COMPARING FRACTURE RESISTANCE OF ENDODONTICALLY TREATED MAXILLARY FIRST PREMOLAR RESTORED WITH LITHIUM DISILICATE ONLAYS, LITHIUM DISILICATE FULL CROWNS AND PORCELAIN FUSED METAL FULL CROWNS - AN INVITRO STUDY

Dissertation submitted to

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY

In partial fulfilment for the Degree of

MASTER OF DENTAL SURGERY

BRANCH IV

CONSERVATIVE DENTISTRY AND ENDODONTICS

2017 - 2020

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY

CHENNAI

DECLARATION BY THE CANDIDATE

I hereby declare that the dissertation titled **"COMPARING FRACTURE RESISTANCE OF ENDODONTICALLY TREATED MAXILLARY FIRST PREMOLAR RESTORED WITH LITHIUM DISILICATE ONLAYS, LITHIUM DISILICATE FULL CROWNS AND PORCELAIN FUSED METAL FULL CROWNS- AN INVITRO STUDY"**is a bonafide and genuine research work carried out by me under the guidance of **Dr. K. SENTHIL KUMAR, M.D.S,** Professor and Head, Department of Conservative Dentistry and Endodontics, Chettinad Dental College & Research Institute, Kelambakkam, Kanchipuram District.

Date :

Place : Kelambakkam

Dr. HARINI.K
Post Graduate student
Department of Conservative Dentistry and Endodontics
Chettinad Dental College & Research Institute
Kelambakkam, Kanchipuram District.

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY

CHENNAI

CERTIFICATE

This is to certify that the dissertation titled **"COMPARING FRACTURE RESISTANCE OF ENDODONTICALLY TREATED MAXILLARY FIRST PREMOLAR RESTORED WITH LITHIUM DISILICATE ONLAYS, LITHIUM DISILICATE FULL CROWNS AND PORCELAIN FUSED METAL FULL CROWNS-AN INVITRO STUDY"** is a bonafide and genuine research work done by **Dr. Harini. K** under my guidance during the study period 2017-2020. This dissertation is submitted to **THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY** in partial fulfilment for the degree of **Master of Dental Surgery in the Branch IV - CONSERVATIVE DENTISTRY AND ENDODONTICS**. It has not been submitted (partially or fully) for the award of any other degree or diploma.

Dr. P. RAJESH M.D.S., DNB, MNAMS, MFDSRCPS, (Glasgow)
Principal,
Chettinad Dental College & Research Institute,
Kelambakkam, Kanchipuram District.

Guide & Head of the Department:
Dr. K. SENTHIL KUMAR, M.D.S.,
Professor and Head,
Department of Conservative Dentistry and Endodontics
Chettinad Dental College & Research Institute,
Kelambakkam, Kanchipuram District.

Date:

Place: Kelambakkam, Kanchipuram District.

PLAGIARISM ANALYSIS REPORT

URKUND

Urkund Analysis Result

Analysed Document: plagiarism check word document.docx (D61690088)
Submitted: 12/27/2019 5:12:00 AM
Submitted By: harini.k21@gmail.com
Significance: 3 %

Sources included in the report:

file merge for plagarism.docx (D59105670)
full.docx (D34396899)
https://www.aegisdentalnetwork.com/id/2011/02/achieving-an-ideal-restorative-material
https://www.researchgate.net/publication/285652026_Fracture_resistance_of_endodontically_treated_teeth_restored_with_indirect_composite_inlay_and_onlay_restorations_-_In_vitro_study
https://www.researchgate.net/publication/7561740_Influence_of_different_posts_and_cores_on_marginal_adaptation_fracture_resistance_and_fracture_mode_of_composite_resin_crowns_on_human_mandibular_premolars_An_in_vitro_study

Instances where selected sources appear:

7

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY

CHENNAI

PLAGIARISM CERTIFICATE

This is to certify that this dissertation work titled **"COMPARING FRACTURE RESISTANCE OF ENDODONTICALLY TREATED MAXILLARY FIRST PREMOLAR RESTORED WITH LITHIUM DISILICATE ONLAYS, LITHIUM DISILICATE FULL CROWNS AND PORCELAIN FUSED METAL FULL CROWNS-AN INVITRO STUDY"** of the candidate **Dr. Harini. K** with registration number **241717751** for the award of **Master of Dental Surgery** in the branch of Conservative Dentistry and Endodontics**.** I personally verified the urkund.com website for the purpose of plagiarism check. I found that the uploaded thesis file from introduction, materials and method, results, discussion and conclusion contain **3%** of plagiarism in the dissertation.

Signature of Guide with seal

Dr. K. SENTHIL KUMAR, M.D.S.

Professor and Head,

Department of Conservative Dentistry and Endodontics,

Chettinad Dental College & Research Institute,

Kelambakkam, Kanchipuram District.

Date:

Place: Kelambakkam, Kanchipuram District

CHETTINAD ACADEMY OF RESEARCH AND EDUCATION INSTITUTIONAL HUMAN ETHICS COMMITTEE APPROVAL

Chettinad
Academy of Research & Education

Institutional Human Ethics Committee

Date: 06.02.2019

To

Dr. Harini. K,

II Year MDS Postgraduate

Department of Conservative Dentistry and Endodontics ,

Chettinad Dental College & Research Institute,

Kelambakkam.

With reference to the Proposal No. 352/IHEC/10-17 dated 23.10.2017, the investigator Dr. Harini.K has requested for the following changes in her research proposal.

Change in the title from "Comparing fracture resistance of Endodontically treated maxillary first premolar restored with Lithium disilicate Onlays, Lithium disilicate full crowns, Lithium disilicate Endocrowns - An Invitro study"to "Comparing fracture resistance of Endodontically treated maxillary first premolar restored with Lithium disilicate Onlays, Lithium disilicate full crowns, Porcelain fused metal full crowns - An Invitro Study", since the change is limited to one group.

The committee reviewed and approved the changes. She can change the title of her research proposal.

Member Secretary
IHEC
CARE

ChettinadHealthCity, Rajiv Gandhi Salai, Kelambakkam,Kancheepuram Dist. Tamil Nadu 603103.
Ph – 91(0)44 47411000 / Fax – 91(0)44 47411011

ACKNOWLEDGEMENT

First of all, I thank GOD for all the blessings he bestowed upon me and helping me in all possible ways for completing my thesis. This thesis would have not been possible without the guidance and assistance of several people. I would like to offer my sincere thanks to all of them.

I take this opportunity to thank our Principal **Dr.P.Rajesh** M.D.S**,** DNB, MNAMS, MFDSRCPS Chettinad Dental College and Research Institute for his support and guidance during my post-graduation course.

I express my heartfelt thanks to **Dr.K.Senthil Kumar,** M.D.S, Professor and Head, Department of Conservative Dentistry and Endodontics, Chettinad Dental College and Research Institute for his meticulous training, for sharing his wisdom and guiding me in all my post-graduation activities and for his constant encouragement, and support throughout the course.

I owe my gratitude to **Dr. Anupama Ramachandran,** M.D.S, Professor, Department of Conservative Dentistry and Endodontics, Chettinad Dental College and Research Institute for giving me intellectual insight on all the research work and for her constructive suggestions that helped me throughout my postgraduation studies.

I owe my sincere thanks to **Dr.K.Sadasiva,** M.D.S, Professor, Department of Conservative Dentistry and Endodontics, Chettinad Dental College and Research Institute for his constant encouragement and perseverance that guided me in the right path towards the success of my postgraduation period.

I extend my heartfelt thanks to **Dr.Manu Unnikrishnan**, M.D.S, Reader, Department of Conservative Dentistry and Endodontics, Chettinad Dental College and Research Institute for his constant support and advice.

I thank **Dr.S.R.Sreeram** M.D.S **and Dr.Honap Manjiri,** M.D.S, Senior lecturers and **Dr.Ayisha Siddiqua,** Lecturer Department of Conservative Dentistry and Endodontics, Chettinad Dental College and Research Institute for their guidance, and support throughout the course of my study.

I extend my thanks **Dr. Cyril Benedict** M.D.S for his guidance and timely help in statistical analysis.

I thank my colleagues, **Dr. Rameezuddin** and **Dr. Deepti J.V** for their co-operation and support throughout my study. I extend my thanks to my junior colleagues **Dr.Shwetha, Dr.Yashini, Dr.Revathy, Dr.Shankar, Dr.Kalai and Dr.Srividya** for their kind help and support.

I like to express my gratitude to my parents, my brother for their constant encouragement, support, and prayers throughout my course without which I would have not reached so far.

I thank my husband **Mr. Anbalagan** for being my pillar of **strength** and motivating me.

I thank my daughter **Deepthi** for her unconditional love and immense patience during the entire course which helped me in pursuing my dream.

ABSTRACT

AIM:

The aim of this invitro study is to compare the fracture resistance of endodontically treated Maxillary First Premolar restored with Lithium disilicate Onlays, Lithium disilicate full crowns and Porcelain fused metal full crowns.

MATERIALS AND METHODS:

48 freshly extracted Maxillary First Premolar samples with straight roots were used for this study. The samples were divided into four groups- **Group 1**: Control (n=12), **Group 2**: Lithium disilicate Onlays (n=12), **Group 3**: Lithium disilicate full crowns (n=12) and **Group 4**: Porcelain fused metal full crowns (n=12). All the samples except control group were subjected to root canal treatment and specimens were prepared according to the groups to receive Lithium disilicate Onlays, full crowns and Porcelain fused metal full crowns. The samples were subjected to thermocycling and fracture resistance for all the samples were tested with Universal testing machine and values recorded in Newtons.

RESULTS:

There was a statistically significant difference when Porcelain fused metal group (1588.41±593.74 N) was compared with Lithium disilicate full crowns (1030.83 ±513.49 N) and control group (1070.91± 623.34 N). Similarly, a statistically significant difference was found when Lithium disilicate Onlay (1542.50 ±283.22 N) was compared with Lithium disilicate full crown (1030.83 ±513.49 N). (P value < 0.05). But there was no significance in results when Porcelain fused metal (1588.41±593.74 N) was compared with Lithium disilicate Onlays (1542.50 ±283.22 N) (P value >0.05).

CONCLUSION:

From this study we conclude that Lithium disilicate Onlays are a suitable alternative to the Porcelain fused metal crown for restoration of endodontically treated tooth. However further in vivo studies are needed for determining the fracture resistance of Onlays with different design and luting agents.

KEYWORDS:

Restoration of Endodontically treated tooth, Partial bonded restorations, Fracture resistance, Lithium disilicate Onlays, Lithium disilicate full crowns, Porcelain fused metal full crowns.

CONTENTS

LIST OF PHOTOGRAPHS

LIST OF TABLES

LIST OF CHARTS

LIST OF ANNEXURES

LIST OF ABBREVIATIONS

ABBREVIATION	WORD EXPLANATION
PFM	Porcelain fused metal
LDS	Lithium Disilicate
NaOCl	Sodium Hypochlorite
GP	Gutta Percha points
EDTA	Ethylene Diamine Tetraacetic Acid
IDS	Immediate Dentin Sealing
GIC	Glass Ionomer Cement
PTG	Protaper Gold
UTM	Universal testing Machine
VMSA	Von Misses Stress Analysis
ANOVA	Analysis of Variance
SPSS	Statistical Package for Social Sciences

INTRODUCTION

Restoration of Endodontically treated teeth is highly important since there is loss of tooth structure due to caries, trauma, access cavity preparation, cleaning and shaping procedures[1,2]. Apart from this it has been believed that there is alteration in physiological characteristics of dentin after root canal treatment and that dentin itself becomes brittle due to loss of collagen cross-linking[1,2]. However, it was proved later that there is no change in physiological characteristics of dentin but it is the loss of structural integrity during access cavity preparation that leads to fracture of endodontically treated teeth[2,3]. In such cases the teeth need to be reinforced with proper restoration to maintain structural integrity and to restore its functions.

Various factors need to be considered when restoring an endodontically treated teeth. Factors like **Number of walls remaining[3]**- (In Mesio-occluso-distal cavity preparations where both proximal walls are involved, there is reduction in tooth stiffness about 63% rather than conservative access preparation where reduction in stiffness is only 5%), **No of cusps involved**- Involvement of more than 2 cusps causes increase in cuspal deflection causing cusp fracture and microleakage at the margins of restoration[4,5], **Condition of periodontium**- Loss of attachment has adverse effect on prognosis of the tooth inspite of proper restoration, and alveolar bone support which plays an important role in determining the success of treatment.[4,5]

Conventionally, restoration of an endodontically treated teeth is done with full coverage crowns.[5,6] The full coverage crowns are luted on a core that is attached to the root by means of a post. This kind of approach is invasive to the crown and the root since there is excess removal of sound tooth structure and loss of pericervical dentin that plays major role in distributing the stresses evenly to the surrounding tooth structures.[6] Apart from this the margins of the full coverage crowns are placed equigingivally which may contribute to plaque accumulation and caries formation.[6]

In order to overcome the disadvantages of full coverage crowns, the bonded partial coverage restorations were introduced as treatment choice.[7] The partial coverage restoration work on the concept of minimally invasive dentistry preserving sound tooth structure and restoring the defect.[7] The adhesion procedures in partial coverage restorations are not entirely related to esthetics but also involve in improving the biomechanical functioning of the teeth.[7,8] These partial coverage restorations can be placed by either direct or indirect methods.[8] The direct techniques involves fabrication of restoration by direct resin composites but this method has disadvantages like poor wear resistance, polymerisation shrinkage stress, difficult to restore forms and functions with proper contact and contours.[8] An Adhesive partial coverage indirect restoration is more favourable to use in such clinical conditions, since they do not remove excess tooth structure for retentive purpose and restore functions with a morphology driven preparation technique.[9,10]

Adhesive indirect restorations are partial coverage restorations that include inlays, Onlays, and overlays and endocrowns.[9,10] These partial coverage restorations are either made of composite or ceramic seated passively and adhesively cemented in a cavity under specific attributes. The advantage of adhesive indirect restoration is that it maintains the occlusal anatomy of the tooth, provides proper contacts and contours, prevents plaque accumulation as the margins of restorations are in self-cleansing areas, and preserve the pericervical dentin that helps in even distribution of forces throughout the tooth.[10] In addition to this, polymerisation shrinkage of indirect restorations is completed outside the oral cavity which helps them to provide good marginal seal and prevent post-operative sensitivity in vital tooth.[10]

When an option was given to choose between composites and ceramics, ceramics are the choice of material for fabrication of indirect restorations.[10,11] Ceramics aid in micromechanical adhesion to resin by etching of ceramic with Hydrofluoric acid along with application of coupling agent (Silanation). Lithium disilicate is one such ceramic material that is widely used in fabrication of indirect restorations.[10] Lithium disilicate Onlays are mainly composed of glass, with inorganic crystals added to the matrix to increase strength.[11]

Lithium disilicate is a silica-based material that contains lithium disilicate in its microstructure. The material has good optical properties, excellent translucency and high flexural strength.[11] Flexural strength is 350-450 MPa and fracture toughness is three times greater than leucite ceramics.[11] The fabrication is done by hot pressing technique -IPS Emax press or by CAD CAM system IPS Emax CAD[11]

Porcelain fused metal (PFM) is a conventionally used ceramic that is primarily used in fabrication of full crowns. PFM has unique characteristics that make it desirable for restoration of endodontically treated teeth.[12] In PFM each atom is surrounded by cloud of electrons that act as glue providing high tensile strength, fracture toughness, resistance to wear and corrosion in oral environment.[12] In addition to this, the thickness of coping material and increase in modulus of elasticity of coping material causes decreased stress development.[12] Both PFM and Lithium disilicate has unique properties. Hence a comparative study between Lithium disilicate Onlays and PFM crowns is inevitable.

Even though there are several studies that compare fracture toughness of Onlays and full crowns, none of the studies compared the fracture resistance of Lithium disilicate Onlays and full crowns with that of standard PFM crowns. Hence the aim of the study is to compare fracture resistance of Lithium disilicate Onlays and full crowns with that of PFM crowns.

AIM AND OBJECTIVES

Aim:

The aim of the study is to compare the fracture resistance of endodontically treated Maxillary First Premolar restored with Lithium disilicate Onlays, Lithium disilicate full crowns and Porcelain fused metal full crowns.

