1A	1	8	32	183
1A	2	7	39	176
1A	3	7	36	192
1A	4	4	39	198
1A	5	5	36	196
1A	6	9	37	198
1A	7	8	23	208
1A	8	6	41	208
1A	9	6	32	202
1A	10	6	39	206
1B	1	16	61	219
1B	2	15	63	167
1B	3	18	54	182
1B	4	17	61	243
1B	5	14	52	218
1B	6	15	48	187
1B	7	13	45	173
1B	8	14	41	164
1B	9	13	46	216
1B	10	17	50	230
2A	1	60	16	250
2A	2	80	15	230
2A	3	90	18	250
2A	4	60	22	260

2A	5	80	14	230
2A	6	70	18	270
2A	7	80	23	290
2A	8	90	22	280
2A	9	80	20	250
2A	10	50	25	220
2B	1	110	62	330
2B	2	120	63	310
2B	3	110	61	180
2B	4	140	60	190
2B	5	120	59	270
2B	6	150	57	220
2B	7	140	61	260
2B	8	130	55	300
2B	9	120	47	280
2B	10	110	41	290

Group 1A – Zirconia ceramic inlay with Base

Group 1B – Zirconia ceramic inlay without Base

Group 2A – Feldspathic ceramic inlay with Base

Group 2B – Feldspathic ceramic inlay without Base

TABLE 3: THE MEAN AND STANDARD DEVIATION COMPARISON OF MARGINAL ADAPTATION IN THE OCCLUSAL AREA BETWEEN ALL THE FOUR GROUPS BY ONE-WAY ANOVA

Groups	**Mean**	**SD**	**P value**
Zirconia ceramic inlay with Base (1A)	13.80	3.29	<0.001**
Zirconia ceramic inlay without Base (1B)	16.20	3.97	
Feldspathic ceramic inlay with Base (2A)	159.30	32.05	
Feldspathic ceramic inlay without Base (2B)	163.90	35.74	

Note - ** denotes significant at 1 level.

TABLE 4: PAIRWISE COMPARISON OF MARGINAL ADAPTATION IN THE OCCLUSAL AREA BETWEEN ALL THE FOUR GROUPS BY POST HOC TESTS - TUKEY HSD

(I) Group	(J) Group	Sig.
Zirconia ceramic inlay with Base (1A)	Zirconia ceramic inlay without Base (1B)	0.996
	Feldspathic ceramic inlay with Base (2A)	<0.001**
	Feldspathic ceramic inlay without Base (2B)	<0.001**
Zirconia ceramic inlay without Base (1B)	Feldspathic ceramic inlay with Base (2A)	<0.001**
	Feldspathic ceramic inlay without Base (2B)	<0.001**
Feldspathic with Base (2A)	Feldspathic ceramic inlay without Base (2B)	0.974

Note - ** denotes significant at 1 level

TABLE 5: THE MEAN AND STANDARD DEVIATION COMPARISON OF MARGINAL ADAPTATION IN THE PROXIMAL AREA BETWEEN ALL THE FOUR GROUPS BY ONE-WAY ANOVA

		Mean	SD	P value
Group	Zirconia ceramic inlay with Base (1A)	71.30	21.27	<0.001**
	Zirconia ceramic inlay without Base (1B)	76.80	15.06	
	Feldspathic ceramic inlay with Base (2A)	273.50	18.65	
	Feldspathic ceramic inlay without Base (2B)	281.00	44.49	

Note - ** denotes significant at 1 level.

TABLE 6: PAIRWISE COMPARISON OF MARGINAL ADAPTATION IN THE PROXIMAL AREA BETWEEN ALL THE FOUR GROUPS BY POST HOC TESTS - TUKEY HSD

(I) Group	(J) Group	Sig.
Zirconia ceramic inlay with Base (1A)	Zirconia ceramic inlay without Base (1B)	0.969
	Feldspathic ceramic inlay with Base (2A)	<0.001**
	Feldspathic without Base (2B)	<0.001**
Zirconia ceramic inlay without Base (1B)	Feldspathic ceramic inlay with Base (2A)	<0.001**
	Feldspathic ceramic inlay without Base (2B)	<0.001**
Feldspathic ceramic inlay with Base (2A)	Feldspathic ceramic inlay without Base (2B)	0.928

Note - ** denotes significant at 1 level.

TABLE 7: THE MEAN AND STANDARD DEVIATION COMPARISON OF INTERNAL ADAPTATION IN THE OCCLUSAL DENTIN AREA WITH ALL THE GROUPS USING ONE-WAY ANOVA

Group	Mean	SD	P value
Zirconia ceramic inlay with Base (1A)	6.60	1.51	<0.001**
Zirconia ceramic inlay without Base (1B)	15.20	1.75	
Feldspathic ceramic inlay with Base (2A)	74.00	13.50	
Feldspathic ceramic inlay without Base (2B)	125.00	14.34	

Note - ** denotes significant at 1 level.

TABLE 8: PAIRWISE COMPARISON OF INTERNAL ADAPTATION IN THE OCCLUSAL DENTIN AREA WITH ALL THE GROUPS USING POST HOC TESTS – TUKEY HSD

(I) Group	(J) Group	P value
Zirconia ceramic inlay with Base (1A)	Zirconia ceramic inlay without Base (1B)	0.230
	Feldspathic ceramic inlay with Base (2A)	<0.001**
	Feldspathic ceramic inlay without Base (2B)	<0.001**
Zirconia ceramic inlay without Base (1B)	Feldspathic ceramic inlay with Base (2A)	<0.001**
	Feldspathic ceramic inlay without Base (2B)	<0.001**
Feldspathic ceramic inlay with Base (2A)	Feldspathic ceramic inlay without Base (2B)	<0.001**

Note - ** denotes significant at 1 level

TABLE 9: THE MEAN AND STANDARD DEVIATION COMPARISON OF INTERNAL ADAPTATION IN THE AXIAL DENTIN AREA WITH ALL FOUR GROUPS USING ONE-WAY ANOVA

