Comparison of Fracture Resistance and Bond Strength of e.max Crowns Restored with Fiber Post and Core with ENDO Crowns

Rohit Mathur
Nova Southeastern University

Follow this and additional works at: https://nsuworks.nova.edu/hpd_cdm_stuetd

Part of the Dentistry Commons

All rights reserved. This publication is intended for use solely by faculty, students, and staff of Nova Southeastern University. No part of this publication may be reproduced, distributed, or transmitted in any form or by any means, now known or later developed, including but not limited to photocopying, recording, or other electronic or mechanical methods, without the prior written permission of the author or the publisher.

NSUWorks Citation

This Thesis is brought to you by the College of Dental Medicine at NSUWorks. It has been accepted for inclusion in Student Theses, Dissertations and Capstones by an authorized administrator of NSUWorks. For more information, please contact nsuworks@nova.edu.
Comparison of Fracture Resistance and Bond Strength of CAD/CAM e.max Crowns Restored with Fiber Post and Core with ENDO Crowns

Rohit Mathur, B.D.S., M.P.H

A Thesis Presented to the Faculty of the College of Dental Medicine of Nova Southeastern University in Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE

June 2018

© Copyright by Rohit Mathur 2018 All Rights Reserved
Comparison of Fracture Resistance and Bond Strength of CAD/CAM e.max Crowns Restored with Fiber Post and Core with ENDO Crowns

By

Rohit Mathur, B.D.S, M.P.H

A thesis submitted to the College of Dental Medicine of Nova Southeastern University in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Department of Prosthodontics
College of Dental Medicine
Nova Southeastern University
June 2018

Approved as to style and content by:

APPROVED BY:
Rafael Castellon, D.D.S, M.S, M.B.A(Committee Chair)
Date

APPROVED BY:
Jeffrey Thompson, B.S. Ph.D (Committee Member)
Date

APPROVED BY:
Marvin Golberg, D.D.S (Committee Member)
Date

APPROVED BY:
Linda Niessen D.M.D., M.P.H. (Dean, College of Dental Medicine)
Date
STUDENT NAME: Rohit Mathur, B.D.S, M.P.H
STUDENT E-MAIL ADDRESS: rm2021@mynsu.nova.edu
STUDENT TELEPHONE NUMBER: (786) 212-8274
COURSE DESCRIPTION: Master of Science in Dentistry with specialty certificate in postgraduate Prosthodontics
TITLE OF SUBMISSION: Comparison of Fracture Resistance and Bond Strength of CAD/CAM e.max Crowns Restored with Fiber Post and Core with ENDO Crowns
DATE SUBMITTED: June 2018

I certify that I am the sole author of this thesis, and that any assistance I received in its preparation has been fully acknowledged and disclosed in the thesis. I have cited any sources from which I used ideas, data, or words, and labeled as quotations any directly quoted phrases or passages, as well as providing proper documentation and citations. This thesis was prepared by me, specifically for the M.S. degree and for this assignment.

STUDENT SIGNATURE:

Rohit Mathur, B.D.S, M.P.H
Date
Dedication

I would like to dedicate this thesis to God, my parents Dr. Rajeev Mathur and Vandana Mathur and to my wife, Dr. Michelle Torres. Without them this would have been very difficult
Acknowledgement

• First, I would like to thank my mentor Dr. Rafael Castellon who helped me and guided me throughout the study.

• I would like to express my gratitude to Dr. Jeffery Y. Thompson for being a mentor, his guidance and his suggestions throughout the study.

• I am grateful to Dr. Marvin Golberg for his valuable suggestions and mentoring this study.

• I am thankful to Dr. chu Jen Hsu for his extremely valuable and helpful suggestions.

• I am grateful to Dr. Max Nahon for always supporting me in this study.

• I am thankful to Dr. Mauricio Guerrero for his support and suggestions during the study.

• I appreciate the help from Ria Achong-Bowe for her help in Bioscience research center. Without her help this study wouldn’t have been possible.
ABSTRACT

Comparison of Fracture Resistance and Bond Strength of e.max Crowns Restored with Fiber Post and Core with ENDO Crowns

DEGREE DATE: June 2018

Rohit Mathur, B.D.S, M.P.H

COLLEGE OF DENTAL MEDICINE NOVA SOUTHEASTERN UNIVERSITY

Thesis Directed by:

- Rafael Castellon, D.D.S, M.S, M.B.A (Committee Chair)
- Jeffrey Thompson, B.S. Ph.D (Committee Member)
- Marvin Golberg, D.D.S (Committee Member)

Objective:

This study evaluated the Fracture Resistance and Bond strength of e.max crowns made with CAD/CAM technology on teeth restored with fiber post and core and compare them to Endo crowns.

Materials and Methods:

32 extracted premolars were collected from the department of periodontics and oral surgery. These teeth were assigned in 2 groups. 16 teeth were assigned to test compressive load resistance and the other 16 were assigned to test tensile strength. These groups were subdivided into 2 groups. One group with 8 teeth received post and core followed by crown
placement and the other group of teeth were prepared to receive Endo crown. After teeth preparation, samples were scanned and e.max crowns were milled. These crowns were then bonded using resin cement. Cyclic loading was done before testing for fracture resistance or bond strength. Mode of failure was also observed for all groups.

**Results**

To compare differences for the outcome measure tensile strength and compressive force two Welch ANOVA models were created. The mean compressive force required for conventional and Endo crowns were 737.9 N and 410.9 N respectively. The mean tensile force required for conventional and Endo crowns were 166.4 N and 205.4 N respectively. There was a significant difference in the measurement of bond strength and fracture resistance by group.

**Discussion**

In our study we found that conventional crowns needed more compressive force for dislodgement/breaking compared to Endo crowns. Additionally, we found that Endo crowns required more tensile force for dislodgement/breakage when compared to conventional crowns. When mode of failure was observed for fracture resistance, the tooth fractured 100% of the time for Endo crowns compared to 75% of the time for conventional crowns. During Tensile testing, fracture of the restoration
was seen 75% for Endo crowns, and debonding was the most common failure (87.5%) for conventional crowns.