Objectives:

1. To evaluate the fracture resistance of endodontically treated Maxillary First Premolar restored with Lithium disilicate Onlays.
2. To evaluate the fracture resistance of endodontically treated Maxillary First Premolar restored with Lithium disilicate full crowns.
3. To evaluate the fracture resistance of endodontically treated Maxillary First Premolar restored with Porcelain fused metal full crowns.

Null Hypothesis:

There is no significant difference in the fracture resistance of endodontically treated Maxillary First Premolar restored with Lithium disilicate Onlays, Lithium disilicate full crowns and Porcelain fused metal full crowns.

REVIEW OF LITERATURE

Restoration of Endodontically treated teeth:

Root canal treatment started in early 18^{th} century when **F.Hoffman** used hot wires for cauterization of pulp. For treatment of the infected pulp, **Taft in 1859**[13] recommended the removal of caries and application of a substance to induce pulp healing. He used gutta-percha dissolved in chloroform or ether as a medicament to induce healing then restored the cavity with a gold inlay.

In **1869 GV Black**[14] introduced usage of crowns for restoring non-vital teeth via retentive principles. He advocated filling the root canal with gold foil and anchoring a threaded gold bolt on top of the filling, which aided in retaining a denture tooth. Thus, laying the foundation for restoration of endodontically treated teeth.[2]

In **1870 Richmond**[15] introduced post and crown technique for restoring endodontically treated teeth. Richmond crown is a crown with attached post and a porcelain facing. Even though it had various advantages like custom fitting to the root configuration, little or no stress at cervical margin, high strength, eliminates cement layer between core and crown so reduces the chances of cement failure it also had some drawbacks like it is time consuming, requires more appointments for patient, high cost, high modulus of elasticity than dentine (10 times greater than natural dentin), less retentive than parallel-sided posts, and acts as a wedge during occlusal load transfer.

Rosen and Frederick et al[16] added to the importance of restoring endodontically treated teeth with the crown. He said that nonvital teeth lose their elasticity due to decreased central blood supply and desiccation and also as a result of root canal flaring, which is necessary for gutta-percha condensation. Hence restoring a nonvital teeth with a crown is of considerable importance.

Sorensen et al in 1984[1] evaluated the effect of tooth location, coronal coverage, and intracoronal reinforcement on the success of root canal treated teeth over an observation period of 1–25 years. The results indicate that that intracoronal reinforcement (post and core) did not significantly increase the clinical success rate of endodontically treated teeth but coronal coverage significantly improved the clinical success rate of endodontically treated posterior teeth.

On the contrary Gher et al 1987[17] stated that crown restoration has been advocated as a means to strengthen a tooth after endodontic treatment, since tooth fractures are more common even after crown placement. He indicated that even though the endodontically treated teeth with complete crowns seemed to have a better prognosis crown coverage did not prevent root fracture. He said that excessive amount of tooth loss associated with crown preparation can be a reason for root fracture.

Metnik et al in 1993[18] **supported sorensons study** and said that the clinical success of maxillary and mandibular premolars and molars, when coronal coverage restorations were present increased to greater extent after a period of 10 years. This finding insists on coronal coverage of posterior teeth to prevent fracture when occlusal forces try to separate the cusp tips.

Goodacre 1994[19] et al stated that crowns generally should be used on endodontically treated posterior teeth and on anterior teeth with substantial loss of tooth structure but are not necessary on relatively sound anterior teeth. He said if the teeth have sound tooth structure not damaged by caries or trauma it can withstand normal forces of mastication.

Aquilino et al in 2002[20] did not agree with Goodacre and said that coronal coverage with full cast crown reduced the risk of tooth fracture. It was also found that endodontically treated teeth restored with crowns had a survival rate six times greater than that of teeth without crowns.

Mannocci et al[21] **in 2002 differs from aquilino by** comparing the performance between the uncrowned teeth restored with a fiber dowel and a direct composite restoration and crowned endodontically treated teeth. Clinical performance was evaluated after 3 years of service, and the results showed similar success rates. There was no report of fracture or tooth loss with fiber posts and direct composite restorations after 3 years of service and results were equivalent to full coverage metal-ceramic crowns.

Nagasiri et al in 2005[22] did a similar study on long-term survival of endodontically treated molars without crown coverage and concluded that overall survival rates of endodontically treated molars without crowns at 1year was 96%, 2 year was 88%, and 5 years was 36%, respectively. Molar teeth with sufficient amount of tooth structure remaining after root canal treatment had a survival rate of 78% at 5 years.

Tikku, Anil Chandra et al[23] **in 2010** stated that Root canal treated posterior teeth without crowns are fractured at a much higher rate than teeth restored with full cast crowns. In order to reinforce the cusps of pulpless teeth, the usage of crown that encloses the cusps to withstand the occlusal forces is highly recommended.

Porcelain fused to metal full crowns (PFM):

The preparation of teeth for crowns by rotary instrumentation is among the oldest techniques in restorative dentistry. Early crowns were cast of gold. Later restorations were veneered with tooth colored acrylic resins or cemented porcelain facings to enhance esthetics. The introduction of the porcelain fused-to-metal (PFM) crowns opened an era of widely available technology for esthetic crown construction.

In 1720 first translucent porcelain was manufactured by Europeans (Feldspar). Feldspathic porcelains were an adaptation of a European formulation containing clay, quartz, and feldspar. The Eupropean formulation was a great improvement over Chinese porcelains of the 1720s. The high firing temperatures and replacing lime (CaO2) with feldspar as a flux brought improvement.

In 1817 Antoine Plantou[24-26] introduction of individual porcelain teeth to America and fabrication of porcelain teeth was started by 1817.

In 1838 Elias Wildman[24-26] improved translucency and color of porcelain with development of vacuum firing.

Land, in 1886[24-26]**,** used a burnished platinum foil substructure and a high, controlled heat gas furnace for the first fused feldspathic porcelain crowns. In the 1950, leucite added to porcelain resulted in an increased coefficient of thermal expansion that allowed porcelain fusion to certain gold alloys for crown.

In 1956 Charles brecker[24-26] fabricated crowns by fusing porcelain to gold.

Macculloh in 1968[24-26] **first** fabricated the First fabrication of crowns with glass ceramic (leading to Dicor, Cerestore). In 1970s New techniques for fabrication of metal-ceramic crowns, were introduced and commercial porcelains developed.

Parkinson et al in1976[85] his study found that overcontoured metal ceramic crowns resulted in plaque accumulation and gingival inflammation. In his study he found that crowns contoured to excess of 0.36mm resulted in increased bleeding on probing, increased plaque index and mobility.

Frankenhauser in 1979[85] examined metal ceramic crowns after a period of three years and found that every overcontouring of 0.5mm there was increased degree of inflammation around the gingival margin. There was also an increased papillary bleeding index, mobility associated with teeth. Overcontouring of crowns limits accessibility for oral hygiene and difficulty in contouring the crowns, removal of excess cement. Overcontouring also causes surface roughness and plaque retention in cement. Minimising plaque retention is essential for survival of crowns. Crown that satisfies superior marginal fit, contour and limited surface roughness is considered ideal for restoration of endodontically treated teeth.

Land in 1980[24-26] was the first to introduce Porcelain jacket crown**.** He used a burnished platinum foil substructure and a high, controlled heat gas furnace for the first fused feldspathic porcelain crowns. By 1986 metal ceramics became the most popular restoration.

In 1989 high strength feldpathic porcelain came into existence, **In 1991** leucite reinforced porcelain (IPS Empress) was introduced. In 1993 All ceramic crowns with alumina came into existence. Zirconia products became available in 2002 with the introduction of CAD-CAM. In 2008 Lithium disilicate restorations came into existence.

A. Jokstad in 1996[27] evaluated the effect of luting cements on porcelain fused metal crowns and found that prognosis of the tooth was good whether retained by glass ionomer or zinc phosphate cement.

Nakada et al in1997[83] found that the usage of cobalt chromium alloys in patients resulted in formation of pustules in foot and palm. However, the symptoms subsided on removing the crowns. Further evidence of allergic reactions to Ni-cr and Co-cr has also been reported.

Walton in 1999[28] evaluated the clinical characteristics and outcome of metal-ceramic crowns and found that crowns on nonvital teeth in the had a significantly greater failure rate (5%) than crowns on vital teeth (1%).

Marklund et al in 2003[29] assessed the clinical survival of zirconia-based crowns (PFZ) and conventional porcelain-fused-to-metal (PFM) crowns on posterior teeth and found that Survival times and survival probabilities of posterior PFZ(Zirconia crowns) crowns did not differ from PFM crowns and were independent of type of coping system and location (molar or premolar teeth).

De becker et al in 2007[30] did a study on the survival of full crowns with or without post and concluded that no statistically significant difference was found between restorations with post and without post and concluded that the placement of post does not reinforce the tooth structure but merely acts as retention for the core.

Ozer et al in 2010[31] evaluated the long-term survival of zirconia and porcelain-fused-to-metal crowns in private practice and found that there are no differences in the clinical long-term survival between PFZ and PFM posterior crowns. The unique anatomically shaped framework of zirconia provides increased occlusal support and ensures an even thickness layer of the veneering porcelain.

According to Naumann et al[32]**, 2011** an estimated 5-year survival of metal-ceramic crowns was 95.7% but major complications with metal ceramic crowns are loss of abutment tooth vitality, abutment tooth fracture and secondary caries

Gupta et al in 2014[33] compared fracture resistance of endodontically treated Premolars restored with PFM crowns and bonded partial restorations and found that if functional cusps are intact the tooth can be restored with bonded partial restoration. However, if functional cusp is lost it has to be restored with full porcelain fused metal crowns.

Lithium disilicate full crowns:

All Ceramic crowns are replacing metals as materials of choice in dental as well as in other biomechanical prostheses. Esthetics is an important advantage of ceramic crown. The thermal conductivity is low for ceramics and also it is highly resistant to corrosion. There are no galvanic reactions for ceramics and are highly biocompatible.

Lithium disilicate (2SiO2eLi2O) dental ceramics were first introduced in **1988** for use as a heat-pressed core material marketed as IPS Empress 2 (Ivoclar Vivadent, Lichtenstein).

Guazzato et al in 2004[34] **Empress 2** was classified as a glass ceramic, a subgroup of particle-filled glasses, and contained approximately 70% crystalline lithium disilicate filler.

Vivadent Ivoclar. Scientific Documentaion IPS e.max CAD. Liechtenstein. **2005 Used** a pressure casting procedure that resulted in a material that possessed less defects and more uniform crystal distribution. The formulation IPS Emax Press was released in 2005.The introduction of Lithium disilicate led to the discontinuation of leucite reinforced ceramic in 2009.

With the advent of digital dentistry and advances in computer-aided design and computer-aided manufacturing methods, IPS e.Max CAD was introduced **in 2006** as a lithium disilicate glass-ceramic, specifically prepared **for CAD/CAM** use. The material comes prepared in a “blue state,” where it is composed primarily of lithium metasilicate (Li2SiO3), which is easier to mill and results in lower bur wear. After the milling process is completed, the material is heat treated and glazed in one step, forming the final lithium disilicate restoration.

Vivadent Ivoclar in 2009 e.Max can be used for monolithic crowns, veneers, and fixed partial dentures, not just as a framework.

Guess et al in 2010[35] suggested that threshold for bulk fracture in a monolithic lithium disilicate crown could be reached in forces as low as 1,100 to 1,200 N. One point of interest is that the 2016 manufacturer indications recommend the use of IPS e.Max CAD for minimally invasive crowns (1 mm material thickness) but this suggests a possible risk of complications when utilizing such a thin restoration. Several studies proposed that material thickness from 1.6 mm to 1.8 mm could lead to an increase in predicted failure loads from 1,400 N to over 2,000 N.

Zhao et al in 2014[36] reported in a load to-failure test of IPS e.max crowns (Lithiuim disilicte crowns) that the monolithic anatomic design shows superior fracture resistance behaviour compared with bilayered IPS e.max crowns.

According to **Irena et al in 2015**[37] all-ceramic crowns made of leucite or lithium-disilicate reinforced glass ceramics or alumina-based oxide ceramics can be recommended as an alternative treatment option to the gold standard metal ceramics. Biological outcomes of all-ceramic crowns were significantly better than the ones of metal-ceramics in anterior and posterior regions

Sulaiman et al in 2015[38] **agrees with zhao et al** on-survival rate of monolithic and bilayered lithium di silicate crowns for period of 4 years. Failure for monolithic Emax crowns was 0.91 % and 1.83% failure for layered single unit crowns. Layered single crowns fractured at approximately twice the rate of monolithic crowns, but the fracture rate was still low.

A.Pozzi et al in 2015[39] conducted a study on marginal fit of lithium di silicate crowns -Emax Press vs Emax CAD/CAM and declared that press type had less marginal gaps than CAD/CAM. No significant difference was found in the marginal fit of lithium disilicate crowns fabricated with digital impression techniques compared with those fabricated with conventional impression method. All impression techniques produced crowns with clinically acceptable marginal fit.

Belle and hofner et al 2016[40] conducted a study on fracture rates and lifetime estimations of lithium di silicate restorations and concluded that the lithium disilicate, machinable glass-ceramic e.max CAD showed significantly better performance than the leucite-based IPS Empress CAD highlighting the role of the microstructure in the fracture process.

Rauch and Reich et al in 2017[41] conducted a six-year-old study on survival rate of monolithic lithium di silicate crowns in which 87 % of crowns remained clinically acceptable without complications.

Alec Willard in 2018[42] **said that** Clinical studies of IPS e.Max CAD have been limited in scope, partially due to the limited time the material has been available on the market. Several studies have shown promising short-term and medium-term survivability for single unit crowns and initial results for implementation for inlays and onlays is also promising.

Onlays:

Onlays are partial or complete occlusal coverage restorations that can be used successfully for restoring endodontically treated teeth. In the past, Onlays were almost exclusively made of gold, but glass-ceramic materials have become widely used. Feldspathic porcelains and resin composites are also used.

Erickson in 1966[43] proposed that the porcelain-fused-to-metal restoration requires considerable reduction of tooth structure. It is known, for a metal-ceramic shoulder preparation, a facial tooth reduction of about 1.3 to 1.5mm is required. The excessive reduction of sound tooth structure was found with increase in pulpal complications. Radiographic periapical pathologies from 0.4 to 2% were found with patients having metal ceramic crowns.

Langelnd in 1970[43] **agreed with Erickson** and said that 2.9% periapical pathologies were reported with usage of full coverage crowns. About ten years later, a rate of 4% increase of periapical pathologies were detected.

Robert in 1970[44] recommended Onlay as retainers for short-span FPD in caries-resistant dentitions. In addition to facilitating superior periodontal health, onlays enable the preservation of healthy tooth structure.

Mondelli et al 1980[45] stated that the loss of tooth structure, either as a result of a carious lesion or a cavity preparation, reduces fracture resistance. When a cavity is wide bucco-lingually, it has lower fracture strength than an intact tooth. Hence the MOD preparation of Onlay proved to be beneficial in restoring tooth with large proximal caries involving the cusps since Onlay preserves sufficient amount of enamel and dentin.

Kishimoto et al in 1983[46] said that most of the teeth for Onlay restorations had previous MOD restorations that proved to be insufficient and needed replacement. The design of a MOD Onlay preparation is led by the condition of the tooth, where the isthmus usually follows caries in the central groove of the occlusal surface. Mesial or distal proximal boxes are often used to remove proximal caries.

Eakle et al in 1986[47] said that, Clinically, glass-ceramic Onlay restorations and the natural tooth cusps are susceptible to fracture under occlusal forces. Hence a thickness of the restorative material forming the Onlay should be adequate to withstand the stresses. In stress bearing areas, a minimum thickness of 1 - 2 mm has been recommended.

Banks et al in 1990[48] said that restoration fracture is not only be related to the mechanical properties of the material used.

Preparation design and restoration outline may contribute to Onlay failure. Different Onlay preparation designs have been described. On one hand, preparation designs have been centered on traditional concepts, using a restrictive retention form.

On the contrary Broderson in 1994[49] said that Onlay preparation does not rely on retention form but it is solely dependent on the adhesive cements used.

Roulet in 1997[50] stated that Onlays may be adhesively bonded to tooth structure, notably to enamel. Such restorations are considered clinically acceptable alternatives to cast gold restorations and amalgam fillings.

