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Clinical Performance of CAD/CAM Versus Conventional Ceramic Restorations on Posterior Teeth: A Retrospective Study

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CLINICAL PERFORMANCE OF CAD/CAM VERSUS CONVENTIONAL CERAMIC RESTORATIONS ON POSTERIOR TEETH: A RETROSPECTIVE STUDY

A Thesis Presented

By

SALEH ALMUKHLIS D.D.S

Submitted to the College of Dental Medicine of Nova Southeastern University in Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE

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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.Sc. degree and for this assignment.

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Dedication

I would like to dedicate this thesis to my wife, who has supported me and stood by me the past three years. Her unyielding support and dedication to my comfort has been exemplary. I would also like to dedicate this thesis to my parents who were supportive every step of the way, I would not be here without them.

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DEGREE DATE:

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Abstract

Brief Background: The utilization of CAD/CAM technology for dental restorations has various benefits over conventional techniques. These benefits incorporate speed, convenience, quality, and eliminate needing a temporary crown. However, failure of dental restorations is a major issue in dental practice, it needs to be quantified and considered against the benefits here stated.

Objectives: To evaluate the clinical performance of ceramic conventional and chairside CAD/CAM Onlay/ crowns placed on posterior teeth by postgraduate student in Operative department.

Methods: This retrospective study employed patient record data stored in AxiUm. In total, 78 CAD/CAM all ceramic crowns/ onlays and 429 all ceramic conventional crowns/ onlays were placed on posterior teeth in 225 patients at the Postgraduate Operative clinic at Nova Southeastern University from 2012 to 2018. These restorations were evaluated using the information on the patients AxiUm records. Specifically, information from the medical records of patients attending the clinic from 2012-2018 were employed to determine the survival time of the crown(s) or onlay(s) by fabrication method. A query was conducted in AxiUm to identify all patients who received the restorations of interest from 2012-2018 and examined, across time, to determine if a restoration(s) was replaced or scheduled for replacement. Restorations

replaced or scheduled for replacement were coded as failed restorations. A cox proportional-hazards model regression analysis was employed to determine the association between the survival time of crowns by fabrication method and selected predictor variables.

Results: Results from the analysis of the data indicated that 429 (84.6%) restorations were fabricated conventionally, and 78 (15.4%) restorations were fabricated via CAD/CAM system. The majority of the patients were female (n=149, 66.2%), while 33.8% were male. Close to half of the patients were designated at or above high caries risk level (47%) and 53.8% of the patients were not using high fluoride toothpaste and/or mouthwash. Molar teeth were most frequently restored (59.5%) while (40%) were premolar teeth. Furthermore, 48% of the patients presented with multiple restorations. There were 19 failed restorations which is equivalent to an overall failure rate of approximately 4% for the restorations placed from 2012 to 2018. Of the 19 failed restorations only two were CAD/CAM fabrications. Overall, the amount of failed restorations was proportionally higher in males, specifically, 88.2% (n=15). The majority of the failed restorations were distributed between the high (n=6) and low (n=10) caries risk groups. There were no significant differences in the survival of crowns across fabrication method and overall survival rate from 2012-2018 was 96%. Results from the Cox regression analysis indicated that gender and high fluoride were associated with survival. In our study, gender was associated with survival time, particularly; the risk of crown failure for females was 5 times higher than for males. Additionally, the risk for crown failure for cases using high fluoride oral treatments was lower than for the group who did not use high fluoride treatment. Although not significant, cases with multiple crown restorations were 5 times more likely to fail.

Conclusion: Our findings suggest there are no significant differences between the survival rate of CAD/CAM restorations and conventional restorations. Care needs to be taken in case selection when recommending these crown restorations, particularly multiple crown restorations, gender and use of high fluoride.