Conclusion

This study concluded that Endo crowns have higher bond strength compared to conventional crowns. However, they have a reduced fracture resistance compared to conventional crowns.
# Table of Contents

Title page ........................................................................................................................................ i
Signature Page ...................................................................................................................................... ii
Disclosure Page ................................................................................................................................... iii
Dedication Page .................................................................................................................................... iv
Acknowledgements ............................................................................................................................ v
Abstract ............................................................................................................................................... vi
Table of Contents ............................................................................................................................... iX
List of Tables ......................................................................................................................................... xi
List of Figures ......................................................................................................................................... xii

## CHAPTER I: INTRODUCTION ............................................................................................................. 1

1.1 Endodontically treated teeth ........................................................................................................ 1
    1.1.1 Endodontic treatment or implant placement ........................................................................ 3
1.2 Ferrule .......................................................................................................................................... 3
1.3 Post and core systems .................................................................................................................. 5
    1.3.1 cast post and core ................................................................................................................. 6
    1.3.2 Prefabricated post and core ................................................................................................. 7
        1.3.2.1 Glass fiber posts ........................................................................................................... 8
    1.3.3 core build up ....................................................................................................................... 9
1.4 CAD/CAM in dental practice ....................................................................................................... 10
    1.4.1 Advantages of CAD/CAM technology ................................................................................ 11
    1.4.2 Disadvantaged of CAD/CAM ............................................................................................. 12
1.5 All ceramic restorations ............................................................................................................... 12
List of Tables

Table 1: Descriptive statistics ................................................................. 46
Table 2: Mode of failure for bond strength ................................. 47
Table 3: Mode of failure for fracture resistance ...... 47
List of Figures

Figure 1: Study groups ............................................................... 25
Figure 2: Teeth in acrylic ............................................................. 26
Figure 3: Tooth dimensions showing tooth left for biologic width ................................................................. 26
Figure 4: Burs used in tooth preparation of Endo crown ... 27
Figure 5: Composite being used to close root canals access ........................................................................ 28
Figure 6: Dimensions of the pulp chamber for Endo crowns ........................................................................ 28
Figure 7: Completed Endo crown preparation ....................... 28
Figure 8: Dimensions of conventional crown preparation ... 30
Figure 9: Burs used in tooth preparation of conventional crown ........................................................................ 30
Figure 10: Post system used ......................................................... 31
Figure 11: Steps for placement of post ..................................... 31
Figure 12: Core build up used ....................................................... 32
Figure 13: Conditioner for core build up ................................. 33
Figure 14: Core build up material placement ......................... 34
Figure 15: Final tooth preparation with post and core ....... 34
Figure 16: Digital crown designing for conventional crown .............................................................................. 36
Figure 17: Digital crown designing for Endo crown .......... 37
Figure 18: Monobond application on crown ........................... 39
Figure 19: Primer being applied on tooth ........................................ 39
Figure 20: Cementation of crown ....................................................... 40
Figure 21: Removal of excess cement from crown .............................. 40
Figure 22: Leinfelder type cyclic wear tester ....................................... 41
Figure 23: Universal testing machine to test fracture resistance .............. 43
Figure 24: Close up view of crown being tested for fracture resistance ......................................................... 43
Figure 25: Universal testing machine to test bond strength ...................... 44
Figure 26: Close up view of crown being tested for bond strength .......... 44
Figure 27: Graph of fracture resistance of conventional crowns .......... 48
Figure 28: Graph of fracture resistance of Endo crowns ..................... 48
Figure 29: Graph of bond strength of conventional crowns ... 49
Figure 30: Graph of bond strength of Endo crowns ........................... 50
Figure 31: Graph of comparison of tensile strength ........................... 51
Figure 32: Graph of comparison of compressive strength .................... 52
Figure 33: Fracture of tooth during fracture resistance test .................. 56
Figure 34: Displacement of crown with fracture during fracture resistance test ................................................................. 56
Figure 35: Fracture of tooth during fracture resistance test for Endo crown ................................................................. 57

Figure 36: Restoration fracture during bond strength test for Endo crowns ................................................................................................................................. 59

Figure 37: Tooth fracture during bond strength test for Endo crowns ................................................................................................................................. 59

Figure 38: Debonding of crown during bond strength test ..... 60

Figure 39: Tooth fracture during bond strength test ........... 61
Chapter 1

Introduction

1.1 Endodontically treated teeth

In 2009, 15 million root canal treatments were performed in the United States. Endodontically treated teeth have a higher incidence of fracture, hence crowning these teeth is considered the standard of care\(^1\). The fracture of these teeth can be a simple cusp fracture, or it can be catastrophic root fracture requiring extraction. Some teeth need post and core build up due to limited tooth structure while others just need a crown, depending on the tooth structure left. The teeth that requires endodontic treatment usually has lost a significant amount of tooth structure either because of caries, fracture or endodontic access. The factors that are considered during the restorative treatment are the pre-existing endodontic status, the quality of root canal filling, the position of tooth in the mouth, and the type of restoration planned\(^2\). The most common reason for failure of endodontically treated teeth are tooth fractures followed by periodontal problems and subsequently endodontic failure\(^3\). This highlights the fact that endodontically treated teeth can also fail because of periodontal conditions, but the most common cause is inadequate restorative treatment. It has been
noted that when distal abutments are endodontically treated there is a higher chance of loss of retention or fracture of teeth in fixed partial dentures.

There are several classic studies in the endodontic literature which suggest that after endodontic treatment, dentine in teeth lose moisture and collagen cross linking makes them more brittle. However, this was not confirmed by later studies which found that neither endodontic treatment or dehydration caused significant change in mechanical and physical properties of dentine. Studies have shown that tooth strength is reduced based on the amount of coronal structure that is lost. They have shown that the there is a direct correlation between the amount of tooth structure left and the ability to resist occlusal forces.

The success of endodontically treated teeth depends both on the endodontic and restorative treatment. It has been found that the clinical longevity of endodontically treated molars and bicuspids is significantly improved when they are restored with a full coverage coronal restoration. There is strong evidence supporting the placement of a crown to encircle the tooth which can increase the resistance to fracture posteriorly. There is evidence that the longevity of
anterior teeth does not depend on the coronal restoration, as the forces exerted are less\textsuperscript{10}.

1.1.1 Endodontic treatment or implant placement

Dental implants can be considered an alternative to endodontic treatment in some situations. Dental implants are often compared to ankylosed teeth as they are fixed in the bone\textsuperscript{11}. The success rates of implants are up to 95\% at 10 years\textsuperscript{12}. However, it must be noted that every patient is not a candidate for dental implants. Also, dental implants are considered a treatment option when teeth are deemed non-restorable.

Despite the efforts made to restore endodontically treated teeth, biomechanical failures still are responsible for a vast majority of failures.