Brunton in 1999[51] Teeth that are restored with composite Onlay restorations showed a higher fracture resistance than those restored using a glass-ceramic. The nano-filled resin-composite contains 80 %, by weight, silica or zirconia nanoparticles within a resinous matrix. Interestingly, a major manufacturer has recently recommended that one of their resin-composite products be limited to inlays and Onlays not crowns “because crowns are debonding at a higher-than anticipated rate” (3M).

Mondelli et al in 2001[52] stated that the thickness of any Onlay restoration must be considered during tooth preparation. In stress bearing areas, a minimum thickness of 1 - 2 mm has been recommended. Occlusal reduction of cusps and pulpal floors are designed to permit 1.5 – 2.0 mm thickness. Axial reduction should have 1.0 – 1.5 mm thickness.

Vandijiken in 2001[53] **evaluated** the durability of restorations with extensive dentin/enamel-bonded posterior partial and complete ceramic coverage crowns. The partial coverage restorations showed many clinical advantages such as less destruction of healthy tissue, and avoidance of endodontic treatment and/or deep cervical placement of restoration margins.

Edelhoff D, Sorensen JA (2002)[54] **stated that** 18-22% of crowns which are placed on endodontically treated teeth are all-ceramic. The ceramic full crowns involve significant tooth reduction. If these tooth preparations are accomplished on a young person with large dental pulps, or a person with sensitive teeth, patients will need endodontic therapy. In such cases a more conservative and longer-lasting restorations could be achieved by preparing the tooth for onlay, preserving the facial and lingual tooth surfaces.

Barghi and Berry et al in 2002[55] show in their study that porcelain overlays with supragingival margins entirely on enamel that rely primarily or entirely on bonding for their retention, can provide excellent aesthetics, good function and perhaps long-term durability if properly designed, fabricated and bonded. Porcelain overlays fabricated from high leucite content porcelain, bonded to sound enamel and dentin with a dual-cure luting resin, and a fourth-generation dentinal adhesive provide satisfactory clinical results and high patient satisfaction.

Meyer et al in 2003[56] supported that direct resin based composite restorations are not ideal restorative material when posterior teeth are weakened, owing to the need for wide cavity preparations. Ceramic inlays and Onlays can be used to achieve aesthetic, durable and biologically compatible posterior restorations in such conditions.

Magne et al in 2005[57] introduced concepts of Immediate dentin sealing after tooth preparation of indirect restorations. Tooth preparation for indirect bonded partial restorations can generate significant dentin exposure. This freshly cut dentin surfaces should be sealed with a dentin bonding agent immediately after tooth preparation, before impression making. First, freshly cut dentin is a good substrate for dentin bonding. Secondly, prepolymerization of the dentin bonding agent improved bond strength. Thirdly, IDS allow for stress-free dentin bond development. Finally, IDS protect the dentin from bacterial leakage and sensitivity during the temporary restoration.

Pascal magne in 2006[58] said that indirect bonded restorations worked on principle of biomimetics to make all dental tissues work under full function as a single unit against masticatory stresses. He said cuspal coverage for endodontically treated teeth stiffen crown and provide cuspal stabilization**.**

Guess et al in 2006[59] found that all ceramic materials IPS e-max (Pressed-Lithium Disilicate) and PRO CAD (CAD/CAM made lithium disilicate), seem to be indicated as a suitable material for partial coverage restorations on molars.

Kramer et al in 2006[60] found IPS Empress Inlays and Onlays bonded with syntac classic were found to have a 92% survival rate after eight years of clinical service. He also evaluated the effect of two different adhesive resins composite combinations for luting of IPS Empress inlays. Syntac/Variolink II, IBS (3M ESPE). They concluded that no difference between the two luting systems was detectable.

Prakki et al in 2007[61] **compared** the effect of resin cement thickness on the fracture resistance of all-ceramic restorations. Cementing ceramics with resin luting agents provides a means of stress transfer from ceramic to resin cement, from resin cement to bonding agent, from bonding agent to hybrid layer, and from hybrid layer to dentin. Increasing the cement layer from 20 to 200 µm, there was a 50% reduction in strength. The authors state that the mixing procedure for a dual-cure luting material incorporates air into the bulk of the material. The incorporation of porosity in composites has been shown to reduce shrinkage stress as a consequence of increased free area inside the bulk. Therefore, this porosity could be more prominent in thick layers distributing this stress more uniformly. The resin cement film thickness did not influence the fracture resistance of 2-mm ceramic plates. When the ceramic thickness falls below about 1 mm, flexural radial cracking becomes predominant. In this case, the stiffness of the substrate, such as luting cements and tooth structure, plays a role in causing failure.

Stappert et al in 2007[62] said that both IPS e-max press and ProCad restorations can withstand loads within the range of mastication forces, both are suitable for use of posterior partial crowns. Since traditional fillings reduce tooth structure to 75%, inlays and onlays can be used as suitable alternative, as they are bonded directly onto the tooth by high strength resins, and increase the strength of a tooth by up to 75%.

Frankenburger in 2008[63] show that IPS Empress Inlays and Onlays (Leucite based), exhibited satisfactory clinical outcomes over a 12-year clinical period. They also declared that dual cure resin cements redeuced incidence of bulk fractures.

Yamanel in 2009[64] stated that the onlay design is more effective in protecting tooth structures than the inlay design.

Magne in 2010[65] said that with the development of superior CAD/CAM techniques and advanced adhesive technology, more conservative thinner restorations can also be considered. He stated that CAD/CAM composite resin for occlusal veneers in posterior tooth had significantly higher fatigue resistance when compared to ceramic occlusal veneers. When porcelain is required, IPS e.max CAD performs much better than IPS Empress CAD.

Rekow in 2011[66] said that Onlays made of modern glass-ceramics have demonstrated good fatigue resistance, enough to fulfill both the functional and esthetic requirements of the oral environment (Rekow et al. 2011).

Murgueitio R, Bernal G (2012)[67] **studied** the survival of IPS-leucite-reinforced ceramic Onlays and partial veneer crowns and concluded that thickness, vitality, location of tooth and type of dentition has a direct influence with survival rate.

Guess et al in 2013[68] said that most of failure of Onlays was due to fracture rather than caries, and debonding. Onlays with ultrathin ceramic showed significantly higher mean fracture loads compared to their standard thickness Onlays. Ceramic thickness had a strong influence on the fracture resistance of the Onlay groups.

Li ma et al in 2013[69] investigated the load bearing properties of minimal-invasive monolithic lithium disilicate and zirconia occlusal Onlay. When bonded to enamel (supported by dentin), the load-bearing capacity of lithium disilicate can approach 75% of that of zirconia, despite the flexural strength of lithium di-silicate (400 MPa) being merely 40% of zirconia (1000 MPa). When bonded to dentin (with the enamel completely removed), the load-bearing capacity of lithium disilicate is about 57% of zirconia, still significantly higher than the anticipated value based on its strength.

Ozoney et al in 2013[70] found that ceramic Onlays had 90% success rate with regard to marginal integrity over a period of 24 months. Margin integrity and discoloration are most likely influenced by the intimacy of margin fit of the ceramic restoration, and mechanical and chemical degradation of the adhesive cement. Such problems are further accentuated if there is inaccuracy in the margin fit of the ceramic restoration, or failure to seat the restoration due to the viscosity of composite cements. Further, a wider gap will increase the portion of cement that is subjected to water sorption and eventual hydrolysis and plasticing of the polymer contents.

Vohra et al in 2013[71] evaluated multiple factors which could potentially influence the resin polymerization of all ceramic bonded restorations. Ceramic restorations of 2mm thickness bonded well to enamel and dentin when luted with dual cure resin cement polymerised with LED curing light. Increasing the ceramic thickness, using opaque resin cement, decreasing the curing light intensity bonding to compromised tooth substrate (carious, sclerotic, bleached dentine) will result in an unpredictable and compromised outcome.

Ahmed Hamdy et al in 2015[72] compared fracture resistance of Lithium disilicate full crowns, inlays, Onlays and Endocrowns and found that Onlays and Endocrowns showed the highest fracture resistance respectively. They concluded that lithium disilicate Onlays are suitable material of choice for restoring molars with intact buccal and lingual walls.

Baader in 2016[73] stated that most common cause for ceramic Onlay failure is debonding which reflects failure at the cementation interface. Although the use of adhesives is commonplace in the modern dental practice, the procedure for ceramic bonding remains technique sensitive. Factors that complicate ceramic adhesion include cement manipulation and adherence to bonding protocol, moisture control and etching. This is even more important for

Onlays due to the generally less retentive preparation and the greater reliance on the adhesive bonding to retain the restoration.

Archibald et al in 2017[74] found that Onlays had greater surface roughness and survived for a period of 42 months. He also evaluated Onlays for hypersensitivity and found 90% survival. A greater chance for Onlays failure occurred for patients with parafunctional habits.

Veneziani et al in 2017[75] gave a morphology driven preparation technique for preparation of Onlays and overlays in which he gives importance to enamel quantity and thickness, minimal dentin exposure and maximum preservation of tooth structure. He also put forth newly developed indirect restorations like overlay, table tops, that can be applied for all traditional indirect restorations.

Abdou et al in 2018[76] evaluated the longevity of **ceramic** Onlays and found the various factors that influence the survival of Onlays. These include fracture, followed by debonding and caries. Loss of marginal integrity and discoloration are most common factors for failure. Longevity of Onlay can be achieved if preparation involves 2mm occlusal reduction and incorporates retentive features. Teeth that are nonvital, in a more posterior region, or teeth for patients with parafunctional habits are associated with greater ceramic failure.

Zarone et al in 2019[77] in his review stated that flexural strength of IPS Emax Press and IPS Emax CAD are similar and manufacturing process did not affect the mechanical characteristics. New technologies like Spark plasma sintering induce refinement and densification of Nano crystalline structure of lithium disilicate ceramics.

Escobar and Anil kishen et al[78] **in 2019** described a technique in which endodontic treatment and permanent restoration were completed in one appointment with CAD/CAM systems. The rapid milling time reduces waiting time and avoids need for permanent restoration.

Edelhoff et al in 2019[79] evaluated the survival rate of occlusal Onlays made with lithium disilicate and found a 100% survival rate for a period of 11 years. No secondary caries, debonding, or biological incompatibility was found and periodontal parameters were good.

MATERIALS AND METHODS

Materials:

Root Canal treatment:

- 48 freshly extracted Maxillary First Premolar
- 3% Sodium Hypochlorite solution (Septodont)
- 15% EDTA and 10% Carbamide Peroxide gel (Endoprep Rc, Anabond Stedman)
- Normal saline solution (0.9%)
- Clear acrylic resin (DPI-RR Cold cure resin)
- Aquasil light body (Dentsply)
- Gutta percha points (Dentsply)
- AH Plus sealer – (Dentsply)

Armamentarium:

- Airotor handpiece (NSK, japan)
- Stainless steel hand K-file # 10, #15, #20, #25 (Dentsply maillefer, Switzerland)
- X-smart rotary motor with handpiece (Dentsply maillefer, Switzerland)
- Protaper Gold files (Dentsply maillefer, Switzerland)
- Disposable syringe (5ml- Dispovan)(30 G sidevent needle)
- Diamond burs- BR 31, TF 12, TF 13, TF 42, TF43 (Mani)
- Light cure unit- (Dentsply)

Luting Materials:

- Etchant – 37% Phosphoric acid (Ivoclar Vivadent)
- Tetric N bond – (Ivoclar vivadent)
- Ceramic Etchant- 5 % Hydroflouric acid (Ivoclar vivadent)
- Monobond N (Ivoclar Vivadent)
- Multilink Primer A and B (Ivoclar vivadent)
- Multilink N Self cure Resin cement (Ivoclar vivadent)
- Type I GlC – (GC Japan)

Ceramic Materials:

- Porcelain fused metal ceramic (PFM) – VITA (Ivoclar vivadent)-A3 shade
- Lithium disilicate (LDS) -IPS Emax Press- (Ivoclar vivadent)-A3 shade.

Equipment Used:

- Thermocycling Unit
- Universal testing Machine (UTM) (M 100) (FSA)

Methodology

Selection of Teeth:

48 freshly extracted sound Maxillary First Premolar with two roots, without any caries, cracks or previous restoration and those extracted for orthodontic purposes were selected for the study. The teeth were examined previously in a stereomicroscope for presence of any pre-existing defects.

Criteria for Selection of Teeth:

Inclusion Criteria:

Intact Maxillary First Premolars with two individual roots extracted for orthodontic purposes.

1. Free of caries
2. Free of cracks
3. Free of restorations
4. Free of root curvatures

Exclusion Criteria:

1. Calcified canals
2. Root with curvatures
3. Tooth with cracks
4. Tooth with caries or restoration

Preparation of Specimen:

Teeth Selection:

Forty-Eight freshly extracted Maxillary First Premolars were selected according to the inclusion criteria. The patients were informed that their tooth will be used for study purposes and informed consent obtained from each patient. The teeth were cleaned for removal of blood, any attached soft tissue, calculus and examined under microscope for presence of cracks. Those with cracks were rejected and teeth free of cracks were selected for study. The teeth were then stored in distilled water to maintain physiologic characteristics and were removed only during testing procedures.

Specimen Preparation:

The Teeth were randomly divided into four groups: (n=12)

Group 1: Control Group (N= 12); (No experiment done)

Group 2: Lithium Disilicate Onlays (N=12);

Group 3: Lithium Disilicate Full crowns (N=12);

Group 4: Porcelain fused to metal crowns (N=12);

The specimen of group 2, 3 and 4 were subjected to root canal treatment. Access cavities were prepared according to standardised form using round bur (BR 31), straight line access achieved and pulp extripated. Apical enlargement was done upto 25 k file and biomechanical preparation was done by crown down technique using Protaper gold files (Dentsply) (Sx, S1, S2, F1 and F2). Obturation was done by Cold lateral condensation technique with Gutta percha using AH Plus Endodontic sealer. Access cavities were restored with composite restoration (Tetric N Ceram, Ivoclar Vivadent) to achieve optimum coronal seal.

All the teeth were surrounded by thin aluminium foil and then placed in a self-curing acrylic block 2mm below the cementoenamel junction. Once the acrylic resin is set the samples are removed. Polyvinyl siloxane light body (Aquasil Light body Dentsply) was injected into acrylic mould to simulate periodontal ligament and tooth samples were inserted back into mould.

Preparation Design:

Group 2 (Onlay Tooth preparation):

Mesio-Occluso Distal cavities were prepared on all teeth under group 2 with cavity width ½ of intercuspal distance, proximal boxes 4mm deep, and margins of boxes placed 2mm above the CEJ. Occlusal reduction 2mm, and occluso-gingival height of both cusps at 2mm, width of shoulder kept at 1.5mm.

Immediate Dentin Sealing:

After tooth preparation for Onlays the samples were subjected to immediate dentin sealing. The tooth samples were etched with 37% phosphoric acid for 30 seconds and rinsed with water. The samples were air dried and a coat of adhesive (Tetric N Bond) was applied to seal the dentin. The adhesive is then light cured for 20 seconds.[57]

Group 3 and 4 (Tooth preparation for full crowns):

The samples under group 3 and 4 were prepared to receive full coverage crowns. Occlusal reduction 2mm for both cusps, 6-degree taper given on the proximal walls, Shoulder finish line of widths 1.5 mm placed 0.5mm above the CEJ.

Restoration fabrication:

Impression of samples under groups 2, 3 and 4 were taken by Polyvinyl siloxane impression material (Aquasil, Dentsply) and master dies fabricated with type IV dental stone. For Group 4 (PFM) the metal copings were prepared by pattern wax and casted with nonprecious cobalt-chromium base metal alloy (d. SIGN 30, Ivoclar-Vivadent). Ceramic (VITA, Ivoclar-Vivadent) was later used to veneer the copings, using a ceramic furnace (Vita Vacumat, Ivoclar-Vivadent). The restorations were then fitted, finished and polished.

For Group 2 and 3 ceramic ingots (IPS EMAX Press-A3 Shade-Ivoclar vivadent) were pressed into refractory mould made by lost wax technique. After pressing, restorations were recovered and final finishing polishing and glazing procedures carried out.