		Mean	SD	P value
Group	Zirconia ceramic inlay with Base (1A)	35.40	5.27	<0.001**
	Zirconia ceramic inlay without Base (1B)	52.10	7.55	
	Feldspathic ceramic inlay with Base (2A)	19.30	3.68	
	Feldspathic ceramic inlay without Base (2B)	56.60	7.18	

Note - ** denotes significant at 1 level

TABLE 10: PAIRWISE COMPARISON OF INTERNAL ADAPTATION IN THE AXIAL DENTIN AREA WITH ALL THE FOUR GROUPS USING POST HOC TESTS – TUKEY HSD TESTS

(I) Group	(J) Group	Sig.
Zirconia ceramic inlay with Base (1A)	Zirconia ceramic inlay without Base (1B)	<0.001**
	Feldspathic ceramic inlay with Base (2A)	<0.001**
	Feldspathic ceramic inlay without Base (2B)	<0.001**
Zirconia ceramic inlay without Base (1B)	Feldspathic ceramic inlay with Base (2A)	<0.001**
	Feldspathic ceramic inlay without Base (2B)	0.368
Feldspathic ceramic inlay with Base (2A)	Feldspathic ceramic inlay without Base (2B)	<0.001**

Note – ** denotes significant at 1 level

TABLE 11: MEAN AND STANDARD DEVIATION COMPARISON OF INTERNAL ADAPTATION IN THE CERVICAL DENTIN AREA WITH ALL THE GROUPS USING ONE-WAY ANOVA

		Mean	**SD**	**P value**
Group	Zirconia ceramic inlay with Base (1A)	196.70	10.60	<0.001**
	Zirconia ceramic inlay without Base (1B)	199.90	28.47	
	Feldspathic ceramic inlay with Base (2A)	253.00	22.63	
	Feldspathic ceramic inlay without Base (2B)	263.00	50.78	

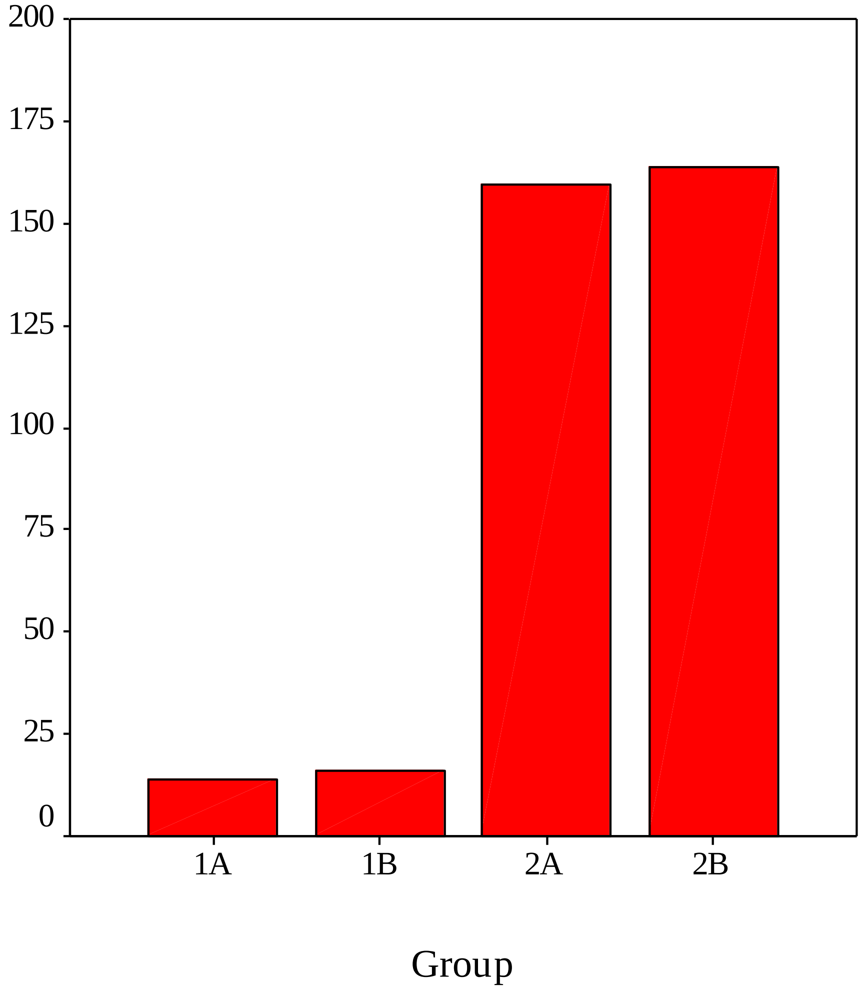
Note - ** denotes significant at 1 level.

TABLE 12: PAIRWISE COMPARISON OF INTERNAL ADAPTATION IN THE CERVICAL AREA WITH ALL THE GROUPS USING POST HOC TESTS – TUKEY HSD TESTS

(I) Group	(J) Group	Sig.
Zirconia ceramic inlay with Base (1A)	Zirconia ceramic inlay without Base (1B)	0.996
	Feldspathic ceramic inlay with Base (2A)	0.002
	Feldspathic ceramic inlay without Base (2B)	<0.001**
Zirconia ceramic inlay without Base (1B)	Feldspathic ceramic inlay with Base (2A)	0.003
	Feldspathic ceramic inlay without Base (2B)	<0.001**
Feldspathic ceramic inlay with Base (2A)	Feldspathic ceramic inlay without Base (2B)	0.894

Note - ** denotes significant at 1 level

GRAPH 1: SHOWS THE MEAN COMPARISON OF MARGINAL ADAPTATION IN THE OCCLUSAL AREA WITH ALL THE FOUR GROUPS USING ONE-WAY ANOVA ANALYSIS