1.2 Ferrule

The most common cause of failure of endodontically treated teeth is fracture. This is seen due to the inability of the tooth to resist horizontal and vertical forces. It is therefore recommended to save internal dentine during
endodontic therapy and restorative procedures\textsuperscript{13}. According to the prosthodontics glossary of terms, ferrule was defined as “a metal band or ring used to fit the root or crown of the tooth”.

In vitro studies have shown that resistance to fracture significantly improves when ferrules were used for post and core restorations \textsuperscript{13, 14}. A study found that when crowns had at least 1.0 mm of coronal tooth structure remaining above the crown margin, the fracture resistance of the tooth was substantially increased \textsuperscript{15}. Therefore, an adequate ferrule is necessary for a successful post-retained restoration.

The term ferrule effect is defined as “a collar of 360° surrounding parallel walls of dentin and extending 1.5 mm to 2.0 mm coronal to the finish line of the preparation”\textsuperscript{16}. It has been found that a preparation with 2.0 mm ferrule is more resistant to fracture than one with no ferruled preparation\textsuperscript{17}. In certain situation when an adequate ferrule cannot be obtained, surgical crown lengthening or orthodontic extrusion is done in order to expose additional tooth surface\textsuperscript{16, 18}. However, the disadvantage is that it can compromise periodontal support and produces gingival margins at different heights. Literature has shown that a 2.0 mm ferrule
width makes teeth more resistant to fracture when compared with 1.0 mm to 1.5 mm ferrule width, regardless of the dowel system. The amount of ferrule width plays a greater role on the fracture resistance of a root restored with a post rather than the post length itself after cyclic loading\textsuperscript{19}.

It has been concluded that a complete ferrule is necessary, but there is no consensus regarding the height of the axial walls. Most studies recommend a ferrule of 2.0 mm, and some other studies suggest a minimum of 1.5 mm\textsuperscript{20}. In our study we decided to use a 2.0 mm ferrule for conventional crowns, based on the literature.

1.3 Post and core systems

Pierre Fauchard is considered the father of modern dentistry, who introduced a post and core in the form of gold and silver posts during the 18th century. The main purpose of a post is to retain the core material in a nonvital tooth that has lost extensive coronal tooth structure. There are different post systems that are available. The two broad categories are prefabricated posts or custom-made posts. A commonly used custom-made post and core is a cast post and core.
1.3.1 Cast post and core

Cast post and cores were considered the standard of care for many years\textsuperscript{21}. Studies have shown that these types of posts do not perform well in in vitro and in vivo studies\textsuperscript{22, 23}. The biggest disadvantage of using cast post and cores are that they require two appointments, temporization, and a laboratory fee\textsuperscript{21}.

However, there are studies that have reported high success rates using cast post and cores\textsuperscript{24, 25}. Cast post and cores prove to be advantageous when the remaining tooth is small, there is minimal coronal tooth structure left or when multiple teeth require posts and an impression can be made and sent to the lab. Another advantage of cast post and cores is their ease of retrievability when compared to other post systems\textsuperscript{21}.

A study found that when teeth with normal bone were restored with cast post and cores, they had significantly higher fracture resistance compared to glass fiber posts with composite resin. However when the bone was resorbed there was no significant difference between cast post and cores versus glass fiber posts with composite resin core build-up\textsuperscript{26}. 
Since cast posts and cores are custom made they have a more intimate fit in the canal compared to prefabricated posts. This leads to a different type of stress distribution. However cast post and cores demonstrate the most catastrophic failures\textsuperscript{27}.

1.3.2 Prefabricated post and cores

Prefabricated posts can be either be made of metal or can be fiber reinforced posts. Metal posts are made of different alloys, which include Ni- Cr, stainless steel, gold or titanium. Metal posts have one common physical property, which is high modulus of elasticity\textsuperscript{28}. These materials are suitable for posts, however because of their rigidity, fractures can occur in the apical portion of the root\textsuperscript{28}.

Fiber reinforced posts are composed of fibers which can be carbon, glass, quartz or polyethylene, that are embedded in a resin matrix\textsuperscript{28, 29}. These posts have gained popularity because of their lower elastic modulus which is closer to dentin. In addition, fiber posts result in more favorable load distributions thus reducing the risk of root fracture.
1.3.2.1 Glass fiber posts

To form glass fibers, kaolin, limestone and caluminate are heated to 1600°C. According to their chemical composition they can be categorized in A (alkali), C (chemically resistant), D (dielectric), E (electrical), R (resistant) and S (high strength). Each of them has different mechanical and chemical properties. The E glass is used mostly because of good tensile and compressive strength. They also have good electrical properties and a relatively low cost\(^3\).

When compared to carbon posts, glass fiber posts are less stiff. They are more flexible than metal and carbon fiber posts, and are considered an advantage by some and disadvantage by others\(^{31, 32}\). Glass fiber posts have variable shades, enhanced mechanical properties and better biocompatibility. However, the worst disadvantage of these are that their diameters cannot be customized to fit the canal\(^{33}\). In our study teeth were restored using glass fiber post system.
1.3.3 Core build up

A core build-up is a restoration that is done on a tooth that has lost a significant amount of tooth structure\textsuperscript{34}. Core build-up materials restore bulk of the coronal portion of the tooth, so that an extra coronal restoration can be placed. An important property of these materials is to resist fracture as they receive multidirectional forces over the years. Pins, posts, and/or a bonding system are used to hold the core in position\textsuperscript{35}.

Core materials can be classified as direct materials or indirect materials. Cast post and cores are an example of indirect core build up. High copper amalgam, visible light cured resin composite, auto cured titanium containing composite, polyacid modified composite and resin-modified glass ionomer, are examples of direct core build up materials\textsuperscript{35}. In our study a dual-cured, glass-reinforced, radiopaque composite system was used as the core build up material.
1.4 CAD/CAM in dental practice

CAD-CAM systems consist of three components: a digital scanner, computer software, and a milling machine. The purpose of a digital scanner is to convert the geometry of the scanned area into data that can be used by a computer.

In order to make an accurately fitting restoration the steps involved require exactness and precision. Recent advances in dentistry have changed the way we make impressions to manufacture crowns. Digital impressions and computer-aided design/computer-aided manufacturing (CAD/CAM) systems have become common in dentistry.