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Chapter 1:Introduction

1.1. Ceramics

1.1.1. Overview

The introduction of tooth-colored restorations fabricated from composite resin or ceramic has resolved many of the esthetic concerns that patients have expressed about the use of silver amalgams or gold alloys. [1] Patients' requests for exceedingly esthetic restorations and patients' concerns about the side effects of the use of dental amalgam for dental restorations have prompted and expanded enthusiasm for the utilization of all-ceramic inlays and onlays to reestablish posterior teeth. [1-4]

Ceramic materials are a good choice for dental restorations because they can mimic the appearance of natural teeth. However, two things have limited the use of ceramics in the fabrication of dental prostheses: 1) brittleness that cause a lack of mechanical reliability and 2) these restoration required more effort and time for processing in comparison to metal alloys and dental composites. New advances in ceramic processing methods have made the work easier for the dental professionals to work with ceramic-made dental restorations and involve better quality control processes resulting in ceramic materials with raised mechanical reliability. As a result, the proportion of restorative treatments using all-ceramic prostheses is quickly growing.[5]

As previously mentioned, ceramic materials have been considered a great choice for dental restorations among patients with highly esthetic demands since these restorations, meet patients standards of appearance coupled with wear resistance, especially in the case of wide posterior restorations.[5] Moreover, ceramics with high flexural strength are also an option for restorations in patients with complicated dental

prostheses needs.[5, 6]

Failure of dental restorations is a major issue in dental practice, especially in the treatment of adults. Hence, placement and replacement of restorations still constitutes the real workload in general dental practice. [7, 8] The clinical assessment of restoration failures varies as indicated by the diagnostic criteria and is commensurate with the variability among operators.

Broad concerns about ceramic restorations are restoration failures from cyclic loading, material flexure, and propagation of fractures inherent in the ceramic material [9, 10] Furthermore, ceramics made by different laboratory techniques, while the composition is similar, prompts the possibility of encountering manufacturer differences, for example, different division of flaws, depth of translucency, and the fit. These differences are important to the dentist because they can lead to the poor clinical performance of crowns and onlays. [5]

1.1.2. Ceramic Materials and Fabrication of Dental Ceramic Restorations

Ceramics fall into three main composition categories: predominantly glass, particle –filled glass and polycrystalline. Predominantly glass ceramic materials are considered highly esthetic and optical effects are controlled by adding small amounts of filler materials. Particle-filled glass ceramics employ the addition of filler particles to the glass matrix, thus, improving its mechanical properties. Fillers can be crystals produced when glass is exposed to high temperatures. Polycrystalline ceramics are not glass products: instead, atoms are packed into a crystalline arrangement less susceptible to crack propagation. Noted is that glass-based ceramics are the preferred materials for dental restorations because they exhibit strength and meet esthetic standards. [10]

There are different techniques for the fabrication of dental restoration prosthesis, such as, the powder condensation (conventional powder slurry ceramics), hot pressing (pressable ceramics) methods, slip casting and CAD/CAM.[11, 12]

The powder condensation ceramic fabrication process is the traditional method for making ceramic prosthesis. This fabrication method involves the addition of water to create a slurry, that is build up in layers on a die material to make the shape and contours of the restorations.[10] One of the biggest problems related to the conventional powder slurry ceramic (sintered ceramic) restorations is the presence of microporosities that evolve during the fabrication process.[13] These microporosities can initiate and cause the development and propagation of cracks, which may result in the development of fractures in the ceramic restoration. [13]Ceramics made by powder condensation can be made with different translucency and shades with characterizing stains and glazes.[10]

Pressable ceramics are accessible from makers as pre-assembled ingots made of crystalline particles conveyed all through a smooth material. The microstructure is comparative to that of powder porcelains, however, the level of porosity in pressable ceramics is lower than in powder porcelains fabrications, and thus pressable ceramics have a higher crystalline appearance because the ingots are made from non-permeable glass ingots by applying a heat treatment that changes a portion of the glass into a crystal. Specifically, the pressable ingots are heated to a temperature transforming the ingots to a viscous fluid. The viscous fluid is gradually pressed into the lost wax molds. Among the benefits of the hot pressing technique is that dental technicians are typically experienced at accomplishing great exactness of fit utilizing the lost wax strategy with metal alloys.[14, 15]

Ceramics that undergo a crystalline particle have bigger resistance to fracture. [9] IPS Empress® and IPS Empress 2® (Ivoclar Vivadent) are representatives of materials fabricated by the hot pressing technique.[16-18]