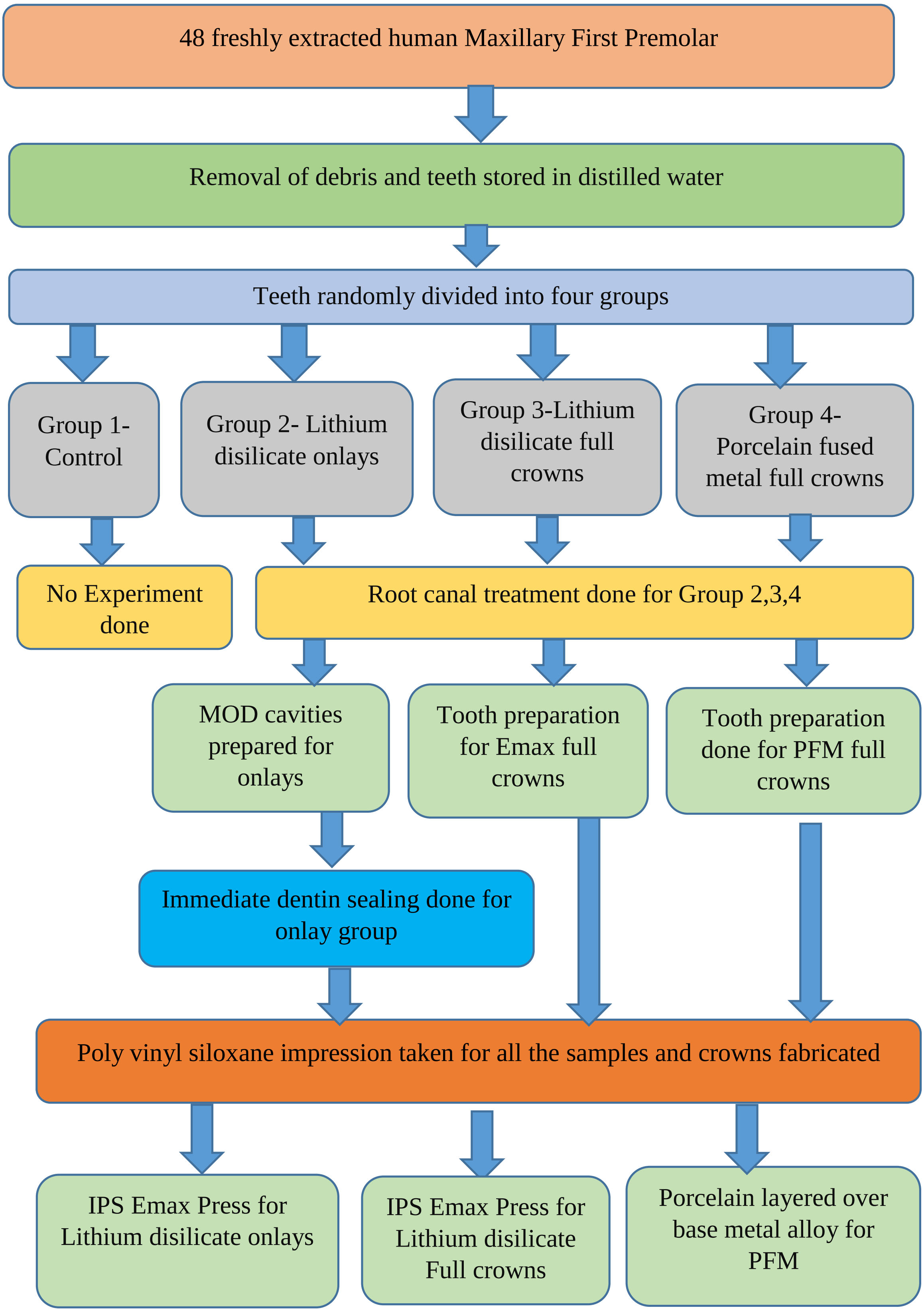
Cementation Techniques:

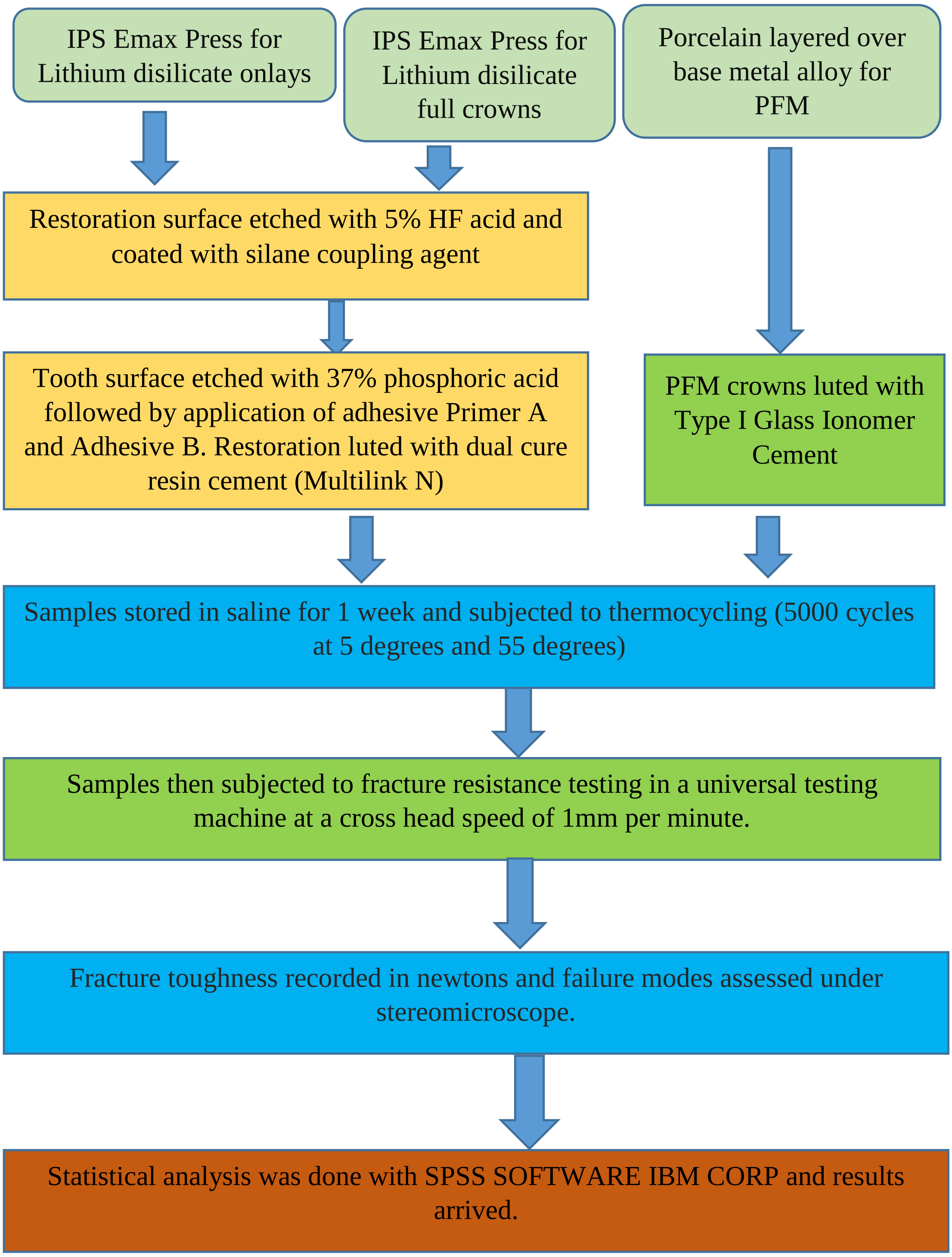
For Group 2 and group 3 the surfaces of the teeth were etched with 37 % phosphoric acid for 20 seconds and then washed followed by application of bonding adhesive (Multilink primer A and Adhesive B).

The restorations are treated with 5% hydrofluoric acid washed for 20sec, dried followed by application of silane coupling agent (Monobond N). The restorations are then luted to teeth with self-cure resin cement (Multilink N Ivoclar vivadent).

For Group 4 the teeth were rinsed with pumice washed dried and luted with Type 1 Glass Ionomer Cement (GC Japan). Excess cement removed with scaler after setting of cement. The samples were stored in normal saline solution for 1 week and subjected to thermocycling.

PROCEDURAL FLOW CHART FOR SPECIMEN PREPARATION




IPS Emax Press for Lithium disilicate onlays
IPS Emax Press for Lithium disilicate full crowns
Porcelain layered over base metal alloy for PFM
Restoration surface etched with 5% HF acid and coated with silane coupling agent
Tooth surface etched with 37% phosphoric acid followed by application of adhesive Primer A and Adhesive B. Restoration luted with dual cure resin cement (Multilink N)
PFM crowns luted with Type I Glass Ionomer Cement
Samples stored in saline for 1 week and subjected to thermocycling (5000 cycles at 5 degrees and 55 degrees)
Samples then subjected to fracture resistance testing in a universal testing machine at a cross head speed of 1mm per minute.
Fracture toughness recorded in newtons and failure modes assessed under stereomicroscope.
Statistical analysis was done with SPSS SOFTWARE IBM CORP and results arrived.

Testing

Thermocycling:

All the samples were subjected to aging by means of thermocycling. The samples are placed in water bath at 5 degree and 55 degree (Dwell time 20 sec in each water bath and transfer time 5 sec) for a period of 5000 cycles and then stored in distilled water for 7 days at room temperature.

Fracture Toughness:

The samples are then subjected to fracture toughness in a Universal testing machine (M 100- FSA). Samples placed in gripping device and controlled load was applied using a steel rod of diameter 0.5mm perpendicular to long axis of the tooth. Crosshead speed was 1mm/min. All samples were loaded until fracture and loads were recorded in Newtons (N). Failure pattern of samples were examined using stereomicroscope 20x.

Analysis of Failure Pattern:

Score 1: Minimal fracture of crown

Score 2: Less than ½ of crown is lost.

Score 3: Crown fracture through midline.

Score 4: More than ½ of crown is lost.

Score 5: Severe fracture of crown or tooth

Statistical Analysis:

Data were analysed with One-way ANOVA and a statistically significant difference was found between groups. (P value < 0.05). Comparison between groups was done by Post-hoc test. Statistical Analysis was done with SPSS version 22(IBM corp).

Fig 1: Total no of Samples (48)

Fig 2 a: Root canal preparation

Fig 2 b: Obturation

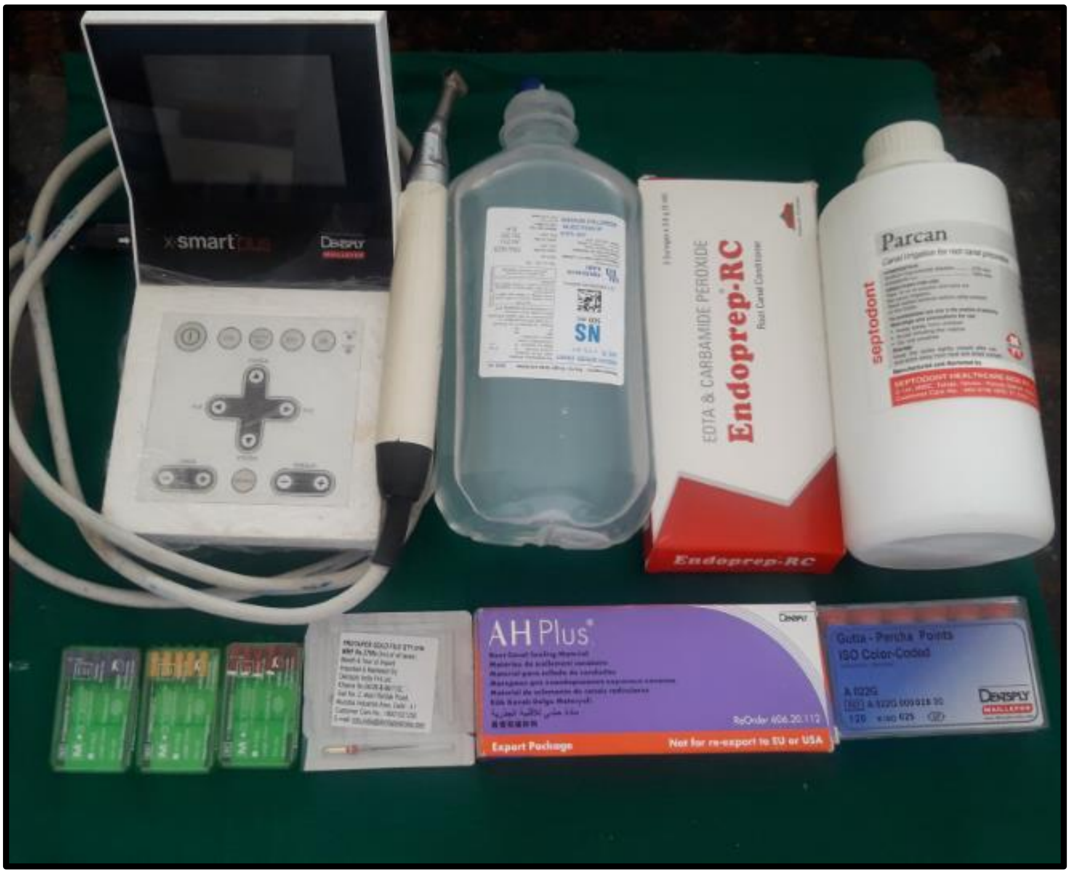


Fig 3: Materials used for Root canal preparation:

Fig 4: Tooth preparation of samples:

Fig 5: Samples after Crown fabrication

Fig 6a: Luting Materials

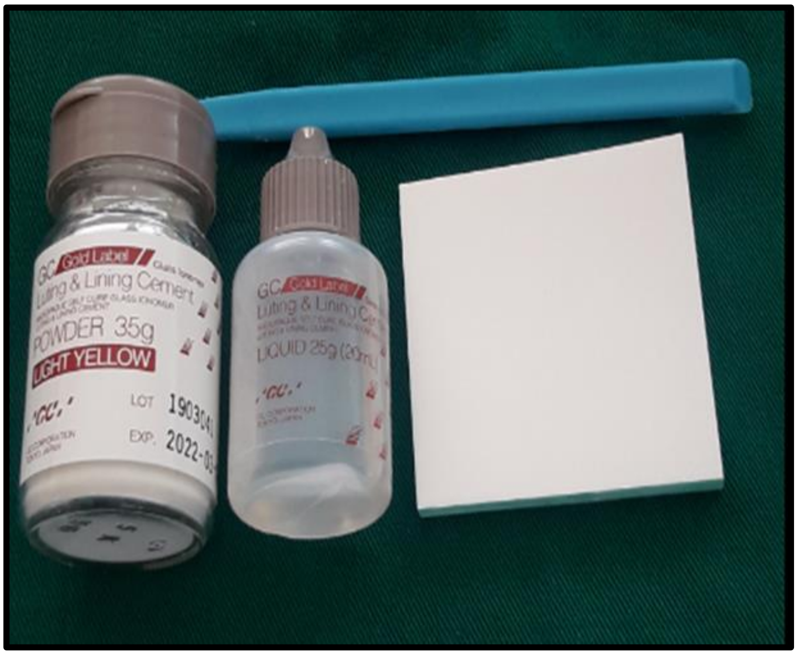


Fig 6b: Luting Materials

Fig 7: Luting of Lithium disilicate Onlays:

Fig 7 a: Etching restoration surface with 5 % HF acid and etching tooth with 37% Phosphoric acid:

Fig 7 b: Application of Silane coupling agent:

Fig 7 c: Luting with resin cement following application of Primer A & B and light cured;