Literature has suggested that crowns made using CAD/CAM technology can produce the same results as traditional approaches. Many CAD/CAM systems are available in the market for fabricating restorations. Studies have reported making digital impressions saves time when compared to conventional impression techniques. In addition, patients prefer to get their impressions digitally rather than having conventional impressions made. CAD/CAM systems reduce the cost of treatment and in addition reduce patient visits as the restorations can be milled and delivered the same day.
CAD/CAM technology can be used to make restorations with ceramics and composite resins. These materials are available in the form of blocks, which are ready to be milled. CAD/CAM materials and chair side systems have become popular because of their ability to fabricate restorations in a single appointment. CAD/CAM ceramics are manufactured under controlled conditions, characterized by uniform high mechanical properties that give them advantages over materials of similar composition used for laboratory fabricated restorations. This in turn limits the voids and volume defects making them more durable.

1.4.1 Advantages of CAD/CAM technology

- One of the biggest advantages of CAD/CAM technology is time. It saves time by eliminating laboratory steps.
- When comparing CAD/CAM blocks to restorations made in a lab, the number of voids and internal defects are minimal in CAD/CAM blocks.
- From a patient’s perspective, the number of visits are reduced as the restorations can be made in the office.
- Patients prefer digital impressions over conventional impressions because they find it more comfortable.
Another added advantage of CAD/CAM is the cost. After initial investment the cost of the restorations are minimal\textsuperscript{40}.

1.4.2 Disadvantaged of CAD/CAM

- One of the biggest disadvantages of CAD/CAM is the initial cost of the equipment\textsuperscript{41}.
- The blocks that are available are monochromatic making them less esthetic. The restorations often require characterization in order to make them more esthetic\textsuperscript{42}. However, polychromatic blocks are also become available.
- The biggest challenge of using intraoral scanners occurs when the finish line of the restoration is deep subgingival\textsuperscript{41}.

1.5 All ceramic restorations

There is an increased demand for esthetic procedures and hence all ceramic restorations have become popular. This is because of their more lifelike appearance, durability and biocompatibility. CAD/CAM materials and chair side systems have become popular because of their ability to fabricate such restorations in single a appointment\textsuperscript{43}.
The strength that is required for all ceramic restorations is achieved by materials with a greater percentage of crystalline phase. Even though this property increases the strength of the restoration it tends to increase the opacity, making them less esthetic\textsuperscript{44}. Based on the crystalline content all ceramic restorations can be divided into 3 groups\textsuperscript{45}.

- Predominantly glass with no crystalline phase: This group is the most esthetic, however as there is no crystalline phase this is also the weakest group mechanically\textsuperscript{46}.

- Particle filled glass: In this group filler particles are added in order to improve the mechanical properties. Many ceramics come under this group including leucite glass based, lithium disilicate glass ceramic, and glass infiltrated alumina based\textsuperscript{45}.

- Polycrystalline ceramics with no glassy phase: These ceramics have no glass content making them strong. However theses restorations are more opaque compared to the other groups\textsuperscript{45}.

In our study Lithium disilicate glass-ceramic (IPS e.max CAD) was used to make the crowns.
1.5.1 IPS e.max CAD (Ivoclar Vivadent, Schaan, Liechtenstein):

e.max is a lithium disilicate glass-ceramic. It is processed when it is in a partially crystallized state. During this state e.max has a characteristic bluish color. In this stage minor adjustments can be made to the restoration including sprue removal and checking the fit of the restoration. Following then, crystallization is done in a furnace which take roughly 20 minutes. This process significantly improves the flexural strength of the material and helps to achieve the desired tooth shade and translucency. e.max is commonly used for veneers, inlays, onlays, partial coverage and full coverage crowns and frameworks. Long term studies of 10 years have shown that e.max crowns show satisfactory results due to limited technical complications and failures.

Ivoclar Vivadent has strict recommendations for tooth reduction for e.max posterior crowns:

- At least 1.5 mm occlusal reduction for cusp tips and the central groove.
- Reduce the buccal or palatal/lingual area by at least 1.5 mm
• Prepare a circular shoulder with rounded inner edges or a chamfer at an angle of approximately 10 to 30 degrees. Ensure that the width of the circular shoulder/chamfer is at least 1.0 mm.

• For conventional and/or self-adhesive cementation, make sure that the preparation demonstrates retentive surfaces and a sufficient preparation height of at least 4.0 mm.

In our study based on manufacturers recommendations, all crowns were made with at least 2 mm of ceramic and 1 mm chamfer margin.

1.6 Endo crowns

Endo crowns are adhesive endodontic crowns and are characterized by crowns that are fixed to devitalized posterior teeth, which are anchored in the pulp chamber and have a supracervical butt joint49.

With advancements of adhesive dentistry, need for using posts and filling cores has become less evident. In addition, the advances in ceramics have improved their mechanical properties. These advances along with resin cements have made
it possible to restore posterior teeth without using post and cores. This makes it more predictable to restore posterior teeth that have lost significant tooth structure by means of onlay, overlay restorations or with endo crowns.\textsuperscript{49}

Endo crowns serve as an alternative to conventional treatment of endodontically treated teeth. These crowns extend in the pulp chamber and partially inside the root canal with a short endo-core. These can be made of either full composite or full ceramic overlays. They restore the coronal portion of the tooth either partially or completely, depending on the amount of tooth loss by extending inside the pulp chamber. This extension helps to stabilize the restoration inside the cavity during the cementation process and also acts as a retention feature.\textsuperscript{50}

Endo crowns have an advantage; they eliminate the need for post and cores, which weaken the tooth structure. In certain situations where there is an excessive loss of coronal tooth structure along with limited inter-arch space, and dilacerated or short roots, traditional post-and-core rehabilitation is impossible. These cases can be restored with Endo crowns.\textsuperscript{49} However even with all this information
there is limited information on how Endo crowns perform over time.

1.7 Cements

The purpose of dental cements is to retain restorations on prepared teeth, help in sealing the microgap present between the restoration and tooth. Cements have also been used in implant dentistry.

At present there are 5 types of cements available for permanent restorations, these include zinc phosphate, zinc polycarboxylate, glass ionomer, resin composite, and resin-modified or hybrid glass ionomer cements.

Zinc phosphate cement is one of the oldest cements. This cement does not chemically bond to the tooth and only provides mechanical retention making tooth preparation parameters critical. Zinc polycarboxylate cements chemically bond to the tooth, however they undergo significant plastic deformation after setting, making them unsuitable for cementing fixed partial dentures.

Glass ionomer cements chemically bond to the tooth by formation of ionic bonds at the tooth/cement interface. The
A drawback of this cement is its potential solubility in water. Resin-modified glass ionomer materials are hybrid materials. They are made of glass ionomer cement with a small supplement of light-curing resin. These materials exhibit properties in between the two having certain characteristics that are superior to glass ionomer materials\textsuperscript{51}. Resin cements have gained popularity in clinical use because of their ability to bond to tooth structure and to restorations. They have good mechanical properties and low solubility when compared to the other cements\textsuperscript{52}.