The slip casting fabrication method involves forming a mold of the desired framework geometry and pouring a slip into the formed mold. A gypsum mold is usually employed because it allows water extraction from the slip. The slip then becomes compacted against the mold forming a framework. The framework is removed from the mold by partial sintering. In-Ceram Alumina belongs to the family of products created by the slip casting technique. In this case, the slip is painted on a gypsum die with a brush to create the underlying core for the ceramic tooth. The water is removed through capillary action of the porous gypsum packing the particles into an inflexible network. The alumina core is then barely sintered in a heater to create an interconnected porous network. Then, glass powder is placed on the core; the glass becomes liquid and flows into the pores by capillary action to produce the interpenetrating network. Finally, porcelain is placed on the core to create the final form of the restoration.[10]

Ceramics created by slip casting can have higher fracture resistance than those delivered by powder condensation because the reinforcing crystalline particles shape a persistent system all through the structure. The constrained use of slip casting in dentistry is presumably because it requires what professionals perceived a muddled arrangement of steps, which give a test to accomplishing exact fit.[14, 15, 19]

1.2. CAD/CAM Technology

1.2.1. Overview

In the last 25 years, Computer-aided design (CAD) and computer-aided

manufacturing (CAM) has become a popular method for the fabrication of inlays, onlays, veneers, crowns, fixed partial dentures, implant abutments, and even full-mouth reconstruction of crowns.[8,20] These technologies can be used in both, the dental lab and the dental office settings.[8] CAD/CAM is additionally being used in orthodontic settings.[8] CAD/CAM technology was developed responding to three fundamental concerns in the field of dental restoration, that is, the quality of the restoration, the appearance of the restoration and the feasibility of the fabrication and restoration process.

CAD/CAM, at times, offers to patients the possibility of a one-time-appointment restoration. Dentists have the option to either mill restorations using CAD/CAM technology in their office or they can take a digital impression of the affected tooth or molar, send it to a laboratory to manufacture the restoration. Once the dental laboratory receives the digital impression, they can make a stone model and either proceed with the traditional fabrication or they can use CAD/CAM technology to fabricate the restoration. The dental laboratory can produce the dental restoration with the necessary specifications from digitized computer images.[6]

1.2.2. CAD/CAM Materials

Numerous resin composite and ceramic materials are available for CAD/CAM dental restorations. Overall, All materials are supplied as pre-made solid blocks. These blocks are created from powder that are blended with a binder and then pressed into a mold or force out into a block form.[13]

Resin composite materials include Paradigm MZ100 (3M ESPE) and,Vita CAD-Temp (Vident) and Telio CAD (Ivoclar Vivadent) two materials for provisional or temporary. The Paradigm MZ100 blocks are polymers containing 85% zirconia-

silica filler particles by weight. Vita CAD-Temp is a highly cross-linked, microfilled polymer and Telio CAD is a millable cross-linked polymethylmethacrylate block for temporary crowns and fixed partial dentures.[21]

Empress CAD is depending on the pressable Empress and the microstructure of this material has the same of a feldspathic glass with about 45% leucite crystal component. Furthermore, these blocks is available in monochromatic and polychromatic stacked shades, also the strength properties of these blocks are similar to Vitablocks.[13]

In addition, machinable ceramics such as IPS e.max CAD have been created for use with computer-aided design and computer-aided manufacturing (CAD-CAM) applications, either chairside or in the laboratory. [22] Moreover, the IPS e.max block is not fully crystallized, which helps to enhance milling time and lower chipping risk from milling. To develop full crystallized blocks, the milled restoration needs to be heated for 20-30 minutes to crystallize the glass and create the final shade and the desired mechanical properties of the restorations.[13]IPS e.max Press and IPS e.max CAD (Ivoclar Vivadent AG) are examples of particle-filled glass ceramics that contain high concentrations of lithium disilicate crystals for enhanced mechanical properties and the e.max block has several translucencies.[16]

Yttrium-oxide–partially stabilized zirconia (Y-TZP) has gained popularity as a metal-free restoration [23]and Y-TZP crowns can be fabricated by computer-aided manufacturing (CAD/CAM) systems.[24, 25] Such restorations are often used due to their esthetics properties, biocompatibility, and strength [26]while also allowing for the use of traditional cementation procedures.[27]

1.2.3. Advantage of CAD/CAM Technology

The utilization of CAD/CAM technology for dental restorations has various benefits over conventional techniques. These benefits include incorporate speed, convenience, quality, and the elimination of placing temporary crown.