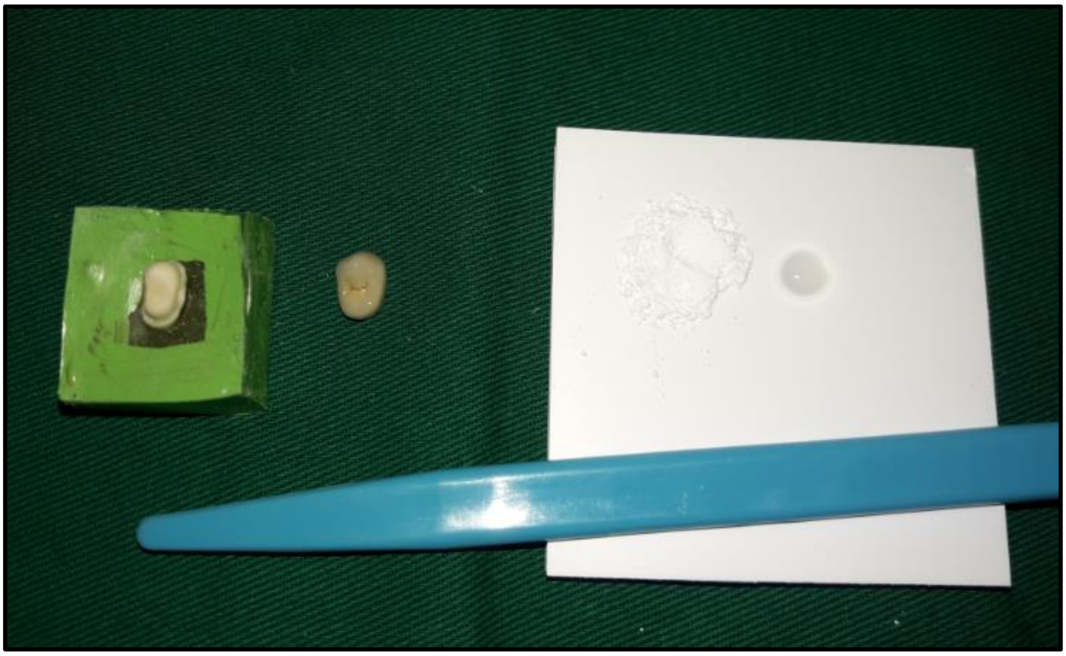


Fig 8: Luting of PFM crowns:

Fig 9: Samples after luting:

Fig 9a: Samples after luting

Fig 10: Fracture toughness testing

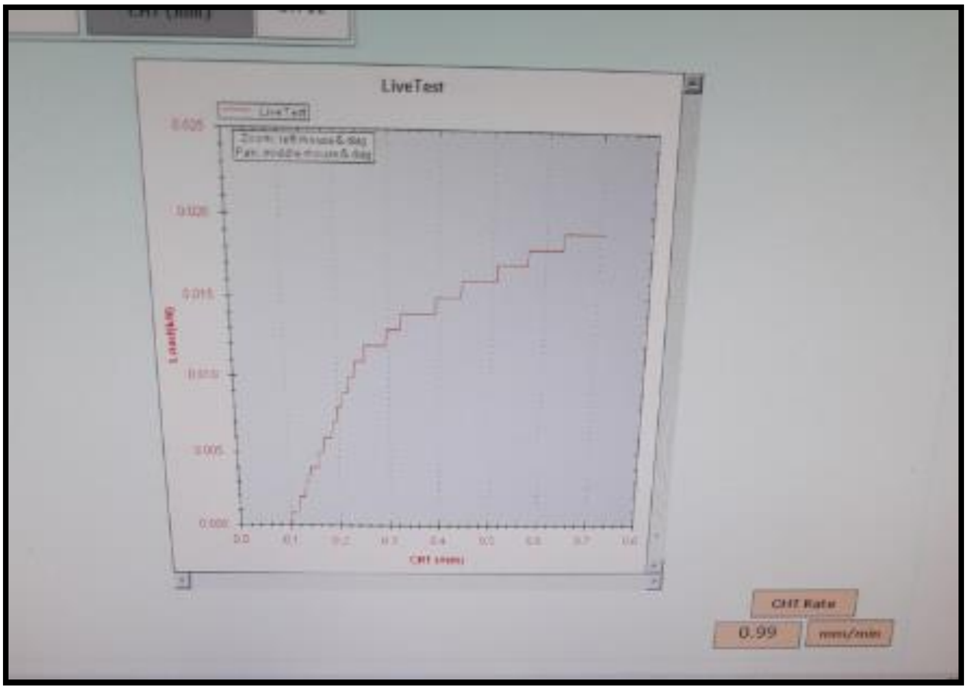


Fig 11: Determination of fracture strength using Universal Testing Machine:

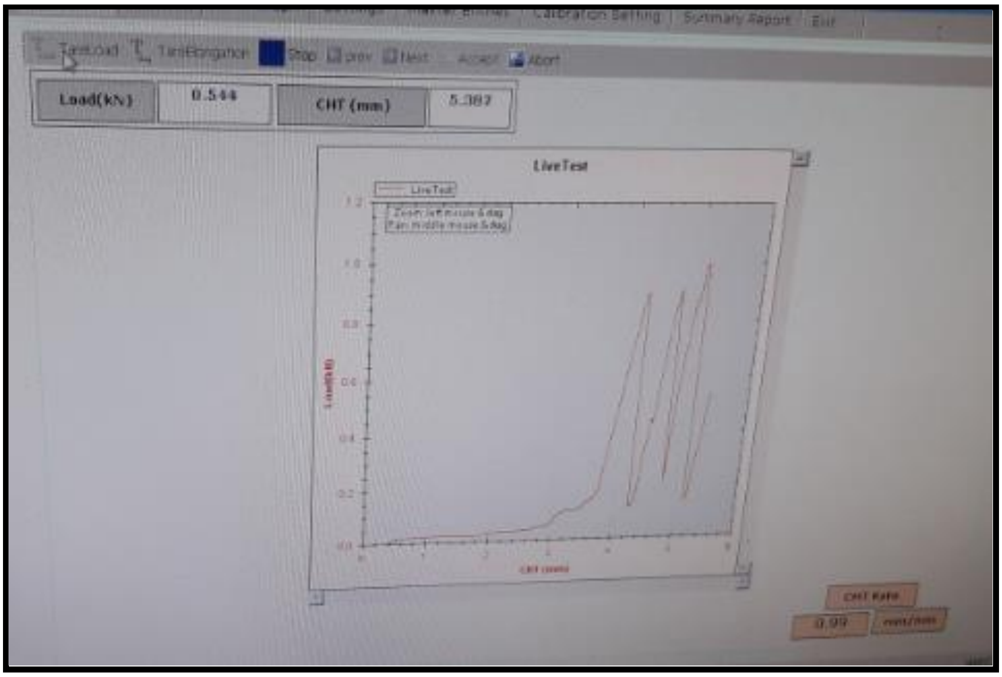
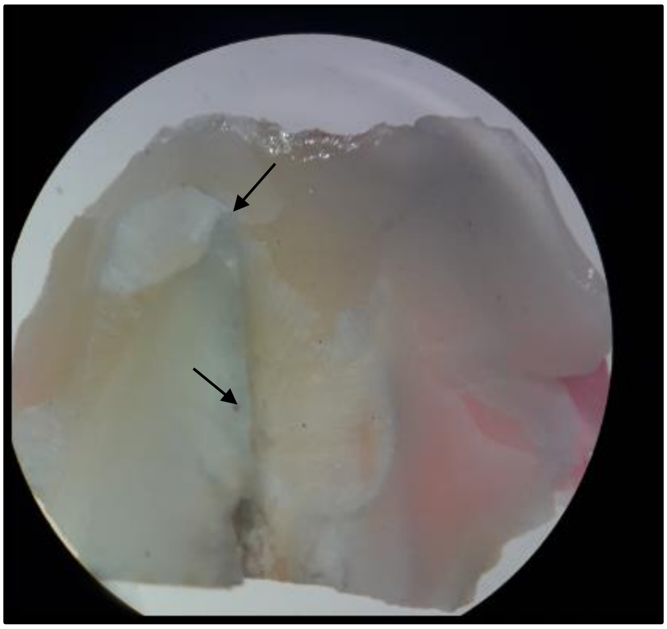


Fig 11a: Peak values indicating fracture of crowns:

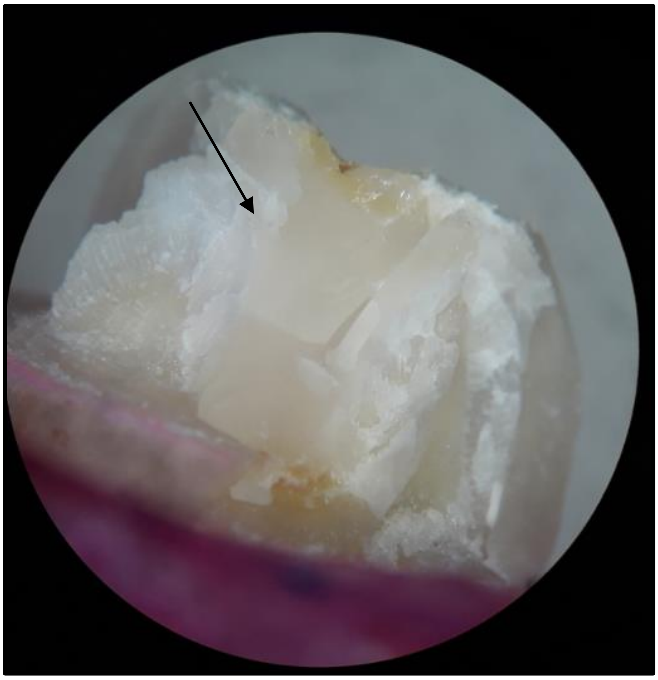
Fig 12: Samples after fracture testing

Fig 12a: Samples after fracture testing:

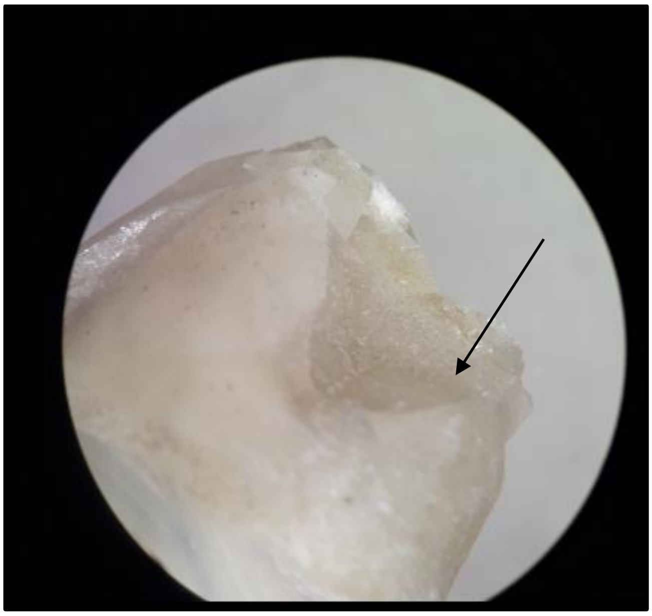
Fig 13: Failure mode analysis



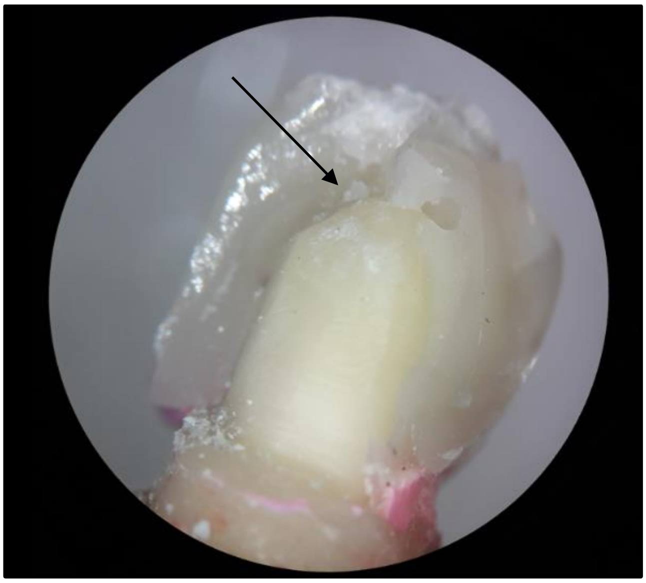
a) Crown fracture through Midline



b) Severe fracture of crown and tooth



c) More than half of the crown is lost



d) Less than half of crown is lost

RESULTS

Table 1: Load at Peak Values (Newton)

S.no	Control Group (Newton) N=12	Lithium Disilicate Onlays (Newton) N=12	Lithium Disilicate full crown (Newton) N=12	Porcelain fused metal full crown (Newton) N=12
1	182	838	583	1498
2	1505	1367	1269	657
3	361	2120	978	1610
4	1903	1695	879	2200
5	659	914	1179	949
6	1829	1618	2515	1192
7	592	1089	688	2089
8	530	1132	560	2166
9	1609	1227	993	1609
10	1700	1724	978	2700
11	1250	989	876	1750
12	731	1567	872	731

Table 2: Compressive strength in Newton/mm^2

S.no	Control group (N=12) (N/mm^2)	Lithium Disilicate Onlays (N=12) (N/mm^2)	Lithium Disilicate full crowns (N=12) (N/mm^2)	Porcelain fused metal full crowns (N=12) (N/mm^2)
1	362.078	1667.149	1159.843	2980.179
2	2994.105	2719.562	2578.312	1307.061
3	718.187	4217.610	1945.671	3202.996
4	3785.901	3372.098	1748.716	4376.765
5	1311.040	1818.347	2345.548	1887.977
6	3638.683	3218.911	5003.438	2371.411
7	1245.803	2166.498	1368.734	4864.177
8	1170.548	2278.382	1120.764	3608.232
9	3117.450	2441.041	1975.512	2900.724
10	2590.249	3813.754	1989.438	5369.494
11	2662.483	2150.583	1748.716	3531.180
12	1438.212	3117.450	1734.790	1357.485

Table 3. Descriptive statistics and One-way ANOVA to compare the difference in mean values between the groups

Variable	Mean	SD	95% CI for Mean		P value
			Lower Bound	Upper Bound	
Control	1070.91	623.34	674.86	1466.97	0.014
PFM	1588.41	593.74	1211.17	1965.66	
Emax Full	1030.83	513.49	704.57	1357.09	
Emax Onlay	1542.50	283.22	1143.46	1473.03	

Table 4. Tukey's HSD Post-hoc test for pairwise comparison between the groups

(I) Group	(J) Group	Mean Difference (I-J)	P value	95% CI	
				Lower	Upper
Control	PFM	-517.50	.019	-946.0092	-88.9908
	Emax Full	40.08	.851	-388.4259	468.5925
	Emax Onlay	-471.91	.032	-900.4259	-43.4075
PFM	Control	517.500	.019	88.9908	946.0092
	Emax Full	557.583	.012	129.0741	986.0925
	Emax Onlay	45.5833	.831	-382.9259	474.0925
Emax Full	Control	-40.083	.851	-468.5925	388.4259
	PFM	-557.58	.012	-986.0925	-129.0741
	Emax Onlay	-512.00	.020	-940.5092	-83.4908
Emax Onlay	Control	471.916	.032	43.4075	900.4259
	PFM	-45.583	.831	-474.0925	382.9259
	Emax Full	512.000	.020	83.4908	940.5092

A post hoc test was done to determine intergroup comparison.