1.7.1 Resin cements

Resin cements have an advantage as they have high compressive strength, resistance to tensile fatigue, and are virtually insoluble in the oral environment. In addition, resin cements bond chemically to porcelain. They are the material of choice for esthetic restorations because they adhere to the restoration and tooth, have high strength, are insoluble in oral environment and can be used to match shade\textsuperscript{53}. The two main types of resin cements: adhesive-based resin cements and self-adhesive resin cements.
1.7.1.1 Adhesive based resin cements

These cements require an adhesive system to be used before cement placement. These cements can have classified as light-cured, self-cured or dual-cured, based on method of polymerization. They can also be either total etch or self-etch resin cement\textsuperscript{54}.

Light-cured adhesive resin cements have a benefit of increased working time as polymerization is under the control of the dentist. However, as light is needed for polymerization they are only used for cementation of laminate veneers or shallow inlays\textsuperscript{55}. Self-cured adhesive cements do not require light for polymerization and are used for cementation of metallic restorations, metal-ceramic restorations and posts. However, these cements have limited working time and color instability\textsuperscript{56}. Dual-cured adhesive resin cements are used when light transmission is possible. These dual-cured cements are polymerized and cure rapidly after the placement of the restoration, when the surrounding environment is devoid of ambient oxygen\textsuperscript{57}. 
1.7.1.2  Self-adhesive resin cement

Self-adhesive resin cements have the ability to adhere to tooth structure without the need for an adhesive or separate etching process. These cements are a combination of restorative composites, self-etching adhesives and dental cements\textsuperscript{58}. These cements do not need pretreatment of the tooth surface. Once they are mixed their application is very simple. These cements offer good esthetics, optimal mechanical properties, dimensional stability, and micromechanical adhesion. These cements are available as dual cure self-adhesive resin cements and hence can be used for all ceramic and metal ceramic restorations. Literature has shown that adhesion of self-adhesive resin cement either to dentin or various restorative materials is considered satisfactory and is comparable to other multistep resin cements currently available in market\textsuperscript{59}.

In our study Multilink cement (Ivoclar Vivadent) was used. It is an example of self-adhesive resin cement.
1.8 Purpose, Specific Aims and Hypothesis

1.8.1 Purpose
The Purpose of this study was to evaluate the fracture resistance and bond strength of crowns made with CAD/CAM technology on teeth restored with fiber post and core, and an e.max crown, and compare them to e.max Endo crowns.

1.8.2 Specific Aims
- The aim of this in vitro study is to compare the fracture resistance of all ceramic crowns (e.max) made with CAD/CAM technology using two techniques. Conventional crowns retained by fiber posts, and ENDO crowns that have an anchorage in the pulp chamber.
- The Second aim of this study was to compare the bond strength of all ceramic crowns (e.max) made with CAD/CAM technology using two techniques. Conventional crowns retained by fiber posts, and ENDO crowns that have an anchorage in the pulp chamber.
- The third aim of this study was to evaluate the failure patterns of the crowns after mechanical testing.
1.8.3 Specific Hypothesis

- If ENDO crowns are more fracture resistance than crowns fabricated by the conventional method (retained by fiber post), then Endo crowns will be able to resist more compressive and lateral forces before catastrophic failure behaviour.

- If ENDO crowns show better bonding behaviour than crowns fabricated by the conventional method (retained by fiber post), then Endo crowns are less likely to become debonded from the prepared tooth during anticipated clinical services.
Chapter 2

Materials and Methods

This study was approved by the institutional review board (IRB) of Nova Southeastern University. Thirty two maxillary premolars with complete roots were collected from Oral Surgery/Department of Periodontics at Nova Southeastern University College of Dental Medicine.

Inclusion criteria:

- Premolar having complete roots
- No fracture of root/ crown
- Teeth extracted atraumatically

Exclusion criteria:

- Caries extending 2mm above CEJ
- Teeth that are damaged near CEJ during extraction
- Dilacerated roots
- Root canal treated
- Old posts
- Treated with pulpotomy

All extracted teeth were cleaned first by scrubbing with detergent and water to get rid of any visible blood and debris. To disinfect the teeth, all teeth
were stored in 5.25% sodium hypochlorite solution for 1 week. Following disinfection, all teeth were stored until used. Teeth were not stored for more than 6 months after extraction. All universal precautions were followed when handling extracted teeth.

Teeth were randomly assigned into 2 groups. One group received the post and core then crown, and the other group received an ENDO crown (Figure 1). Teeth were fixed individually in brass cylinders using orthodontic acrylic (Dentsply Caulk Orthodontic resin).
Figure 1
Study groups
2.1 Endo crown preparation

After mounting the teeth in acrylic (Figure 2), the occlusal portion was reduced leaving only 2 mm of tooth structure which represents the biologic width (Figure 3).

![Figure 2](image1.png) Teeth mounted in acrylic

![Figure 3](image2.png) Endo crown preparation

Endo crown preparations involved opening of the access cavity using # 4 round carbide bur (FG 4 Henry Schein). This was followed by using # 557 burs (FG 557 Henry Schein) for removal of the pulp chamber roof, excessively retentive areas, and alignment of the pulpal walls (Figure 4). The finish line where the crown will seat was finished using a finishing diamond bur (856-018F Henry Schein). All preparations were done using a high speed handpiece (Kavo LUX M8900L) with water irrigation. The space for the ENDO crown was prepared in the pulp chamber only. Root canals were not used for retention or resistance of the crown.
and hence were sealed. Flowable composite resin (Natural elegance flowable nanohybrid composite, Henry Schein) was used to close the entrance of the canals. Preparations were finalized, allowing a path of draw without interferences. The smoothing and rounding of the internal angles of the margins started with a diamond bur (856-018F Henry Schein) and completed with polishing of the margins and internal angles with rubber cups. The internal portion of the pulp chamber was 3 mm deep, which was designed to provide retention for the crown. The outer walls of the pulp chamber were 2 mm only because of tooth structure being lost as part of deroofing the pulp chamber. The final endo crown preparation is shown in figure 7.