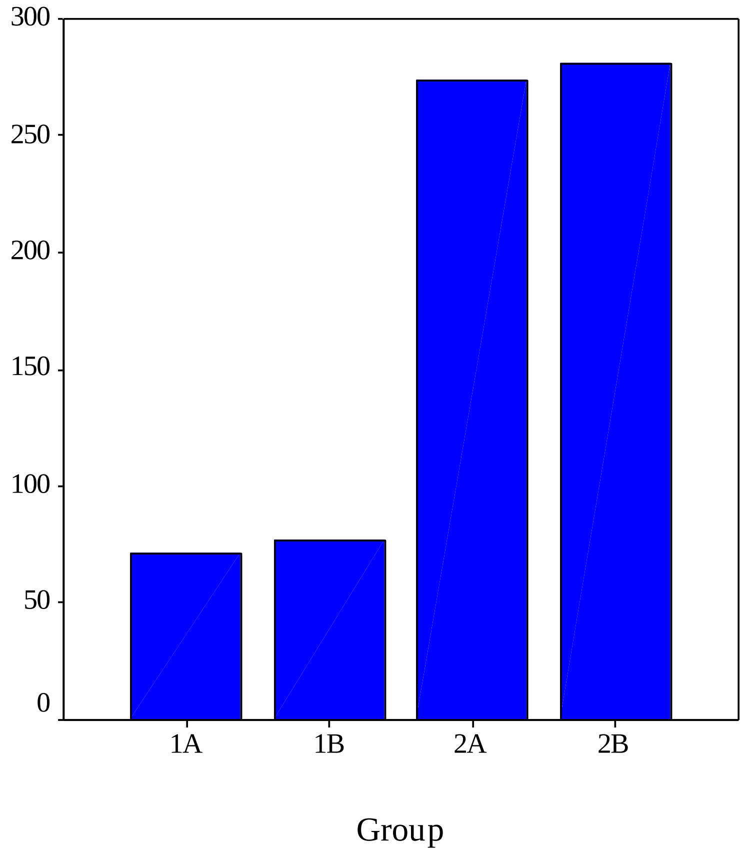
Group 1A – Zirconia inlay with Base

Group 1B – Zirconia inlay without Base

Group 2A – Feldspathic ceramic inlay with Base

Group 2B – Feldspathic ceramic inlay without Base

GRAPH 2: SHOWS THE MEAN COMPARISON OF THE MARGINAL ADAPTATION IN THE PROXIMAL AREA WITH ALL THE FOUR GROUPS USING ONE-WAY ANOVA ANALYSIS



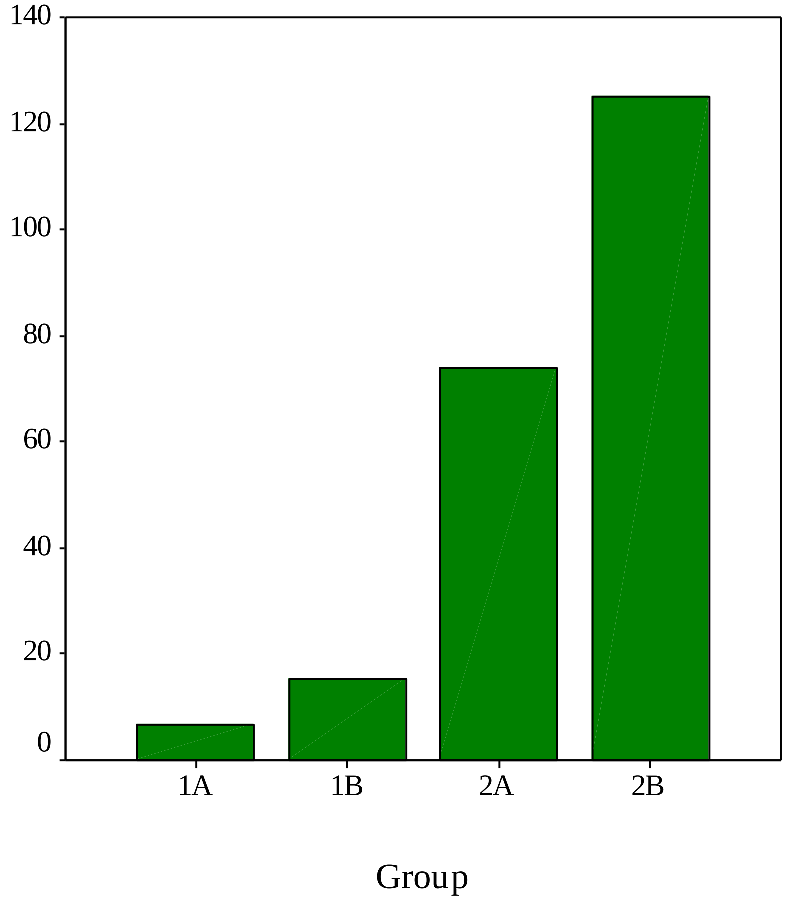
Group 1A – Zirconia inlay with Base

Group 1B – Zirconia inlay without Base

Group 2A – Feldspathic ceramic inlay with Base

Group 2B – Feldspathic ceramic inlay without Base

GRAPH 3: SHOWS THE MEAN COMPARISON OF INTERNAL ADAPTATION IN THE OCCLUSAL DENTIN AREA WITH ALL THE FOUR GROUPS USING ONE-WAY ANOVA ANALYSIS