Inference:

Significant difference is found between

- Control & PFM – **PFM higher**
- Control & Emax Onlay – **Onlay Higher**
- PFM & Emax Full – **PFM higher**
- Emax Onlay & Emax Full – **Emax Onlay higher**
- **EMAX ONLAY AND PFM ARE COMPARABLE (P=0.83 or P >0.05)**

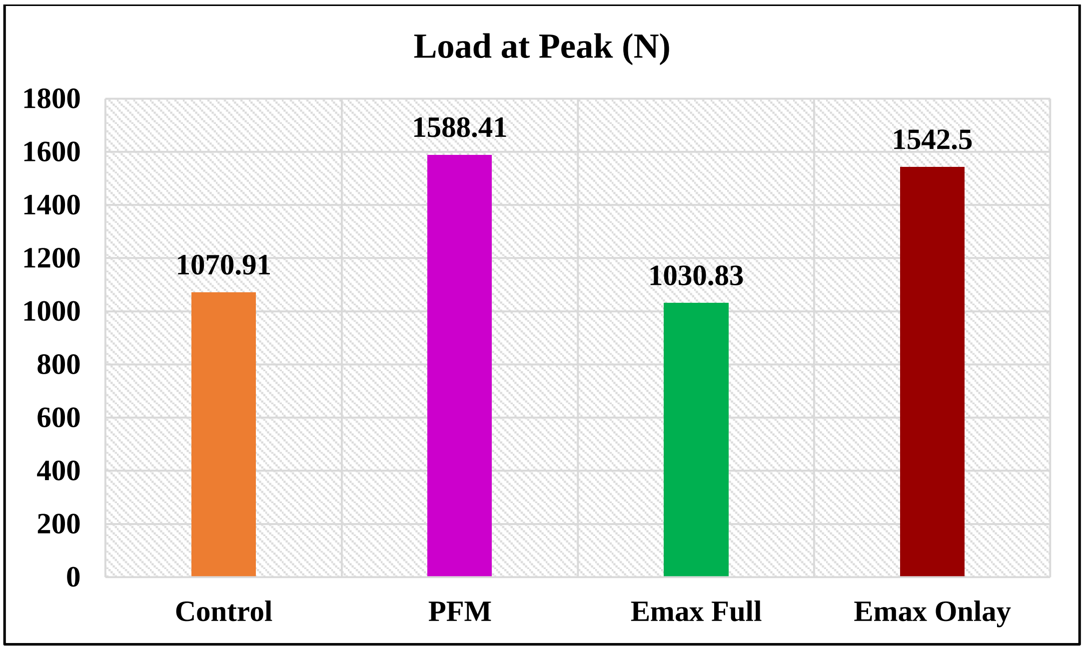
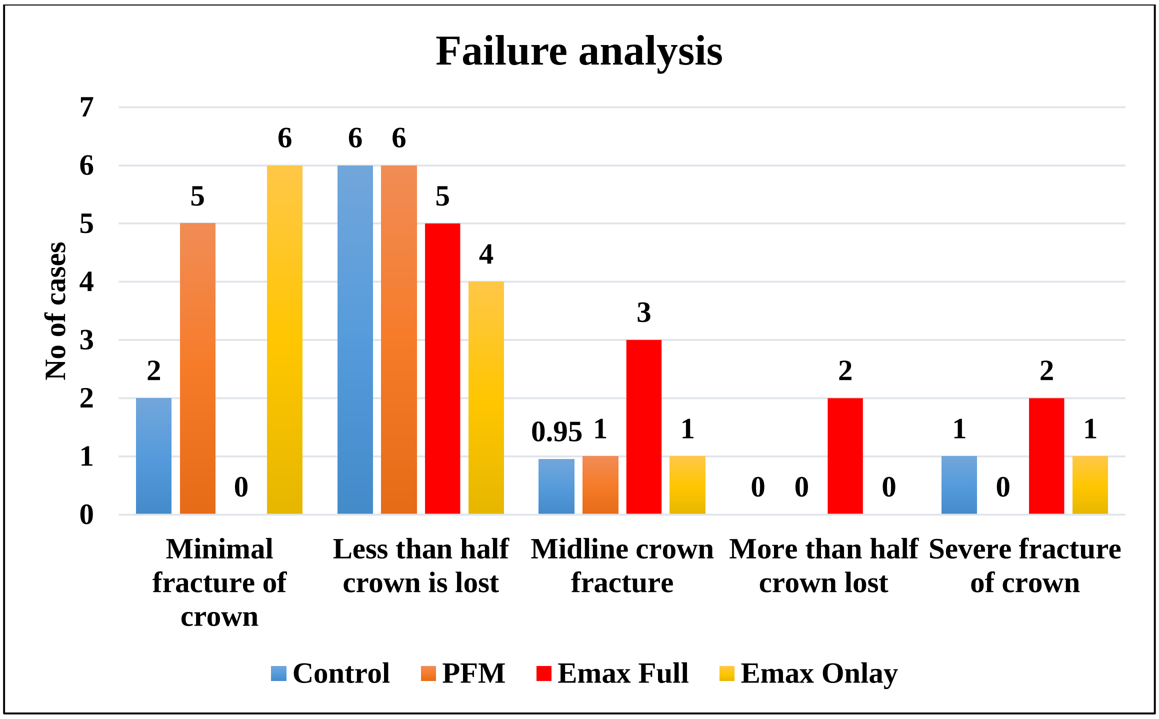


Chart 1. Comparison of mean 'Load at peak' values between the groups

Table 5. Chi square cross tabulations for distribution of fracture grades among the groups

	Failure analysis					Chi square statistic	P value
	Minimal fracture of crown	**Less than half crown is lost**	**Midline crown fracture**	**More than half crown lost**	**Severe fracture of crown**		
Control	2	6	0.95	0	1	17.52	0.13
PFM	5	6	1	0	0		
Emax Full	0	5	3	2	2		
Emax Onlay	6	4	1	0	1		

Inference: There is no significant difference in distribution of fracture grades among the groups



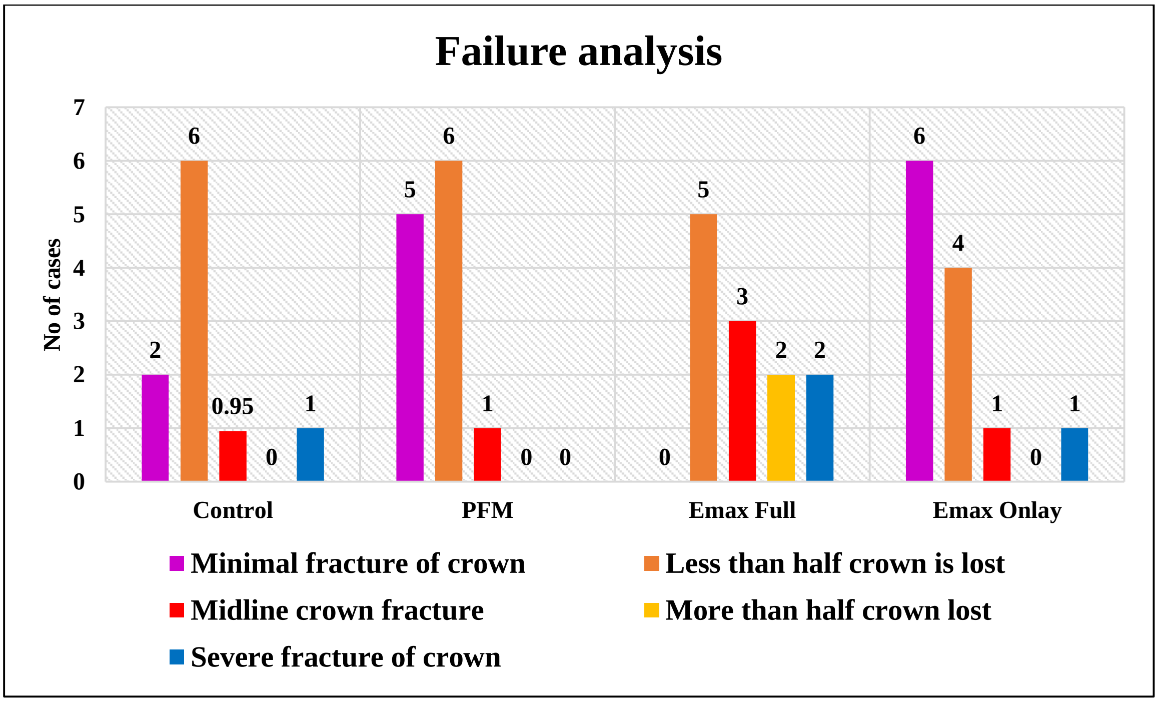


Chart 2. Distribution of fracture grades among the groups

DISCUSSION

The endodontically treated teeth are easily susceptible to fracture due to wide proximal cavities and extensive restorative procedures resulting in excessive loss of tooth structure.[1] Hence the restoration of such teeth should not only improve the fracture resistance but also restore the tooth in order to maintain proper functions in the oral cavity.[1]

Conventional methods for restoration of endodontically treated tooth involve the placement of appropriate post and core techniques followed by placement of full crown.[33] But these procedures reduce excessive amount of sound tooth structure for retention and restoration purpose, making the remaining tooth structure easily susceptible to fracture. The development of more than one interface between post and core and final crown interferes with adhesion and will also lead to crack propogation and ultimately fracture.[33]

Tooth preparation for full crown reduce greater amount of sound tooth structure, have hazardous effect on periodontium interferes with biological width, and also require the development of a new occlusal scheme.[1,33,81] Partial coverage bonded restorations on the other hand retains maximum amount of tooth structure and maintain natural contours of the tooth.[33] Such restorations have a monoblock effect on the tooth and also provide superior periodontal health as the margins are placed in self-cleansable areas.[81]

In considering restoration of endodontically treated teeth porcelain fused metal crowns are considered as gold standard. According to studies done by Ozer et al[31], PFM crowns had similar long-term clinical survival when compared with Zirconia crowns, and no significant difference was found when PFM crowns where compared with Zirconia. Naumann et a[32] in his study declared that a survival rate of 95.7% was seen over a period of 5 years with respect to PFM crowns. Hence PFM crowns have been considered as conventional method for restoring endodontically treated teeth.

Lithium disilicate (2SiO2eLi2O) dental ceramics were first introduced in 1988 for use as a heat-pressed core material marketed as IPS Empress 2 (Ivoclar Vivadent, Lichtenstein).[11] Empress 2 was classified as a glass ceramic, a subgroup of particle-filled glasses, and contained approximately 70% crystalline lithium disilicate filler. The use of a pressure casting procedure resulted in a material that possessed less defects and more uniform crystal distribution.[11] Reformulation and refinement of the production process of Empress 2, led to the production of a new ceramic line. The new ceramic formulation was released in 2005 under the brand of IPS EMax Press[11]. According to Zhao et al[36] and Irena et al[37] Lithium disilicate has been considered as suitable replacement for conventional PFM crowns. According to studies conducted by Pascal magne[58] and Guess et al[59] in 2006 Lithium disilicate is the material of choice for indirect restorations like Onlays and inlays.

The fracture toughness of various ceramic indirect restorations has been compared in several invitro studies.[83,84,87] However, none of the studies compared the efficacy of Lithium disilicate Onlays and full crowns with that of gold standard PFM crowns for restoring the endodontically treated posterior teeth. Hence the purpose of the study was to compare the fracture resistance of LDS Onlays and full crowns with that of conventional PFM crowns and to determine if the minimally invasive, morphology driven preparation design of Onlays along with proper adhesion protocols increases the fracture resistance of Onlays when compared to the PFM crowns and aid in long term survival of the restoration.

The maximum occlusal force in humans in posterior region ranges from 300-880N.[88] Schwickerath and Coca[88] also reported that force of 400 N is generated in the molar region during mastication. Maxillary first premolars were selected for the study because premolars are subjected to more lateral forces than molars and undergo flexion and fracture during mastication. They also require esthetic restoration and undergo occlusal loading similar to molars. Hence in order to achieve long term result the Maxillary First Premolar should be able to withstand the maximum occlusal forces.

In the current study resistance to fracture is shown as Mean ± SD for all four groups. The statistical significance of differences across the four groups has been assessed using One-way analysis of variance with Post hoc test for multiple group comparisons. P value of less than 0.05 was considered statistically significant.

From the result it has been concluded that all the above restorations are suitable for restoring the endodontically treated teeth since the compressive strength of all the restorations were greater than the normal masticatory load. Hence for restoring an endodontically treated Maxillary First Premolar Lithium disilicate full crowns, Lithium disilicate Onlays and Porcelain fused metal crowns are considered acceptable.

The mean force applied to cause failure for Group 1(Control) was 1070.91± 623.34 N, for Group 2 (Lithium disilicate Onlay) 1542.50 ± 283.22 N, and for Group 3 (Lithium disilicate full crown) 1030.83 ±513.49 N, Group 4 (PFM) 1588.41±593.74 N. From the result it has been inferred that Porcelain fused metal group had significant difference in fracture resistance when compared with Control and Lithium disilicate full crown (P value < 0.05) However, between Lithium disilicate Onlays and PFM group no significant difference was found in fracture resistance (P value-0.8). The failure modes involved in all the groups included tooth and restoration fracture. The least amount of fracture resistance was seen in Lithium disilicate full crown group and the highest fracture resistance was seen in Porcelain fused metal group (PFM group). Lithium disilicate

Onlay group showed fracture resistance comparable to that of Porcelain fused metal (PFM) group.

Failure mode analysis was done by Chi-square test and found no significant difference in distribution of fracture modes between the groups. However, group 3 showed incidence of oblique, vertical root fractures that cannot be restored by any other means. In Lithium disilicate Onlay and PFM group most of the failures were Score 1 and Score 2. In such instances the tooth can be salvaged with re-restorative procedures.

Porcelain fused metal crowns had highest fracture resistance compared to all the groups. It is observed that thickness of coping material and increase in modulus of elasticity of coping material led to decreased stress development regardless of type of preparation used[84]. Hence the cracks associated with PFM crowns were within Score 1 and Score 2 not extending to the underlying tooth. However, the coping metal can also bring adverse reactions in patients.[85] The coping metal can be either a noble metal alloy like gold, platinum, and palladium or a base metal alloy such as nickel and cobalt. The coping material used in the present study is cobalt chromium alloy. (d SIGN 30). Porcelain fused metal crowns with noble metal alloys have excellent biocompatibility whereas the base metal alloys are known to cause gingival irritation and recession.[85] According to Nakada et al[85] placement of cobalt chromium base metal alloy causes hypersensitivity reactions in patients. Patients who are allergic to cobalt-chromium developed pustules in their palms and foot for 1 month after receiving metal ceramic restorations and the symptoms subsided on removal of crowns.[85]

Plaque retention in relation to PFM crowns is another important aspect influencing the health of surrounding tissues. According to Parkinson et al[86] metal ceramic crowns with overcontoured facial and lingual surfaces resulted in greater accumulation of plaque and calculus leading to gingival inflammation. In a similar study conducted by Frankenhauser et al[87] the metal ceramic crowns after period of 3 years and saw increased inflammation around the gingival margins, increased gingival bleeding and mobility. According to him 80% of metal ceramic crowns are overcontoured to a mean value of 0.36mm. This overcontouring limits ability for oral hygiene resulting in plaque accumulation. However, in case of Lithium disilicate Onlays the margins of the restorations are placed in self-cleansable areas that aids in improving the oral hygiene of patients and dentist's ability to remove excess cement and to provide smooth plaque free restoration.

LDS full coverage crowns had the least fracture resistance compared to all the groups.[88] This is primarily due to loss of pericervical dentin and removal of sound tooth structure that weaken the tooth during restoration purposes. According to Tao Yu et al[88] the thickness of Emax crowns has direct influence on its fracture toughness (Ideal thickness-1-1.2mm). Thickness of Emax crowns ranges from 1.5-2mm results in 75% loss of tooth structure, In this study the increased occlusal reduction of 1.5- 2mm might have been a contributary factor for causing fracture of LDS crowns.

According to Junxin zhu et al[89] in an FEA study, the Von misses' stresses (VMS) were concentrated in occlusal area in enamel and in dentin VMS was concentrated in cervical area of the tooth. When lithium disilicate was used as restorative material stresses were distributed equally on enamel, dentin and restorative material, under occlusal load.[89]In LDS Onlay the pericervical dentin is preserved which prevents the forces from acting directly on the cervical margins of the tooth making it a suitable restoration for endodontically treated teeth in a biomechanical perspective.[89]

LDS onlay group has high fracture resistance next to PFM group. The reason for high fracture resistance is because the stress between the onlay and the tooth is equally distributed to the surrounding strutures. This is based on the Compression Dome concept by Greame Milicich[90] who said that Enamel itself acts as Compression dome transferring the stresses to the underlying dentin. The dentinoenamel junction acts as medium and transfers the stresses to dentin. Once the occlusal enamel is violated the stresses are concentrated in dentin rather than dissipating to surrounding structures.[90] Enamel compression dome has many microstructures like peripheral rim or biorim. Biorim is the area that lies below the maximum convexity. If Enamel acts as compression dome, the biorim forms the walls of the dome and transfers the stresses avoiding the forces to be transferred directly to the dentin.[90]

Lithium disilicate Onlay acts on the principle of compression dome.[90] The occlusal Onlay acts as compression dome and transfers the stresses to the external walls. The marginal chamfer is kept above the height of contour that acts as a biorim and transfers the compression stresses and avoids the tensional stresses from affecting the underlying dentin.[90] This concept works only with Lithium disilicate that has high modulus of elasticity since materials with low modulus of elasticity undergo high flexibility. Lithium disilicate performs equally to that of zirconia and metal ceramics because the primary advantage of Lithium disilicate is that it can be adhesively bonded.[90] It is proved that the presence of a liner or a base increases the risk of fracture twice that of material without liner or base. The adhesive technology along with high strength Lithium disilicate material helped in providing a restoration that mimics close to the biomechanical state of the tooth before it got affected by caries.[90]

Lithium disilicate is also known to have superior esthetics when compared to porcelain fused crowns, since PFM has a metal substructure as base that prevents light to pass through restoration.