Figure 4
Burs used in Endo crown preparation
Figure 5
Flowable composite

Figure 6
Endo crown preparation

Figure 7
Final Endo crown tooth preparation
2.2 Conventional crown Preparation

For the conventional crown, after the teeth were secured in acrylic resin, occlusal reduction was done leaving 4 mm of tooth structure. 2.0 mm of tooth structure is for the ferrule and the remaining 2.0 mm is for the biologic width (Figure 8). Following occlusal reduction an access cavity was made using #4 round carbide burs (FG 4 Henry Schein). This was followed by using #557 burs (FG 557 Henry Schein) for removal of the pulp chamber. The axial tooth preparation was 2.0 mm buccal and 2.0 mm lingual reduction and a 1.0 mm chamfer finish line. Preparation was done with a coarse chamfer bur (856-018C Henry Schein) followed by a fine bur (856-018F Henry Schein) to finish the preparation (Figure 9). All preparations were measured by using depth grooves, and a high speed handpiece (Kavo LUX M8900L) was used under constant water irrigation. After axial reduction the canal was prepared for the post space with the bur included in the post system (SybronEndo Peerless post kit) (Figure 10). A slow speed latch type hand piece (Kavo intramatic 20E) was used to create the post space. A post length of 6 mm into the canal was used.
All the teeth received the post with 0.7 mm apical and 0.6 taper (Figure 11). After the post space was created the post was cemented and the core build up was done using ParaCore (Coltene Parapost ParaCore system) (Figure 12).
Figure 10
Post kit

Figure 11
Steps for placement of post
A root canal was not performed in any teeth, as we are not evaluating the apical seal. In addition, some gutta percha might have been left in the pulp chamber, which could have interfered with the bonding, in turn affecting the results of the study.

After post space creation, the tooth was dried, and non-rinse conditioner was used inside the canal and on the tooth for 30 seconds. Air was used to dry the conditioner. This was followed by mixing liquid A and B in a 1:1 ratio, which was then applied in the canal and on the tooth and air dried. Paracore white was luted around the post and in the canal, and the post was placed in the canal using cotton pliers. After the
post was placed more material was added in order to do the core build up. A curing light (SDI Radii plus) was used to cure the dual-cure material. The tooth preparation was then finished using a fine diamond bur (856-018F Henry Schein). The final tooth preparation had a 5mm height from the finish line (2 mm of ferrule and 3mm of core material). The procedure is depicted in figure 13-15

Figure 13
Conditioner for core build up
2.3 Crown design and milling

After tooth preparations were done, the specimens (teeth) were sent to the lab (Precision Esthetics, West Palm Beach). The specimens were transferred in moist environment so that teeth did not get dehydrated.

Preparations were scanned using a lab scanner (Degree of Freedom HD lab scanner, Korea). In order to scan the ENDO crowns, the intaglio surface of the tooth (pulp chamber) and the external walls of the tooth were scanned. For conventional crowns, the external walls including the core material and the finish lines were scanned. The scans were examined to make sure each restoration was identical in all dimensions. Once
all the margins and walls of the preparations were captured the crowns were designed.

2.3.1 Designing of crowns for compressive test

A maxillary premolar restoration was designed. For the conventional crown there was 2 mm of ceramic occlusally and uniform 2 mm of ceramic axially. This is the amount of reduction recommended by the manufacturer (Ivoclar Vivadent e.max). For ENDO crowns there was 3 mm of ceramic in the pulp chamber and 7 mm of ceramic from the margin of the restoration to the cusp tip. In such a way, both types of restoration had the same height. Axially there was just ceramic as there is no tooth structure in an endo crown (Figure 16).
2.3.2 Designing of crowns for Tensile retention test

A maxillary premolar restoration was designed for tensile retention testing. For this test there was a hole (2 mm in diameter) designed in the restoration which was used to pull the crown from the embedded tooth. The hole was designed using CAD technology and the crown milled with a hole, hence not compromising the strength of the specimen. For conventional crowns, there was 1.0 mm of ceramic below the hole and 3.0 mm of ceramic above the hole providing adequate strength for the material. For Endo crowns there was 1.0 mm of ceramic below the hole and 3.0 mm of ceramic above the
hole. Apart from this, the Endo crown had 3.0 mm of ceramic anchored in the pulp chamber (Figure 17).

![Digital crown designing for Endo crowns](image)

**Figure 17**
Digital crown designing for Endo crowns

All crowns were milled by the same lab technician at Precision Esthetics, West Palm Beach. Coritec 350i (Imes-icore) is a 5-axis milling machine that was used by the lab to mill e.max crowns for this study (IPS e.max CAD CER/inLab LT C4 A14). After the crowns were received from the lab the margin and fit were evaluated using a dental explorer. Multilink (Ivoclar vivadent) was used to cement the crowns.
2.4 Crown cementation

The crowns were dried and Monobond Plus was applied with a micro brush and left to react for 60 seconds before being air dried (Figure 18). On the tooth preparation, Multilink Primer A/B were mixed and was applied onto the entire bonding surface using a micro brush (Figure 19). This was started at the enamel surface with an application time of 30 sec. Excess Multilink Primer was removed with air. This was done until the mobile film disappeared. As the primer is self-curing, light-curing was not required. Multilink automix was dispensed from the automix syringe and was applied directly on the restoration. The restoration was seated and held in place using constant finger pressure for 1 min and simultaneously light cured (SDI Radii plus) for 1 min. (Figure 20). After the crown was cemented, excess cement was removed using a dental explorer (Figure 21). After cementation the crowns were stored in a moist environment for 24 hrs. before testing.
Figure 18
Monobond application on crown

Figure 19
Primer application on tooth
2.5 Cyclic fatigue test

Specimens were placed in a custom holder for the cyclic loading machine. The specimen holder was filled with distilled water in order to prevent dehydration of the teeth. The specimens were then placed in a Leinfelder type cyclic
wear tester (custom made for NOVA Southeastern University, Fl.) and secured in place using screws (Figure 22). The pistons were placed on the machine and adjusted for 75 N force. Each specimen was loaded at 75 N force for 100,000 cycles simulating approximately 1 year of function. It took approximately 26 hrs. to complete 100,000 cycles, and the specimens were monitored periodically. After completing the cyclic loading, the specimens were transferred to a universal testing machine. The first 16 samples were subjected to a compressive test and the following 16 samples were subjected to a tensile test. 

Figure 22
Leinfelder type cyclic wear tester
2.6 Compressive test

To test the fracture resistance, a specimen was placed obliquely on the base of a universal testing machine (Instron Fast Track 8800) at an angle of 30 degrees to the horizontal platform. The specimen was secured in place using fixation screws on the lower member. A compressive load was applied by means of a flat end metal rod attached to the upper member of the machine. The upper member was set at a speed of 1 mm/min until failure occurred, represented by fracturing and/or debonding of the tooth and/or crown (Figure 23,24).