CAD/CAM technology has been researched and there are many published studies that cover the benefits and disadvantages of using this technology for the fabrication of dental restorations. For example, a randomized clinical trial investigation was done by Ahrberg et al, The purpose of this study was to examine the marginal and internal gaps of CAD/CAM zirconia crowns using direct versus indirect digitalization (using conventional polyether impression with Impregum pent soft). Also, the working time for each group (conventional vs digital impression) was compared. The direct digitalization showed a smaller marginal gap (61.08 μm) and consumed less working time (less 1 minutes and 34s) when compared to the indirect digitalization method (70.40 μm).[28]

The literature highlights the benefits of CAD/CAM technology as a more effective time procedure and thus more cost effective for the dentist and the patient. Furhermore, CAD/CAM offer the possibility of a speedier restoration process for the patients and a more comfortable way to collect patients' dental impressions avoiding the use of gag-inducing impressions typically used in traditional dental restoration methods.[6, 28] The survivability of CAD-CAM onlays has also been studied, noting that marginal fits accomplished by the use of CAD/CAM technology are if not better but at least equally as good as those observed in conventional fabrication methods.[29-31]

1.2.4. Disadvantage of CAD/CAM Technology

There are also disadvantages associated with the use of CAD/CAM technology

that has been documented in the literature. For example, the underlying expense of the equipment and programming is high, and the dentist needs to invest time and money on training.[32] Dentists without a sufficiently volume of restorations will not see their investment pay off in a reasonable amount of time. As with traditional impressions, the dentist needs to produce an exact recording of the tooth in need of restoration. The scan needs to capture the finish line and absolutely copy the surrounding and occlusive teeth.[6]

Other disadvantages cited in the literature are that the original porcelain blocks used in CAD/CAM dental restoration fabrications were monochromatic. These blocks did not include intrinsic staining, translucency, or opacity, it is not easy to gain an exact color match. Monochromatic blocks do, however, meet less demanding esthetic requirements, such as those for posterior restorations.[33]

1.2.5. Clinical Performance of CAD/CAM Restorations

One way to measure the success of CAD-CAM technology for full-coverage restoration is to examine their short and long-term survival compared with those fabricated using traditional impressions. However, there is a paucity of clinical research published about the survival rate of CAD/CAM restorations when compared to those restorations fabricated by conventional methods. Up to date, there is one study that examines the survival rate of CAD/CAM restorations at 10 years of placement and remaining similar studies span an examination period from one to five years from placement of the restoration. Thus, it is possible to gain information about the study designs, materials and methods used, sorts of restorations fabricated, and the outcomes of these researches to see how well CAD/CAM restorations function over time.

Among the few studies available in the literature that examined the survival rate

of CAD/CAM restorations when compared to those restorations fabricated by conventional methods, is a systematic review published by Wittneben et al, aimed at determining the long-term clinical survival rates of single-tooth restorations fabricated with computer-aided design/computer- assisted manufacture (CAD/CAM) technology, as well as the frequency of failures depending on the CAD/CAM system, the type of restoration, the selected material, and the luting agent. A total of 16 articles representing 14 prospective and 2 retrospective studies were selected for data analysis. A total of 170 failures were identified, resulting in an overall survival rate of 91.6% after 5 years. The author concluded that there were no significant differences between the failure rates of the different CAD/CAM systems assessed in this study. However, glass-ceramic restorations had a substantially higher failure rate than all other materials Glass-ceramic restorations exhibited a significantly higher failure rate than feldspathic porcelain ($P < .001$, 18.18% versus 1.19%). Restorations composed of ceramic with aluminum oxide, ceramic with aluminum and magnesium oxide, and a resin-based composite were not significantly different from the feldspathic restorations. “Endo” crowns (crowns that extend into the pulp chamber as one piece) showed a significantly higher failure rate than any other type of restoration ($P = .026$, 3.90%). The luting cements did now not appear to affect the failure rates.[34]