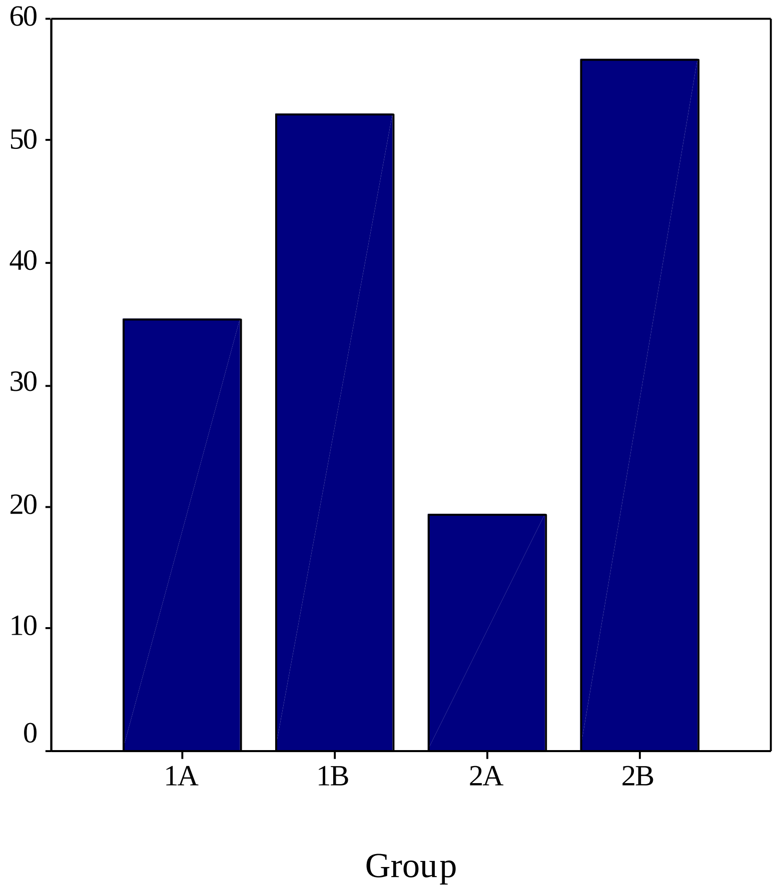
Group 1A – Zirconia inlay with Base

Group 1B – Zirconia inlay without Base

Group 2A – Feldspathic ceramic inlay with Base

Group 2B – Feldspathic ceramic inlay without Base

GRAPH 4: SHOWS THE MEAN COMPARISON OF THE INTERNAL ADAPTATION IN THE AXIAL DENTIN AREA WITH ALL THE FOUR GROUPS USING ONE-WAY ANOVA ANALYSIS



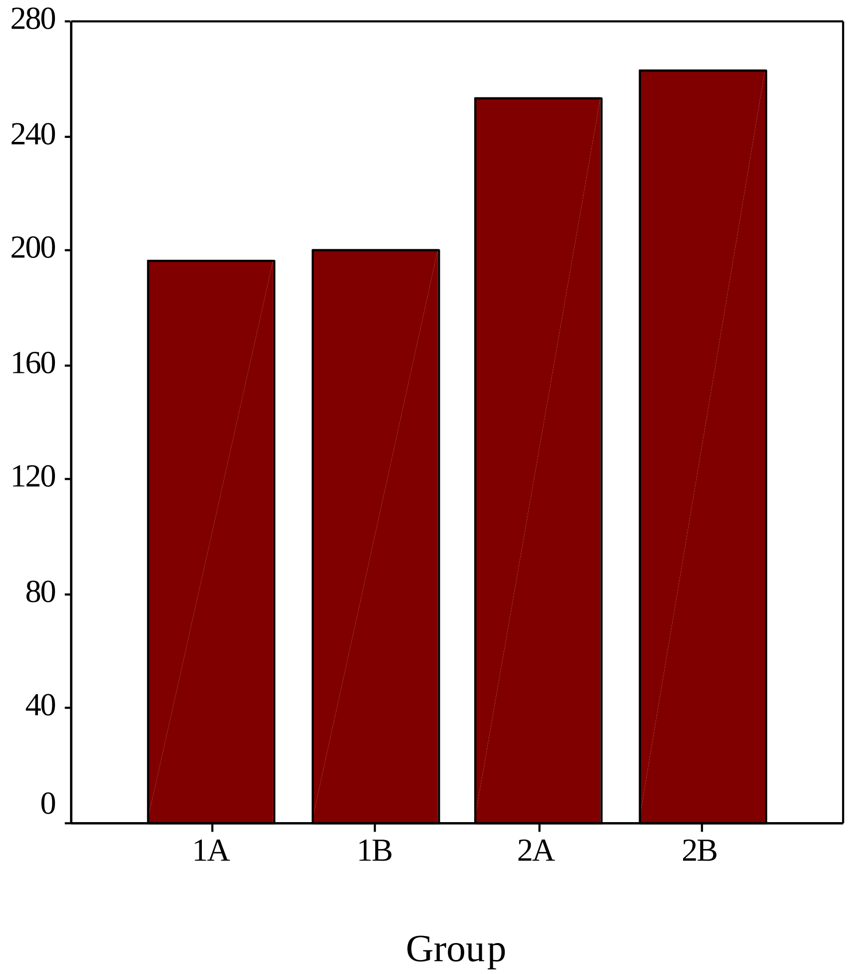
Group 1A – Zirconia inlay with Base

Group 1B – Zirconia inlay without Base

Group 2A – Feldspathic ceramic inlay with Base

Group 2B – Feldspathic ceramic inlay without Base

GRAPH 5: SHOWS THE MEAN COMPARISON OF THE INTERNAL ADAPTATION IN THE CERVICAL DENTIN AREA WITH ALL THE FOUR GROUPS USING ONE-WAY ANOVA ANALYSIS



Group 1A – Zirconia inlay with Base

Group 1B – Zirconia inlay without Base

Group 2A – Feldspathic ceramic inlay with Base

Group 2B – Feldspathic ceramic inlay without Base

Discussion

DISCUSSION

Dental restorations are given primarily to rebuild defective tooth tissues lost by dental caries, tooth wear, fractures or even pre-existing restorations.[49] The direct composites are possible restorative options when aesthetics, function and durability are primary concerns in addition to accessibility, visibility and isolation.[61] Reproduction of the occlusal morphology, proximal and intermaxillary contacts and need for a skilled operator are few predominant limiting factors of direct restorations[49] along with the combined "Negative" effect of composite polymerization shrinkage and functional stresses.[51]

On the other hand, indirect restorations such as ceramics are long lasting as they have better marginal adaptation and are more resistant to deterioration over time due to wear, fracture and discolouration. But the need of the hour is to create a strong restoration which is compatible with the mechanical, biologic and optical properties of the dental tissues which forms the basis of the Biomimetics approach (MAGNE P, BELSER U 2002) for a restoration.[49]

"Biomimetics is a concept of medical research that involves the investigation of both structures and physical functions of biological "composites" and the designing of new and improved substitutes."[39]