Esthetics is primarily dependent upon translucency of material. According to Zarone et al[77] Lithium disilicate crowns are highly translucent than the crowns with metal substructure. So, the Lithium disilicate crowns are used in teeth with high translucency similar to natural teeth.

Immediate dentin sealing (IDS) was done to the Lithium Disilicate Onlay groups immediately after tooth preparation. The purpose of IDS was to seal the dentinal tubules from contamination, prevent microleakage, reduce the stress development during luting procedures. Since the dentin remained free of contamination, IDS can be considered as a contributing factor for the increased the fracture resistance of LDS onlays.[57]

Similar results were observed with Morimoto et al[91] where 99% survival was seen with feldspathic occlusal Onlays (VITA MARK II) over a period of 93 months. The feldspathic ceramic has compressive strength one third of Lithium disilicate hence better results can be expected with LDS Onlays.

Schulte[92] in his study determined the fracture resistance of IPS Empress ceramics (Leucite reinforced) Onlays and found that they had a survival rate of 95% at the end of 9.5 years. The success of these weaker materials was attributed to adhesive lamination concept where ceramics can be adhesively bonded to the enamel. The Enamel acts as circumferential tie provides good marginal adaptation, reduces microleakage and increases bond strength[92]

The crack that occurred with Lithium disilicate Onlays were most commonly oblique fracture resulting in loss of cusp. Once the compression dome is violated the stresses are directly transferred to the underlying dentin[90]. Hence the fracture of Lithium disilicate crowns showed loss of minimal portion of crown and in some cases loss of half portion of crown. However, these fractures were restricted to crown and did not involve the tooth indicating that the tooth can be restored again with restorative material.

Based on these results it can be concluded that partial bonded restorations preserve greater amount of tooth structure, and maintain natural contours of the tooth. They can be considered as a suitable alternative to the porcelain fused metal crowns.

The limitation of the study is specimens are prepared according to the standardized criteria. However, other factors like type of finish line, position of finish line, type of luting cement may also influence the fracture resistance of porcelain fused metal and all ceramic restorations. Hence further long-term in vivo studies are needed to arrive at a conclusion.

SUMMARY

The major objective of restoring the endodontically treated teeth is to restore its form and functions with minimal loss of tooth structure. Bonded partial coverage restoration provides a suitable means of restoring the endodontically treated teeth by preserving majority of tooth structure, provide good retention and resistance against occlusal forces by maintaining good adhesion with enamel and dentin.

The aim of the study is to compare the fracture resistance of endodontically treated Maxillary First Premolar restored with porcelain fused metal crowns, Lithium disilicate full crowns and Lithium disilicate Onlays. Freshly extracted Maxillary First Premolar (n=48) with two straight roots were selected for the study. The teeth were randomly divided into 4 groups of 12 teeth each namely, Group 1: Control (n=12), Group 2: Porcelain fused metal crown (n=12), Group 3: Lithium disilicate full crown (n=12), Group 4: Lithium disilicate Onlay (n=12).

All the teeth were endodontically treated and prepared to receive full crowns and Onlay restoration except the control group. The Crowns were luted and subjected to thermocycling for 5000 cycles at 5 degrees and 55 degrees and fracture strength was determined with a universal testing machine (N). The teeth were

then examined under stereomicroscope for failure mode analysis and data were assessed with SPSS software version 22 (IBM Corp).

The following results were obtained

- There was a statistically significant difference in mean fracture strength of LDS onlays when compared with LDS full crowns ($P>0.05$)
- LDS onlay group had the advantage of retaining maximum amount of tooth structure and preservation of pericervical dentin when compared with other two groups and hence was found to be statistically significant, ($P<0.05$)
- With PFM crowns no statistically significant result was obtained with onlay group as the LDS onlay produced results comparable to that of metal ceramic crowns.
- PFM crowns had the greatest fracture resistance when compared to all other groups since the metal coping has high modulus of elasticity that helped in distribution of stresses evenly throughout the tooth structure.
- LDS full crowns had the least resistance due to concentration of stresses at the crown tooth interface and excessive reduction of tooth structure that may have contributed to least resistance to fracture load.

CONCLUSION

- From this study it can be concluded that Lithium disilicate Onlay restoration can be used as a suitable alternative to Porcelain fused metal crowns for restoring endodontically treated teeth.
- Porcelain fused metal had the highest fracture resistance and Lithium disilicate full crowns had the least fracture resistance for restoring endodontically treated teeth.
- Bonded partial restorations can be used as a suitable choice of material for restoring the endodontically treated Maxillary First Premolar.

BIBLIOGRAPHY

1. Carter JM, Sorenson SE, Johnson RR. Punch shear testing of extracted vital and endodontically treated teeth. J Biomech. 1983;16(10):841-8.
2. Sedgley CM, Messer HH. Are endodontically treated teeth more brittle? J Endod. 1992 Jul;18(7):332-5.
3. Reeh ES, Messer HH, Douglas WH. Reduction in tooth stiffness as a result of endodontic and restorative procedures. J Endod. 1989 Nov;15(11):512-6.
4. Steele A, Johnson BR. In vitro fracture strength of endodontically treated premolars. J Endod. 1999 Jan;25(1):6-8.
5. Cotert HS, Sen BH, Balkan M. In vitro comparison of cuspal fracture resistances of posterior teeth restored with various adhesive restorations.Int J Prosthodont.2001Jul-Aug;14(4):374-8.
6. Sorensen JA, Martinoff JT. Intracornal reinforcement and coronal coverage: A study of endodontically treated teeth. J Prosthet Dent. 1984 Jun;51(6):780-4.
7. Dietschi and spearafico -current clinical concepts for adhesive cementation of tooth colored posterior restorations Pract Periodontics Aesthet Dent. 1998 Jan-Feb;10(1):47-54.
8. Ferraris F. Posterior indirect adhesive restorations (PIAR): preparation designs and adhesthetics clinical protocol. Int J Esthet Dent. 2017;12(4):482-502.

9. Dietschi D, Magne P, Holz J. Recent trends in esthetic restorations for posterior teeth. Quintessence Int. 1994 Oct;25(10):659-77.

10. Veneziani M. Posterior indirect adhesive restorations: updated indications and the Morphology Driven Preparation Technique. Int J Esthet Dent. 2017 Jun;12(2):204-30.

11. Willard A, Gabriel Chu TM. The science and application of IPS e.Max dental ceramic. Kaohsiung J Med Sci.2018 Apr;34(4):238-242.

12. Weinstein LK, Weinstein AB, inventors. Fused porcelain-to-metal teeth. United States patent US 3,052,982. 1962 Sep 11.

13.. Taft J. A practical treatise on operative dentistry. P. Blakiston, son; 1883.

14. Henderson D. Greene Vardiman BLACK (1836–1915), The Grand Old Man of Dentistry. Med Hist. 1961 Apr; 5:132-43

15. Rosenstiel SF, Land MF, Fujimoto J, Cockerill JJ. Contemporary Fixed Prosthodontics.4th Edition.St. Louis. Mosby, Inc. 2001;2001:380-416.

16. Rosen H. Operative procedures on mutilated endodontically treated teeth.J Prosthet Dent. 1961 Sep 1;11(5):973-86.

17. Gher JM, Dunlap RM, Anderson MH, Kuhl LV. Clinical survey of fractured teeth. J Am Dent Assoc. 1987 Feb;114(2):174-7.

18. Mentink AG, Meeuwissen R, Käyser AF, Mulder J. Survival rate and failure characteristics of the all metal post and core restoration. J Oral Rehabil. 1993 Sep;20(5):455-61.

19. Goodacre CJ, Spolnik KJ. The prosthodontic management of endodontically treated teeth: a literature review. Part I. Success and failure data, treatment concepts. J Prosthodont. 1994 Dec;3(4):243-50

20. Aquilino SA, Caplan DJ. Relationship between crown placement and the survival of endodontically treated teeth. J Prosthet Dent. 2002 Mar;87(3):256-63.

21. Mannocci F, Bertelli E, Sherriff M, Watson TF, Ford TP. Three-year clinical comparison of survival of endodontically treated teeth restored with either full cast coverage or with direct composite restoration.J Prosthet Dent. 2002 Sep;88(3):297-301.

22. Nagasiri R, Chitmongkolsuk S. Long-term survival of endodontically treated molars without crown coverage: a retrospective cohort study. J Prosthet Dent. 2005 Feb;93(2):164-70.

23. Tikku AP, Chandra A, Bharti R. Are full cast crowns mandatory after endodontic treatment in posterior teeth? J Conserv Dent. 2010 Oct;13(4):246-8.

24. Naylor WP, King AH. Introduction to metal-ceramic technology. Third Edition. Quintessence Publishing Company; 2009.

25. Anusavice KJ. Degradability of dental ceramics. Advances in dental research. Adv Dent Res. 1992 Sep; 6:82-9.

26. McLean JW. Evolution of dental ceramics in the twentieth century. J Prosthet Dent. 2001 Jan;85(1):61-6.
27. Jokstad A, Mjör IA. Ten years' clinical evaluation of three luting cements. J Dent. 1996 Sep;24(5):309-15
28. Walton TR. A 10-year longitudinal study of fixed prosthodontics: clinical characteristics and outcome of single-unit metal-ceramic crowns. Int J Prosthodont. 1999 Nov-Dec;12(6):519-26.
29. Marklund S, Bergman B, Hedlund SO, Nilson H. An intraindividual clinical comparison of two metal-ceramic systems: a 5-year prospective study. Int J Prosthodont. 2003 Jan-Feb;16(1):70-3.
30. De Backer H, Van Maele G, De Moor N, Van den Berghe L, De Boever J. An 18-year retrospective survival study of full crowns with or without posts. Int J Prosthodont. 2006 Mar-Apr;19(2):136-42.
31. Ozer F, Mante FK, Chiche G, Saleh N, Takeichi T, Blatz MB. A retrospective survey on long-term survival of posterior zirconia and porcelain-fused-to-metal crowns in private practice. Quintessence Int. 2014 Jan;45(1):31-8.
32. Naumann M, Ernst J, Reich S, Weißhaupt P, Beuer F. Galvano- vs. metal-ceramic crowns: up to 5-year results of a randomised split-mouth study. Clin Oral Investig. 2011 Oct;15(5):657-60
33. Gupta A, Musani S, Dugal R, Jain N, Railkar B, Mootha A. A comparison of fracture resistance of endodontically treated

teeth restored with bonded partial restorations and full-coverage porcelain-fused-to-metal crowns. Int J Periodontics Restorative Dent. 2014 May-Jun;34(3):405-11

34. Guazzato M, Albakry M, Ringer SP, Swain MV. Strength, fracture toughness and microstructure of a selection of all-ceramic materials. Part I. Pressable and alumina glass-infiltrated ceramics. Dent Mater. 2004 Jun;20(5):441-8.

35. Guess PC, Zavanelli RA, Silva NR, Bonfante EA, Coelho PG, Thompson VP. Monolithic CAD/CAM lithium disilicate versus veneered Y-TZP crowns: comparison of failure modes and reliability after fatigue. Int J Prosthodont. 2010 Sep-Oct;23(5):434-42.

36. Zhao K, Wei YR, Pan Y, Zhang XP, Swain MV, Guess PC. Influence of veneer and cyclic loading on failure behavior of lithium disilicate glass-ceramic molar crowns. Dent Mater. 2014 Feb;30(2):164-71.

37. Sailer I, Makarov NA, Thoma DS, Zwahlen M, Pjetursson BE. All-ceramic or metal-ceramic tooth-supported fixed dental prostheses (FDPs)? A systematic review of the survival and complication rates. Part I: Single crowns (SCs). Dent Mater. 2015 Jun;31(6):603-23.

38. Sulaiman TA, Delgado AJ, Donovan TE. Survival rate of lithium disilicate restorations at 4 years: A retrospective study J Prosthet Dent. 2015 Sep;114(3):364-6.

39. Azar B, Eckert S, Kunkela J, Ingr T, Mounajjed R. The marginal fit of lithium disilicate crowns: Press vs. CAD/CAM. Braz Oral Res. 2018;32:e001

40. Belli R, Petschelt A, Hofner B, Hajtó J, Scherrer SS, Lohbauer U. Fracture rates and lifetime estimations of CAD/CAM all-ceramic restorations. J Dent Res. 2016 Jan;95(1):67-73.

41. Rauch A, Reich S, Schierz O. Chair-side generated posterior monolithic lithium disilicate crowns: clinical survival after 6 years. Clin Oral Investig. 2017 Jul;21(6):2083-2089.

42. Willard A, Gabriel Chu TM. The science and application of IPS e. Max dental ceramic. Kaohsiung J Med Sci.2018 Apr;34(4):238-242.

43. Lin LM, Pascon EA, Skribner J, Gängler P, Langeland K. Clinical, radiographic, and histologic study of endodontic treatment failures. Oral Surg Oral Med Oral Pathol. 1991 May;71(5):603-11.

44. Shillingburg Jr HT, Fisher DW, Dewhirst RB. Restoration of endodontically treated posterior teeth. J Prosthet Dent 1970 Oct 1;24(4):401-9.

45. Steagall L, Ishikiriama A, de Lima Navarro MF, Soares FB. Fracture strength of human teeth with cavity preparations. J Prosthet Dent. 1980 Apr 1;43(4):419-22.

46. Kishimoto M, Shillingburg Jr HT, Duncanson Jr MG. Influence of preparation features on retention and resistance. Part I: MOD onlays. J Prosthet Dent. 1983 Jan 1;49(1):35-9.

47. Eakle WS. Fracture resistance of teeth restored with class II bonded composite resin. J Dent Res. 1986 Feb;65(2):149-53.

48. Banks RG. Conservative posterior ceramic restorations: a literature review. J Prosthet Dent. 1990 Jun 1;63(6):619-26.

49. Broderson SP. Complete-crown and partial-coverage tooth preparation designs for bonded cast ceramic restorations. Quintessence Int. 1994 Aug;25(8):535-9.

50. Roulet JF. Benefits and disadvantages of tooth-coloured alternatives to amalgam. J Dent. 1997 Nov;25(6):459-73

51. Brunton PA, Cattell P, Burke FT, Wilson NH. Fracture resistance of teeth restored with onlays of three contemporary tooth-colored resin-bonded restorative materials. J Prosthet Dent 1999 Aug 1;82(2):167-71.

52. Mondelli J, Sene F, Ramos RP, Benetti AR. Tooth structure and fracture strength of cavities. Braz Dent J. 2007;18(2):134-8.

53. Van Dijken JW, Hasselrot L, Örmin A, Olofsson AL. Restorations with extensive dentin/enamel-bonded ceramic coverage. A 5-year follow-up. Eur J Oral Sci. 2001 Aug;109(4):222-9

54. Edelhoff D, Sorensen JA. Tooth structure removal associated with various preparation designs for anterior teeth. J Prosthet Dent. 2002 May;87(5):503-9

55. Barghi N, Berry TG. Clinical evaluation of etched porcelain onlays: a 4-year report. Compend Contin Educ Dent. 2002 Jul;23(7):657-60

56. Filho, Araujo E, Baratieri LN. Ceramic inlays and onlays: clinical procedures for predictable results. J Esthet Restor Dent. 2003;15(6):338-51.
57. Magne P. Immediate dentin sealing: a fundamental procedure for indirect bonded restorations. J Esthet Restor Dent. 2005;17(3):144-54
58. Magne P. Composite resins and bonded porcelain: the postamalgam era. J Calif Dent Assoc. 2006 Feb;34(2):135-47.
59. Stappert CF, Guess PC, Chitmongkolsuk S, Gerds T, Strub JR. All-ceramic partial coverage restorations on natural molars. Masticatory fatigue loading and fracture resistance. Am J Dent. 2007 Feb;20(1):21-6.
60. Krämer N, Taschner M, Lohbauer U, Petschelt A, Frankenberger R. Totally bonded ceramic inlays and onlays after eight years. J Adhes Dent. 2008 Aug;10(4):307-14
61. Prakki A, Cilli R, Da Costa AU, De Paiva Gonçalves SE, Lia Mondelli RF, Pereira JC. Effect of resin luting film thickness on fracture resistance of a ceramic cemented to dentin. J Prosthodont. 2007 May-Jun;16(3):172-8.
62. Stappert CF, Att W, Gerds T, Strub JR. Fracture resistance of different partial-coverage ceramic molar restorations: An in vitro investigation. J Am Dent Assoc. 2006 Apr;137(4):514-22.
63. Frankenberger R, Petschelt A, Krämer N (2000) Leucite-reinforced glass ceramic inlays and onlays after six years: clinical behaviour. Oper Dent. 2000 Nov-Dec;25(6):459-65.