The failure pattern was also being observed which included either fracture of conventional or ENDO crown, fracture of tooth, fracture of tooth with displacement, displacement without fracture of crown, or fracture of crown and tooth with displacement. Displacement was defined as loss of adhesion of conventional or Endo crown.
2.7 Tensile test

To test bond strength, specimens were put on the base of a universal testing machine (Instron Fast Track 8800) at an angle of 90 degrees from the upper member. Each specimen was secured in place using fixation screws on the lower member. A tensile load was applied by means of a hook (60-gauge stainless steel wire) that engaged through the hole created in the crown during milling. The upper member was set at a crosshead speed of 1 mm/min until failure occurred,
represented by fracturing and/or debonding of the tooth and/or crown.

Failure pattern was also being observed which included either by debonding of the crown, fracture of restoration, fracture of the tooth, debonding of the restoration with restoration fracture.

Figure 25
Universal testing machine to test bond strength

Figure 26
Close up view of specimens being tested for bond strength
2.8 Analysis

Means, and standard deviation were calculated for continuous measures. To compare outcome measures ANOVA was used. All significance levels were accepted at $p< 0.05$. 
Chapter 3

Results

Means and standard deviations were calculated for all continuous measures. To compare differences for the outcome measure debonding load and fracture resistance two Welch ANOVA models were created. R Studio and R 3.2.2 were used for all statistical analyses, and significance was accepted at \( p < 0.05 \).

In our study, tensile testing was performed to measure debonding load and compressive testing was performed to measure fracture resistance. The descriptive statistics are presented in table 1.

<table>
<thead>
<tr>
<th></th>
<th>Groups</th>
<th>N</th>
<th>M</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bond Strength</td>
<td>Tensile Force</td>
<td>8</td>
<td>166.35N</td>
<td>17.77</td>
<td>135.30N</td>
<td>191.70N</td>
</tr>
<tr>
<td></td>
<td>Conventional</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tensile Force</td>
<td>8</td>
<td>205.43N</td>
<td>47.58</td>
<td>148.70N</td>
<td>300.60N</td>
</tr>
<tr>
<td></td>
<td>Endo</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fracture Resistance</td>
<td>Compressive</td>
<td>8</td>
<td>737.90N</td>
<td>155.20</td>
<td>500.90N</td>
<td>1000.60N</td>
</tr>
<tr>
<td></td>
<td>Force</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Conventional</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Compressive</td>
<td>8</td>
<td>410.88N</td>
<td>71.78</td>
<td>313.50N</td>
<td>510.20N</td>
</tr>
<tr>
<td></td>
<td>Force</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Endo</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1
Descriptive statistics

The mode of failure was also observed. Table 2 shows mode of failure when bond strength was being tested using tensile
force. Table 3 shows mode of failure for fracture resistance when compressive force was being applied.

<table>
<thead>
<tr>
<th></th>
<th>Debonding</th>
<th>Fracture of Restoration</th>
<th>Fracture of Tooth</th>
<th>Fracture with Crown Fracture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>7 (87.5)</td>
<td>0 (0.0)</td>
<td>1 (12.5)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>Endo Crown</td>
<td>0 (0.0)</td>
<td>6 (75.0)</td>
<td>2 (25.0)</td>
<td>0 (0.0)</td>
</tr>
</tbody>
</table>

Table 2
Mode of failure for bond strength

<table>
<thead>
<tr>
<th></th>
<th>Fracture of Crown</th>
<th>Fracture of Tooth</th>
<th>Fracture with Displacement</th>
<th>Displacement without Fracture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>6 (75.0)</td>
<td>2 (25.0)</td>
</tr>
<tr>
<td>Endo Crown</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>8 (1.0)</td>
<td>0 (0.0)</td>
</tr>
</tbody>
</table>

Table 3
Mode of failure for fracture resistance

Compressive force required to test fracture resistance for conventional crowns is depicted in figure 27 and compressive force required to test fracture resistance for Endo crown is shown in Figure 28.
Figure 27
Fracture resistance of conventional crowns

Figure 28
Fracture resistance of Endo crowns
Tensile force required to test bond strength for conventional crowns is depicted in figure 29 and tensile force required to test bond strength for Endo crown are shown in Figure 30.

Figure 29
Bond strength of conventional crowns
There was a significant difference in the measurement of debond load strength by group $F(1,14) = 4.73$, $p = 0.047$, eta-squared = 25% - meaning 25% of the variability in bond strength was accounted for by the differences in groups. Endo crowns had significantly more bond strength than Conventional crowns -- difference was 39.1 (95% CI:0.55,77.59). Hence Endo crowns needed more tensile force for dislodgement/breaking when compared to conventional crowns.

Figure 31 is a plot of Tensile force by Treatment Group. The blue bars are confidence intervals for the means, and the red arrows are for the comparisons among groups.
There was a significant difference in the measurement of fracture resistance by group $F[1,14] = 29.26, \ p < 0.001, \ \text{eta-squared} = 68\%$ – meaning $68\%$ of the variability in compressive force was accounted for by the differences in groups. Conventional crowns had significantly more fracture resistance than Endo crowns -- difference was $327.01 (95\% \ CI:456.68,197.34)$. Hence conventional crowns needed more compressive force for dislodgement/breakage when compared to Endo crowns.
Figure 32 is a plot of Compressive Force by Treatment Group. The blue bars are confidence intervals for the means, and the red arrows are for the comparisons among groups.
This study tried to find if Endo crowns can withstand more compressive load than crowns over a fiber post and core. In addition, this study attempted to find if Endo crowns need more tensile force for debonding/breakage since they are anchored in the pulp chamber when compared to crowns cemented on teeth with a post and core.

Endo crowns are fabricated when teeth have no ferrule. Literature has reported that teeth should not be restored if there is no ferrule\textsuperscript{60}. Various values for the amount of ferrule varying from 0.5 mm to 3.0 mm have been suggested\textsuperscript{60,61}. However, at present a 1.5 to 2 mm of ferrule is considered optimal. Literature has also reported that beyond 3 mm the amount of tooth structure does not display a significant improvement in abutment fracture resistance\textsuperscript{61}. In our study for conventional crowns 2 mm of ferrule was used.