The chief goal of this biomimetics approach in restorative dentistry is to bring back, all the prepared tooth tissues to complete function by creating a hard tissue bond which ultimately allows functional stresses to pass through the tooth and bringing back the restoration into the final functional, biologic and aesthetic result. Meanwhile the adhesive restorative techniques targets for maximum preservation of sound tooth structure by maintaining the vitality of the teeth to be restored.[39]

Partial indirect restorations classified as inlays (without covering the cusps), onlays (covering at least 1 cusp), and overlays (covering all cusps) (Felden et al. 1998; Fuzzi and Rappelli 1998; Schulz et al. 2003) enable conservation of the remaining dental structure, promoting reinforcement of a tooth compromised by caries or fractures (Fuzzi and Rappelli 1998; Fabianelli et al. 2006; Guess et al. 2009).[44]

Earlier, the gold standard for indirect partial restorations were cast gold inlays whose longevity is an established fact. Their durability, strength, minimal wear on antagonist teeth and less corrosive properties were significant for its success.[31] Gold inlays remain a possible option for restoring teeth in the posterior aspects were strength and load bearing is crucial. Then again, the difficulties faced in manipulation, fabrication and aesthetics which becomes the foremost criteria, lead to the diminish in use of cast gold.[31]

A number of composite resin and ceramic materials are available for fabricating indirect partial restorations whose mechanical strength is crucial for the durability of the restoration in the posterior regions.[44]

Since 1980's the hot-pressed ceramics were fabricated using the lost-wax technique. They were able to press a plasticized ceramic ingot into a heated investment mould. Ceramics containing high amounts of leucite glass or optimal pressable ceramics were initially used for this process and later in 2006, lithium disilicate became the second generation of material to use this method.[26]

In the mid 1990's, the first all-ceramic product with a CAD/ CAM substructure was introduced. The core consisted of 99.9% alumina on which a feldspathic ceramic was layered. The use of CAD/CAM technology expanded machinable ceramic fabrication by allowing scanning, designing, and milling of either a full-contoured restoration or a single- or multiple-unit framework by a computer. The available materials for the CAD/CAM processing include silica-based ceramics, infiltration ceramics, lithium-disilicate ceramics, and aluminium / zirconium oxide high-performance ceramics.[26]

Zirconia has emerged as a versatile and promising material among dental ceramics due to its excellent mechanical properties owing to the transformation toughening mechanism. Zirconia (ZrO2) is a white oxide of zirconium which is a polycrystalline ceramic without a glassy phase and exists in three crystalline forms: monoclinic (m), tetragonal (t) and cubic (c). It has a flexural strength of 900–1200MPa and a compression resistance of 2000MPa with an average load-bearing capacity of 755N. They have fracture loads ranging between 706N, 2000N and 4100N and all of the studies demonstrated that in dental restorations zirconia yields higher fracture loads than alumina or even lithium disilicate. The mechanical properties are similar to that of metals and its colour to that of tooth. Hence it has been called as ‘Ceramic Steel’ by Garvie.[4]

With the addition of stabilizing oxides in concentrations less than those required for complete stabilization obtained at room temperature, zirconia can also be partially stabilized in a multiphase form, known as partially stabilized zirconia (PSZ). It consists of cubic zirconia, as the major phase, and monoclinic and tetragonal zirconia precipitates, as the minor phase.[4]

When the whole material is constituted by transformable tetragonal-zirconia grains it is called Tetragonal zirconia polycrystals (TZP). To date, Zirconia stabilized with y2O3 (yttrium – oxide) has the best properties for dental applications. It is basically a fully tetragonal fine-grained zirconia ceramic material made of 100% small metastable tetragonal grains (y-TZP) after the addition of approximately 2 to 3 mol% yttrium oxide (y2O3) as a stabilizing agent. This yttrium-Oxide Partially Stabilised Zirconia (y-PSZ) [Ceramill Amann Girrbach] was used in this study in Group 1 to fabricate inlays using CAD/CAM technology.[4]

CAD/CAM zirconia restorations are produced according to two different techniques: “soft machining” of pre-sintered blanks or “hard machining” of fully sintered blanks.[4]

Soft machining was the process used in this study to fabricate the inlays of Group 1 with yttrium-Oxide Partially Stabilised Zirconia (y-PSZ) [Ceramill Amann Girrbach] which was available as pre-sintered blanks.

The tooth sample used in this study was scanned directly, after which, a virtual, enlarged framework is designed by sophisticated computer softwares (CAD). Then, through a CAM milling procedure, a framework with enlarged, accurately controlled dimension is machined out of the blank. The sinterization of the framework is completed at high temperature. During sinterization the framework regains its proper dimensions as it undergoes a linear volume shrinkage.[4]

Today, the main classic porcelain ceramics are based on feldspar and glass or a metal oxide. Glass gives ceramics an aesthetic translucent property, while oxide ceramics provide high-strength. Feldspathic ceramics are produced in a powder based form and can be applied to many different substructure materials. These materials can also be formed into a block to be used in a milling unit or can be pressed in a mould to form a restoration. The first generation of heat-pressed dental ceramics contains leucite as reinforcing crystalline phase. The second generation is lithium disilicate-based.[19]

Feldspathic porcelain reinforced with Lithium disilicate glass-ceramics have been used in this study for fabricating inlays in Group 2 [IPS Emax Press – IVOCLAR]. Lithium disilicate glass-ceramics for all-ceramic restorations contain about 65 volume % lithium disilicate as the main crystalline phase, with about 1% porosity and have mechanical properties far superior to that of the first generation leucite glass ceramic. They also have relatively low refractive index making them translucent even with the high crystalline content in lithium-disilicate crystals.[76]

The group 2 Feldspathic ceramic inlays were fabricated by hot pressing the ceramic in layers. It involves pressure moulding and the heated ceramic ingot is pressed through a heated tube into a mould, where the ceramic form cools and hardens to the shape of the mould, which is later recovered after cooling. Hot pressing usually occurs over a 45 mins at a high temperature to produce the ceramic sub-structure. Then it is stained, glazed or coated by veneering porcelain, which results in translucent ceramic core, moderately high flexural strength, excellent fit & excellent aesthetics.[76]