64. Yamanel K, Çaglar A, Gulsahi K, Özden UA. Effects of different ceramic and composite materials on stress distribution in inlay and onlay cavities: 3-D finite element analysis. Dent Mater J. 2009 Nov;28(6):661-70.

65. Magne P, Schlichting LH, Maia HP, Baratieri LN. In vitro fatigue resistance of CAD/CAM composite resin and ceramic posterior occlusal veneers. J Prosthet dent. 2010 Sep 1;104(3):149-57.

66. Rekow ED, Silva NR, Coelho PG, Zhang Y, Guess P, Thompson VP. Performance of dental ceramics: challenges for improvements. J Dent Res. 2011 Aug;90(8):937-52.

67. Murgueitio R, Bernal G. Three-year clinical follow-up of posterior teeth restored with leucite-reinforced IPS Empress onlays and partial veneer crowns. J Prosthodont. 2012 Jul;21(5):340-5.

68. Guess PC, Schultheis S, Wolkewitz M, Zhang Y, Strub JR. Influence of preparation design and ceramic thicknesses on fracture resistance and failure modes of premolar partial coverage restorations. J Prosthet dent. 2013 Oct 1;110(4):264-73.

69. Ma L, Guess PC, Zhang Y. Load-bearing properties of minimal-invasive monolithic lithium disilicate and zirconia occlusal onlays: finite element and theoretical analyses. Dent Mater. 2013 Jul;29(7):742-51.

70. Oz FD, Bolay S. Comparative Evaluation of Marginal Adaptation and Fracture Strength of Different Ceramic Inlays Produced by CEREC Omnicam and Heat-Pressed Technique. Int J Dent. 2018 Apr 26; 2018:5152703.

71. Vohra FA, Rashid H, Ab Ghani SM. Modern Adhesive Ceramic Onlay, A Predictable Replacement of Full Veneer Crowns. J Dow Univ of Healt Sci (JDUHS). 2014 Apr 10;8(1).

72. Hamdy A. Effect of full coverage, endocrowns, onlays, inlays restorations on fracture resistance of endodontically treated molars.J Dent Oral Health 2015;1(5).

73. Baader K, Hiller KA, Buchalla W, Schmalz G, Federlin M. Self-adhesive Luting of Partial Ceramic Crowns: Selective Enamel Etching Leads to Higher Survival after 6.5 Years In Vivo. J Adhes Dent. 2016;18(1):69-79

74. Archibald JJ, Santos Jr GC, Santos MJ. Retrospective clinical evaluation of ceramic onlays placed by dental students. J Prosthet dent. 2018 May 1;119(5):743-8.

75. Veneziani M. Posterior indirect adhesive restorations: updated indications and the Morphology Driven Preparation Technique. Int J Esthet Dent. 2017 Jun 1;12(2):204-30.

76. Abduo J, Sambrook RJ. Longevity of ceramic onlays: A systematic review. J Esthet Restor Dent. 2018 May;30(3):193-215.

77. Zarone F, Di Mauro MI, Ausiello P, Ruggiero G, Sorrentino R. Current status on lithium disilicate and zirconia: a narrative review. BMC Oral Health. 2019 Jul 4;19(1):134.

78. Escobar PM, Kishen A, Lopes FC, Borges CC, Kegler EG, Sousa-Neto MD. A CAD/CAM-based strategy for concurrent endodontic and restorative treatment. Restor Dent Endod. 2019 Jul 24;44(3):e27

79. Edelhoff D, Güth JF, Erdelt K, Brix O, Liebermann A. Clinical performance of occlusal onlays made of lithium disilicate ceramic in patients with severe tooth wear up to 11 years. Dent Mater. 2019 Sep;35(9):1319-1330

80. Dickerson WG, Hastings JH. Indirect composite restorations. Current opinion in cosmetic dentistry. 1995:51-6.

81. Dietschi D, Maeder M, Meyer JM, Holz J. In vitro resistance to fracture of porcelain inlays bonded to tooth. Quintessence Int. 1990 Oct;21(10):823-31

82. Stappert CF, Guess PC, Chitmongkolsuk S, Gerds T, Strub JR. All-ceramic partial coverage restorations on natural molars. Masticatory fatigue loading and fracture resistance. Am J Dent. 2007 Feb;20(1):21-6.

83. Schwickerath H, Coca I. Single crowns of glass-ceramic Phillip J Restaur Zahnmed. 1987 Dec;4(6):336-8...

84. Imtiyaz Ahmed M, Talib Amin N, Shafait UK, Mohammad Yunis SB, Muhammad Waqar H. Influence of Shoulder and Chamfer Margin Design on the Stress Distribution Pattern in

Different All Ceramic Restorations by Three-Dimensional Finite Element Analysis. J Dent Oral Health. 2018;1(3).

85. Nakada T, Iuima M, Nakayama H, Maibach HI. Role of ear piercing in metal allergic contact dermatitis. Contact Dermatitis. 1997 May;36(5):233-6

86. Parkinson CF. Excessive crown contours facilitate endemic plaque niches. J Prosthet Dent. 1976 Apr 1;35(4):424-9.

87. Frankhauser G. Clinical investigation of metallo.ceramic crowns: University of Zurich, 1979

88. Yu T, Wang F, Liu Y, Wu T, Deng Z, Chen J. Fracture behaviors of monolithic lithium disilicate ceramic crowns with different thicknesses. RSC Advances. 2017;7(41):25542-8

89. Zhu J, Rong Q, Wang X, Gao X. Influence of remaining tooth structure and restorative material type on stress distribution in endodontically treated maxillary premolars: A finite element analysis. J Prosthet dent. 2017 May 1;117(5):646-55.

90. Milicich G. The compression dome concept: the restorative implications. Gen Dent. 2017 Sep-Oct;65(5):55-60.

91. Morimoto S, Rebello de Sampaio FB, Braga MM, Sesma N, Özcan M. Survival rate of resin and ceramic inlays, onlays, and overlays: a systematic review and meta-analysis. J Dent Res. 2016 Aug;95(9):985-94

92. Schulte AG, Vöckler A, Reinhardt R. Longevity of ceramic inlays and onlays luted with a solely light-curing composite resin. J Dent. 2005 May;33(5):433-42.

ANNEXURE – I

PARTICIPANT INFORMATION SHEET (ENGLISH)

NAME OF INVESTIGATOR: HARINI.K

PHONE NO: 9894871222

TOPIC: COMPARING FRACTURE RESISTANCE OF ENDODONTICALLY TREATED MAXILLARY FIRST PREMOLAR RESTORED WITH LITHIUM DISILICATE ONLAYS, LITHIUM DISILICATE FULL CROWNS AND PORCELAIN FUSED METAL FULL CROWNS-AN INVITRO STUDY

The aim of the study is to determine the fracture resistance of extracted teeth restored with different crowns. No risk will be involved as the tooth is extracted for orthodontic or periodontal problems. Your records will be maintained confidential and you have freedom to participate or withdraw from research at any point of time.

The details of the research have been explained to me in a language which I understand. I hereby give permission for using my records, and extracted teeth for professional research and education purpose only.

SIGNATURE OF PATIENT: -

ANNEXURE – II

PARTICIPANT INFORMATION SHEET (TAMIL)

தேதி -

முதன்மை ஆய்வாளரின் பெயர் - ஹரிணி

கைபேசி எண் - +91 9894871222

தலைப்பு: வேர் சிகிச்சை செய்த பற்களுக்கு பலவிதமான பல் கிரீடம் அணிவித்து அதன் பிளவின் வலிமையை ஆய்வதே இந்த ஆராய்ச்சியின் குறிக்கோள்.

இந்த ஆராய்ச்சி பிடுங்கப்பட்ட பற்களில் மேற்கொள்ளப்படுவதால், நோயாளிகளுக்கு எவ்வித பாதிப்பும் ஏற்படாது. பல் சீரமைப்பு அல்லது ஈறுநோய் பாதிப்பினால் பிடுங்கப்பட்ட பற்களில் மட்டுமே இந்த ஆராய்ச்சி மேற்கொள்ளப்படும் என்று உறுதியளிக்கிறேன்.

தங்களது பதிவுகள் ரகசியமாக பாதுகாக்கப்படும் என்றும், விருப்பமின்றி பற்கள் பயன்படுத்தபடாது என்றும் உறுதியளிக்கிறேன்.

ஆராய்ச்சியாளரின் கையொப்பம்

இந்த ஆராய்ச்சியின் குறிப்புகள் எனக்கு தெளிவாக விளக்கப்பட்டன, அவற்றை நான் முழுமையாக புரிந்து கொண்டேன்.

இந்த ஆராய்ச்சிக்காக எனது பிடுங்கிய பற்களை உபயோகிக்கலாம் என முழுமனதுடன் சம்மதிக்கிறேன்.

நோயாளியின் கையொப்பம்

ANNEXURE – III

PARTICIPANT INFORMED CONSENT FORM (PICF)-ENGLISH

IHEC Proposal S.No: 352

Date: ______

Title of the Project: Comparing fracture resistance of Endodontically treated maxillary first premolar restored with Lithium disilicate Onlays, Lithium disilicate full crowns and Porcelain fused metal full crowns -An invitro study

Name of the Principal Investigator: Dr. Harini. K

Mobile No: +91 9894871222

The contents of the information sheet dated__________that was provided have been read carefully by me / explained in detail to me, in a language that I comprehend, and I have fully understood the contents. I confirm that I have had the opportunity to ask questions.

The nature and purpose of the study and its potential risks / benefits and expected duration of the study, and other relevant details of the study have been explained to me in detail. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my medical care or legal right being affected.

I understand that the information collected about me from my participation in this research and sections of any of my medical notes may be looked at by responsible individuals from CARE. I give permission for these individuals to have access to my records.

I agree to take part in the above study.

____

(Signatures / Left Thumb Impression)

Date:

Place:

Name of the Participant: ______

Son / Daughter / Spouse of: ___

Complete Postal Address: _____

This is to certify that the above consent has been obtained in my presence.

Date:

Place:

____

Signature of the principal Investigator

1. Witness – 1 2. Witness – 2

______________________________ ______________________________

Signature Signature

Name & Address Name & Address

ANNEXURE-IV

PARTICIPANT INFORMED CONSENT FORM (PICF)-TAMIL

முறையான அனுமதி படிவம்

தேதி: ____________

தலைப்பு: வேர் சிகிச்சை செய்த பற்களுக்கு பலவிதமான பல் கிரீடம் அணிவித்து அதன் பிளவின் வலிமையை ஆய்வதே இந்த ஆராய்ச்சியின் குறிக்கோள்.

முதன்மைஆய்வாளரின் பெயர்: ஹரிணி

கைப்பேசி: 9894871222

இந்ததகவல்தாளின் உள்ளடக்கங்களை நான் கவனமாக படித்தேன் / அது என்னுடைய மொழியில் எனக்கு விளக்கப்பட்டது. நான் அவற்றை முழுமையாகப் புரிந்து கொண்டேன். எனக்கு எற்பட்ட சந்தேகங்களை தீர்த்துகொள்ள வாய்ப்பு அளிக்கப்பட்டது என்பதை உறுதிப்படுத்துகிறேன்.

இந்தஆராய்ச்சியின் முடிவில் என்னுடைய பெயர் மற்றும் என்னை பற்றிய தகவல்கள் வெளியே வராது என்பதையும், நான் விரும்பும் பட்சத்தில் இவ்வாராய்ச்சியிலிருந்து எப்பொழுது வேண்டுமானாலும் விலகி கொள்ளலாம் என்றும் அவ்வாறு விலகும் பொழுது அது எனக்கு அளிக்கப்படும் சிகிச்சையை ஒருபொழுதும் பாதிக்காது என்றும் அறிந்து கொண்டேன்.

இந்தஆராய்ச்சியில் பங்கேற்பதற்கு முழுமனதாக நான் சம்மதிக்கின்றேன்.

நோயாளியின் கையொப்பம் / இடது பெருவிரல் ரேகை

ஆராய்ச்சியாளரின் கையொப்பம்

பங்கேற்பவரின் பெயர்: ______________________________

பங்கேற்பவரின் முகவரி:

____

____

____

சாட்சி(1)

பெயர்:

முகவரி::

கையொப்பம்:

சாட்சி(2)

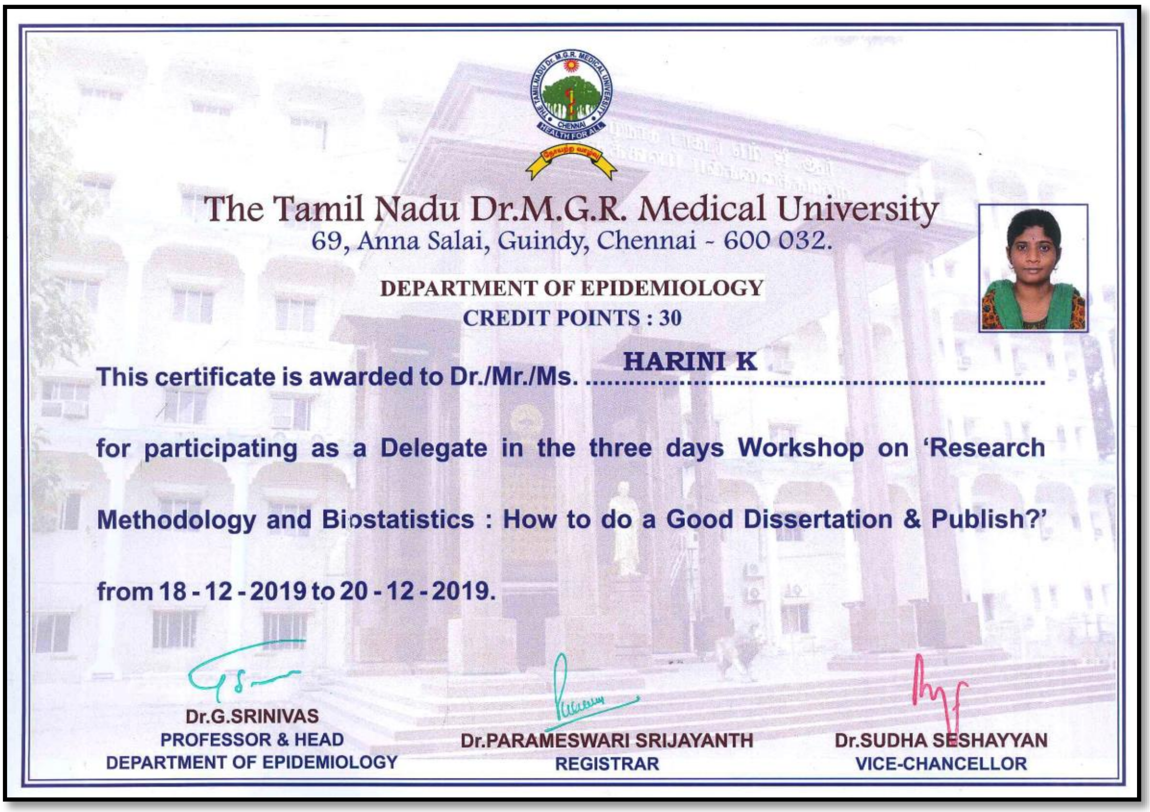
பெயர்:

முகவரி:

கையொப்பம்:

ANNEXURE –V

RESEARCH METHODOLOGY CERTIFICATE



The Tamil Nadu Dr.M.G.R. Medical University
69, Anna Salai, Guindy, Chennai - 600 032.

DEPARTMENT OF EPIDEMIOLOGY
CREDIT POINTS : 30

This certificate is awarded to Dr./Mr./Ms. HARINI K

for participating as a Delegate in the three days Workshop on 'Research Methodology and Biostatistics : How to do a Good Dissertation & Publish?' from 18 - 12 - 2019 to 20 - 12 - 2019.

Dr.G.SRINIVAS
PROFESSOR & HEAD
DEPARTMENT OF EPIDEMIOLOGY

Dr.PARAMESWARI SRIJAYANTH
REGISTRAR

Dr.SUDHA SESHAYYAN
VICE-CHANCELLOR