Literature has reported that during mastication, a molar should be able to withstand loads ranging from 60 to 200 N\textsuperscript{62}. In our study, premolars were used and they were subjected to cyclic loading of 100,000 cycles with a load of 75 N. Cyclic
loading is the repeated loading of a specimen. After cyclic loading teeth were placed in a universal testing machine at an angle of 30 degrees. Previous studies have used various angles for testing compressive failure load of crowns ranging from 30 degrees to 45 degrees\textsuperscript{62, 63}.

In our study, when testing compressive load to failure, we found that Endo crowns fractured at lower values when compared to teeth restored with post and core followed by crown placement. A study done by Biacchi et al, tested Endo crowns on molars, with crowns placed on teeth restored with a glass fiber post and core. They found that Endo crowns needed more force to fracture when compared to conventional crowns. However, this study was done on molar teeth which have more tooth structure compared to premolars\textsuperscript{49}. A study done by Guo et al compared endodontically treated mandibular premolars restored with endo crowns to teeth restored by glass fiber post and core retained conventional crowns. This study found that Endo crowns had no advantage in fracture resistance when compared to conventional crowns. The study concluded that “both of the two methods cannot rehabilitate endodontically treated teeth with the same fracture resistances that intact mandibular premolars have\textsuperscript{64}.” In Guo et al study, the conventional crowns had 1.5 mm of ferrule, as compared to our
A study done by Shibri et al found that Endo crowns made of IPS e.max showed lower fracture resistance than e.max crowns on teeth with fiber post and core\(^6\). Finite element and Weibull analyses to estimate failure risks in ceramic endo crown and classical crown for endodontically treated maxillary premolar was done with Lin. He found that probability of failure of Endo crowns and conventional crowns is similar\(^6\). The results of our study are consistent with Shibri et al. In this study it was also found that endo crowns fractured before conventional crowns. However, the results imply that this is correlated to the amount of tooth structure remaining. Whenever there is not enough tooth structure left around the access opening, we believe endo crowns are not a good treatment option. Biacchi et al reported good success with Endo crowns in molars\(^4\), and this could be because of the amount of remaining tooth structure.

When the mode of failure was analyzed for fracture resistance (compressive force), of conventional crowns with a post and core, most of the specimens experienced fracture of the tooth with displacement of the crown (75\%) (Figure 33) while some of the other specimens had displacement of the crown without fracture of the tooth or restoration (25\%) (Figure 34). For
conventional crowns, fracture of the restoration was not observed in any of the specimens.

![Figure 33](image1.png)  ![Figure 34](image2.png)

Figure 33  Fracture of tooth  Figure 34  Debonding of crown

When looking at the mode of failure for Endo crowns in all of the specimens (100%), the tooth fractured, and the restoration came out (Figure 35). Just like the conventional crowns, no fracture of the restoration was observed. Debonding only was not observed. Debonding was only seen when the tooth fractured. Teeth always fractured towards the side of the force. The findings of this investigation are similar to studies done in the past. Guo et al, found that failure mode of both the Endo crowns and the conventional crowns done on mandibular premolars were unfavorable. Biacchi et al, found that for Endo crowns 90% of the failures involved fracture of the tooth or restoration with displacement (loss of adhesion) of the Endo crowns, and for conventional crowns
80% of the failures involved fracture of the tooth or restoration with displacement (loss of adhesion) of the conventional crown.

Figure 35 (a) Fracture of the tooth

Figure 35(b)

The other portion of this study was to test the tensile strength for crowns restored on teeth with post and core and compare them to Endo crowns. There is very limited information in the literature about debonding of e.max crowns that are bonded on endodontically treated teeth with post and core. In addition, there is no prior articles based on our literature review, which reports de-bonding of Endo crowns.

When testing de-bonding, we found that conventional crowns with a post and core had a lower de-bonding load compared to Endo crowns. We found that in most cases the Endo crowns needed more force to dislodge/break the crown, except when
the tooth fractured apically to the crown. Simon et al did a study to measure the force required to remove ceramic crowns with high taper angles made by CAD/CAM technology. They used several cements to bond the crowns on the tooth, and found that for many cements, the bond strength surpassed the tensile strength of the ceramic crown. They found that the crowns fractured before the cemented part of the crown came off the tooth. However, in this study they did not mention the ceramic thickness for retention tests. In the current study, in order to prevent crown fracture, the amount of ceramic above the hole was fixed at 3 mm. We were not able to compare the results of de-bonding load of Endo crowns with any other studies, as there is no published data based a review of the literature.

When comparing the mode of failure for de-bonding (tensile force), it was found that for Endo crowns in most of the specimens the restoration fractured from the tooth (75%) (Figure 36) and in the remaining 25% there was fracture of the tooth (Figure 37). It was observed that when the tooth fractures, the values of debond load (mean: 150.2 N) were comparatively lower than when the restoration fractured (Mean: 223.84 N). Whenever a restoration fractured, it was observed that the extension of an Endo crown that extends
into the pulp chamber was retained on the tooth, while the coronal portion fractured off (Non-catastrophic fracture). In cases when the tooth fractured, fracture occurred at the root level making the tooth non-restorable.

Figure 36
Restoration fracture

Figure 37
Tooth fracture

When looking at failure mode for conventional crowns, it was found that in 87.50% the crown debonded (Figure 38) and in
the remaining 12.50% the tooth fractured (Figure 39). It was interesting to note that when a crown de-bonded, most of the core material was still attached to the crown. It was found that more catastrophic failures occurred with Endo crowns in debond testing when compared to conventional crowns. During testing there was porcelain chipping seen on some of the specimens, but none of the crowns broke completely, and we attribute this to having enough ceramic thickness beyond our hole. It was not possible to compare these results to other studies, no studies were found in the literature that compared similar parameters.

Figure 38
De-bonding of crown
Based on the results of this study, it is concluded that since Endo crowns have less fracture resistance and higher bond strength compared to crowns placed on a post and core, they should be used based on clinical judgement. Endo crowns can be recommended when there is sufficient tooth structure surrounding the access opening, especially in molars. These crowns however should be avoided in patients who have parafunctional habits, as they have less fracture resistance. These 2 factors aren’t the only considerations when selecting the type of restoration. A sound clinical judgement should be used in determining which restoration will be better for a particular case, as both restorations showed favorable results in our study.
Chapter 5

Bibliography


7. Dietschi D, Duc O, Krejci I, Sadan A. Biomechanical considerations for the restoration of endodontically


20. Santos Pantaleon D, Morrow BR, Cagna DR, Pameijer CH, Garcia-Godoy F. Influence of remaining coronal tooth