In indirect restorations, the stress caused by the polymerization shrinkage is limited to the resin cement layer. The presence of a resin coating is believed to act as a layer absorbing the tensions, originated by the polymerization shrinkage of the resin cement and the stress induced by occlusal load distributed during chewing. Thus, increasing the possibility of clinical success of the restorations.[42] Hence to overcome these issues the resin coating technique (RCT) has been proposed by Satoh. M et al in 1994.[42] It consists of hybridization of the exposed dentin followed by the application of a hydrophobic monomer or a low viscosity resin, protecting the dentine exposed after the cavity preparation. A considerable reduction has been observed in the formation of microcracks at the tooth-restoration interface and an improvement of the bond strength at the interface using the Resin Coating Protocol.[42]

Furthermore, in the absence of a liner or base the removal of the temporary restoration, re-exposure and cleaning of the prepared dentin surfaces, as well as the positive pressure induced during inlay/onlay insertion, will frequently induce discomfort in patients. This demands anaesthesia which is generally not needed with lined cavities. The application of a base or liner underneath semi-direct and indirect restorations fulfils many requirements, such as reinforcing undermined cusps, filling undercuts and providing the necessary geometry for an inlay/onlay restoration. It also represents a common, non-invasive alternative to surgical crown lengthening in order to relocate cavity margins from an intra-crevicular to supra-gingival position [51] and facilitates impression technique and cementation procedures.[54] Therefore, the application of a base underneath indirect or chair-side inlays and onlays has clear technical, biological and clinical advantages over the classical protocol, which leaves dentin unsealed until the restoration cementation.[54]

The elastic modulus (E) of the Flowable composites among, other physical properties is of great importance to evaluate their potential stress-absorbing effect and tooth reinforcement effects.[54] The optimum "stress absorbing effect" is thought to be at around 7–7.5 Gpa which is about half of the elastic modulus of dentin which is 18.6 Gpa (Craig and Peyton). The Flowable composites were used due to its ease of placement and not requiring further adjustments, thus eliminating the risk for a mechanical disruption of the dentinal seal.[51]

Thus in this study a flowable composite base [TETRIC-N-FLOW - Ivoclar] was given in Group 1A (y-PSZ) on the pulpal floor and axial wall alone in the class II inlay cavity and in Group 2 A (IPS Emax Press – IVOCLAR) on the pulpal floor and axial wall alone in the class II inlay cavity.

The polymerization shrinkage of composite resins is a drawback for its use and scientific literature reports that the amount of this volumetric shrinkage is in the range of 3 to 7% of the starting mass. Polymerization shrinkage can reduce the bond strength, thus not allowing a close contact between the restorative material and the tooth structure. Hence they create gaps at the composite-tooth interface with increased chances of failure of the restoration.[38] This is one of the main causes of marginal failure and subsequent microleakage.[35] The primary concern is the seal at the interface between cementum/dentin and the composite resin, because adequate seal is critical at these margins.[35]

When applying a base or liner underneath indirect restorations, the interface quality between the resinous base and luting composite and then between the luting composite and inlay, resulting from micro-mechanical retentions or copolymerisation was crucial. Procedures such as soft air abrasion or airborne particle abrasion are used with the aim to clean the cavity and to increase micro-mechanical retention between the resinous base and the luting cement.[54] Sandblasting is a pre-treatment procedure done on the inner surface of indirect restorations which were developed to improve effectiveness and stability of bond between luting cement and restoration. It also increases the adhesive area, surface activation and silanization.[81]

Air abrasion is the pseudo-mechanical, non-rotary method of cutting and removing dental hard tissue. Studies have shown that the bonding of enamel and dentin surfaces prepared with air abrasion is much better than that with conventional carbide burs or acid etching prior to placement of luting agents.[40] With the introduction of flowable and nano-filled composites it is easier to restore cavities which do not confer with the specifications of GV Black's concepts.[30]

Common interface treatment options are grinding, abrasion with diamond rotary instruments, airborne particle abrasion with aluminum oxide, sodium bicarbonate, acid etching and combinations of any of these methods.

Preferred surface treatment methods are acid etching with hydrofluoric acid solutions (2.5% to 10%) and subsequent application of a silane coupling agent along with air borne particle abrasion. The lithium-disilicate glass-ceramic IPS Empress 2 has a high crystalline content and exhibits significantly higher bond strengths than IPS Empress. The ceramic microstructure has a significant influence on the fracture resistance of the composite-ceramic adhesion zone. Hence, a combination of airborne particle abrasion (aluminium oxide), etching with hydrofluoric acid, and application of a silane coupling agent is recommended for glass ceramics.[12]

Retention of zirconia-based ceramic restorations depends on mechanical roughening of the surface and chemical bonding with adhesive monomer in special primers or resin cements. An acidic adhesive monomer such as MDP [10-methacryloyloxydecyl dihydrogen phosphate] bonds to zirconia-based ceramics. The addition of a MDP-containing bonding/silane coupling agent to enhance bonding of resin cements has produced positive results. It was shown that particle air-abrasion, followed by the application of MDP-containing bonding/silane coupling agent, resulted in increased bond strength.[4]

Hence in this study, a soft air abrasion interface treatment was done to all the 40 teeth cavities with sodium bicarbonate 100 µm at 3 bar pressure for better micromechanical bonding to the luting cement.[41,54] Then the inner surface of all the 40 inlays were subjected to interface treatment by sandblasting with aluminium oxide 27µm at 2 bar pressure to increase the cohesion between two layers of composite.[41,51] The group 1 zirconia ceramic inlays after sandblasting with aluminium oxide underwent silanization with Monobond -S silane coupling agent containing MDP. The group 2 feldspathic ceramic inlays after sandblasting with aluminium oxide underwent etching with 5% hydrofluoric acid for 60 secs and then silanization with Monobond -S silane coupling agent.

Simon and Darnell in 2012 stated that the resin cements have the ability to bond to the tooth structure and the internal surface of the restoration.[77] Luting cements should have good compressive strength to be able to withstand masticatory forces in the mouth. As resin cements are bonded to both the tooth structure and the restoration, a high compressive strength of the cement also increases the fracture resistance of the restoration.[77] Resin cements are approximately 20 times stronger and 130 times tougher in flexure than conventional cements, which make them the material of choice in the cementation of all-ceramic restorations (Chun and White 1999).[77]

As a rule, luting cements should exhibit low film thickness. A low cement film thickness improves seating of the restoration and decreases marginal discrepancies which in turn will help reduce plaque accumulation, periodontal disease, cement dissolution, and eventual secondary caries formation. Evidence shows that a lower cement film thickness (less than 50μm) is more advantageous for all-ceramic restorations (Levine 1989).[77]

Dual Cure cements are cured by both light curing and chemical curing, hence the name "dual." These types of cements contain both a self-cured initiator (benzoyl peroxide) and a light-cured initiator (camphoroquinone). The initial set is usually achieved with light curing to quickly seal the gingival margins (Vohra et al. 2013). The self- curing component ensures that the cement will cure underneath restorations that are too thick or too opaque to allow transmission of light through it (Pegoraro et al 2007). Dual-cured resin cements although they can set through chemical reaction still require light curing to achieve a high degree of polymerization.[77]

The luting cement used in this study was a dual cure resin cement (Variolink – N – Ivoclar) and was luted in a dental surveyor under 5 kg load simulating oral masticatory load (mechanical loading).[16] According to Jorgensen's, it has already been demonstrated that marginal adaptation is not improved with a seating force excesses 5 kg.[25] White et al reported that the film thickness of resin cement was decreased when heavy forces were applied. In addition, it is suggested that the heavy force should be maintained on the restoration until the cement setting is completed.[18]

Marginal adaptation is the foremost important criteria in indirect restorations, because it influences their longevity and it is known that the cement layer is challenged by the chewing load. A suitable alternative to reduce the stress produced by the masticatory forces and also by the polymerization shrinkage of the resin cement, is the RCT [resin coating technique]. This distributes the stress that would concentrate on the cement layer to the hybridized dentin and the liner material.[42]

The marginal and internal gap between the inlay and the tooth substance can influence the longevity of the restoration. The wear, discolouration, leakage, dissolution, physio-chemical degradation of luting agent and the restorations ability to withstand loading can be affected by marginal and internal gap sizes.[59]

In this present study, the marginal and internal adaptation of class II Zirconia ceramic inlays fabricated by CAD/CAM were compared with the Class II Feldspathic ceramic inlays fabricated by hot pressing, with and without a flowable composite base. After different interface treatments, such as sandblasting and soft air abrasion were done; the inlays were luted with dual cure resin cement and evaluated with SEM. The results were recorded and tabulated. Statistically analysis for inter group evaluation was done using one-way ANOVA and Post-hoc -Tukey HSD tests.

The results of the present study established that the marginal adaptation in the occlusal and proximal areas were statistically significant with zirconia ceramic inlays fabricated by CAD/CAM than the feldspathic ceramic inlays fabricated by hot pressing. The presence or absence of a base had no major effect on the marginal adaptation of the ceramic inlays. These results were similar to the study done by Simon Addi et al in 2002[59] where they evaluated the interface gap sizes of manually and CAD/CAM manufactured ceramic inlays/onlays. He used the Decim CAD/CAM system which used yttrium-oxide-partially stabilized zirconia ceramic blocks for fabricating ceramic inlays (Denzir) and compared this with IPS Empress and Opc heat pressed ceramic systems. He measured the marginal adaptation in the occlusal, gingiva-proximal and proximal measuring points of all the 3 systems where the latter two heat pressed systems had wider gap widths than the Denzir system. Hence the Denzir CAD/CAM system had lower interface gaps in the margins occlusally and proximally.

On comparing the internal adaptation on the occlusal dentin area, the present study revealed that the groups which had the flowable composite as a base showed lesser values when compared to groups which did not receive a base immaterial of whether they were fabricated with zirconia or feldspathic ceramic inlays. The zirconia ceramic inlays had a better internal adaptation with or even without the base than the feldspathic ceramic inlays with base. Thus, indicating that the presence of a flowable composite base has better internal adaptation in the occlusal dentin area which is similar to the studies done by Maria Jose Sandoval and Giovanni Tommaso Rocca et al in 2015[54] where they measured the marginal and internal adaptation of class II CAD/CAM ceramic restorations with different resinous bases and interface treatments.[54]

Also, the study on Effect of Ceramic Thickness and Composite Bases on Stress Distribution of Inlays - A Finite Element Analysis by Letícia Brandão Durand in 2015[21] evaluated the effect of cavity depth, ceramic thickness, and resin bases with different elastic modulus on von Mises stress patterns of ceramic inlays. It was found that thicker inlays distribute stress more favourably and bases with low elastic modulus increase stress concentrations on the internal surface of the ceramic inlay. The increase of ceramic thickness tends to present more favourable stress distribution, especially when bonded directly onto the cavity without the use of supporting materials. When the use of a composite base is required, composite resin with high elastic modulus and reduced thickness should be preferred[21] similar to the protocols followed in this present study.

The internal adaptation in the axial dentin indicated that the presence of a flowable composite base proved to have a better internal fit in the axial dentin region with lesser values observed in the feldspathic ceramic inlays with base than the zirconia ceramic inlays with base followed by zirconia ceramic inlay without base and feldspathic ceramic inlays without base.

According to Tuntiprawon and Wilson,[17] all ceramic restorations with smaller gap dimensions at the axial walls and the margins demonstrated the best compressive strength[17] and the results of this study were comparable to the study done by Petra.C. Guess et al in 2014[27] where he measured the marginal and internal fit of heat pressed versus CAD/CAM fabricated all ceramic onlays after exposure to thermo-mechanical fatigue and concluded that heat pressed had better internal fit.[27]

The internal adaptation in the cervical dentin area showed that there was not much difference between the zirconia ceramic inlay group and feldspathic ceramic inlay group either with or without base. Even then the zirconia ceramic inlays had little lesser values compared to the feldspathic ceramic inlays.

Chuang et al[15] determined the influence of flowable composite linings on microleakage and internal voids in Class II composite restorations. It was found that a flowable composite lining in Class II resin filling could effectively reduce voids in the restoration, but may not necessarily improve marginal sealing.[35] Hence this study incorporated the use of a flowable composite only on the pulpal floor and axial wall and not on the cervical dentin area.

Thus, results of the present study were comparable to the one done by Sedat Guven et al in 2015.[28] It suggested that the use of adhesive bonding materials and resin composites improves the clinical success of the ceramic inlay restorations and thus significantly increases the fracture resistance. Zirconium can be used safely in inlay and onlay restorations, due to its high durability and superior detail ability.

Also, the study done by Medina et al in 2012[42] suggested the use of a RCT (Resin Coating Technique) for better marginal and internal adaptation of indirect restorations which is comparable to the results of the present study.

The interface treatments such as soft air abrasion and sandblasting helped in additional micromechanical retention in this study and no percentages of gaps were observed along the composite and ceramic interface indicating that the co-polymerisation and soft air abrasion along with sandblasting was helpful in having a stable interface. This was similar to the results obtained by Maria Jose Sandoval and Giovanni Tommaso Rocca et al in 2015 where they measured the marginal and internal adaptation of class II CAD/CAM ceramic restorations with different resinous bases and interface treatments.[54]

Thus, the present study concluded that the marginal adaptation in the occlusal and proximal areas were comparatively better in the group which fabricated inlays with zirconia using CAD/CAM than the feldspathic ceramic group where the inlay was fabricated by hot pressed ceramics. The use of flowable composites as a base underneath indirect restorations had superior internal adaptation in the zirconia ceramic inlay and feldspathic ceramic inlay groups with a flowable composite base.

The placement of base in the cervical dentin area [gingival seat] is still debatable even though many in vitro studies suggest the use of base in the cervical dentin. This may be because the increased monomer content in the flowable composites which can dissolve the base or the luting cement in oral conditions with saliva and gingival fluid contamination.[15,38]

Though, the present study used established protocols to simulate the oral conditions, the actual in vivo environment cannot be achieved in this type of experimental study. While, the cavity preparation and application of base was done according to the principles of Rocca et al 2015[52], difficulties such as isolation, salivary contamination, seepage of gingival fluids are key factors in the oral environment which cannot be simulated. Moreover, simulation of pulpal circulation and the thermomechanical loading are other limitations of the present study. Hence more long term studies are required to evaluate the marginal and internal adaptation of Class II indirect ceramic restoration in the in vivo environment.

Summary

SUMMARY

This study was performed to compare and evaluate the marginal and internal adaptation of Class II Zirconia ceramic inlays to Feldspathic ceramic inlays with and without a resin base and different interface treatments using SEM.

40 extracted human mandibular molar teeth were selected and then they were randomly divided into 4 groups of 10 teeth each per group. All the teeth underwent Class II [MO] cavity preparation. The groups were

- 1A – Zirconia ceramic inlay with a flowable composite base which is fabricated using CAD/CAM
- 1B – Zirconia ceramic inlay without a base fabricated using CAD/CAM
- 2A – Feldspathic ceramic inlay with a flowable composite base fabricated using hot pressing technique
- 2B – Feldspathic ceramic inlay without a base fabricated using hot pressing technique.

Before luting of the inlays all the cavities of 40 teeth underwent soft air abrasion and the inner surface of all the 40 inlays underwent sandblasting. Then the inlays were luted with dual cure resin cement under 5 kg mechanical load on a dental surveyor. Then the samples were cut using diamond disc and sliced mesio-distally to obtain one side of the undamaged sample.

Then SEM analysis was done for measuring the marginal adaptation in the occlusal and proximal areas and for measuring the internal adaptation in the occlusal, axial and cervical dentin areas.

All the SEM values were recorded and tabulated for statistical analysis. One-way ANOVA and Post hoc Tukey HSD tests were done to obtain the results.

Conclusion

CONCLUSION

Within the limitations of the present study, it was concluded that:

1. The marginal adaptation in the occlusal and proximal area was better with zirconia ceramic inlays irrespective of whether a base was used or not.
2. Internal adaptation in the occlusal dentin area was found to be better in the groups with base than without the base irrespective of whether the inlays were fabricated with zirconia or feldspathic ceramic.
3. Feldspathic ceramic inlay with base showed the best internal adaptation in the axial dentin area followed by zirconia inlay with base.
4. When the internal adaptation in the cervical dentin area was checked, zirconia inlays with and without base showed significantly better results than the feldspathic ceramic inlay groups with and without base.
5. Interface treatments done on the cavity with soft air abrasion and sandblasting done on the inner surface of the inlay helped in producing a continuous interface between the inlay and the tooth or the inlay and the composite base.

Hence this study established that the ceramic inlays luted in the presence of a flowable composite base had better adaptation than the inlays luted directly to the tooth. Zirconia ceramic inlays (manufactured by

CAD/CAM) with a flowable composite resin base had better marginal and internal adaptation than zirconia ceramic inlays without base and feldspathic ceramic inlays (manufactured by hot pressing) with and without a base.

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Annexure

ANNEXURE

RAGAS DENTAL COLLEGE & HOSPITAL

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TO WHOMSOEVER IT MAY CONCERN

DATE: 30/12/2016

From

The Institutional Ethics Board,

Ragas Dental College and Hospital,
Uthandi,
Chennai – 600119

The dissertation topic titled **"COMPARATIVE EVALUATION OF MARGINAL AND INTERNAL ADAPTATION OF CLASS II ZIRCONIA CERAMIC INLAYS Vs FELDSPATHIC CERAMIC INLAYS WITH AND WITHOUT A RESIN BASE AND DIFFERENT INTERFACE TREATMENTS – AN IN- VITRO SCANNING ELECTRON MICROSCOPIC STUDY"** submitted by **Dr. Sridevi Shalini Saichandran** has been approved by the Institutional Ethics Board of Ragas Dental College and Hospital.

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