In a randomized clinical trial study by Cehreli et al, the investigators compared the clinical performance of slip-cast glass-infiltrated alumina/Zirconia and CAD/CAM Zirconia all-ceramic crowns. In this study, thirty InCeram Zirconia (Slip-casting zirconia) and thirty Cercon Zirconia (CAD/CAM crown) crowns were made and placed in twenty patients with baseline, 6-months, 1- year, and 2- year recall. Marginal integrity, anatomic form, and color and surface were assessed according to California Dental Association quality evaluation system. InCeram Zirconia was rated excellent

(73%) compared to Cercon Zirconia (80%) in marginal integrity. Regarding to color and surface, this study reported a slight color mismatch to adjacent teeth higher for InCeram Zirconia (66%) compared to Cercon Zirconia (26%). For anatomic form, four InCeram Zirconia had slightly undercontoured (26%) while one Cercon Zirconia crown had slightly undercontoured. [35]

Another systematic review publsihed by Carvalho et al, assessed the clinical performance of single-tooth restorations fabricated with CAD/CAM technology with a minimum follow-up of three years. Reported failures were assessed by CAD/CAM system, type of restoration, restorative material, and luting agent. This systemic review was published in 2016 and there was no lower time frame for this study, and reported for identified studies through MEDLINE Pubmed for 1,475 articles. The criteria for inclusion in this systematic review were articles published in English, in vivo studies, minimum follow-up of 3 years, and subjects were adults aged above 18 years old. In this study, the relevant and chosen literature revealed an overall survival rate of 87.5% after 5 years and an estimated failure rate of 2.17% per year. Regarding the restoration type, crowns ($P < .001$; 2.61%) and endo crowns (crowns that extend into the pulp chamber as one piece) ($P < .001$; 2.56%) had a significantly higher failure rate than all other investigated restorations when compared with inlay/onlay restorations. Inlay/onlay restorations had a higher 5-year survival rate (90.9%), while reduced crowns had the lowest (86.4%). The survival rates after 5 years for core crown (87.7%), crown (87.8%), and endo crown (88.0%) restorations were quite similar. The study outcomes by type of material showed a low failure rate for glass-matrix ceramics compared to polycrystalline ceramics ($P < .001$; 1.79% vs 4.07%). The highest 5-year survival rate was obtained by glass- matrix ceramics (91.4%), followed by resin-matrix ceramics (82.5%) and polycrystalline ceramics (81.6%). The results by

type of ceramic showed that resin-matrix ceramics (3.85%; 95% CI: 1.16% to 12.77%) and poly- crystalline ceramics (4.07%; 95% CI: 1.69% to 9.81%) had the highest failure rates. Among the CAD/CAM systems used, KaVo ARTICA SYSTEM (17.21%) and Lava (3M ESPE) system (4.02%) appeared significantly higher failure rates compared to CEREC 2 (2.03%).[36]

Gherlone et al, conducted a 3 years retrospective study of clinical performance for zirconia crowns made from intraoral digital impression. Eighty-six crowns were included in this study. After the three-year observation, sixty crowns had no any issues. However, the chipping rate increased gradually within the three-years follow up (9.3% after 12 months, 14% after 24 months, and 30.2% after 36 months).[38]

Seydler et al conducted a study; his study evaluated 2 different types of CAD/CAM ceramic crowns (crown in veneered zirconia, monolithic lithium disilicate) at 2 years of placement. Sixty crowns were placed in a private practice and randomly distribute to 2 groups (crown in veneered zirconia, monolithic lithium disilicate). Two endodontic problems were found in both groups in the first year of the examination. In both of the groups, no caries or marginal discoloration, ceramic or tooth fractures occurred after two years services. [39]

Weidhahn et al, evaluated 617 porcelain laminate veneers in 260 patients for up to 9.5 years (mean = 4.7 ± 1.98 years). All restorations were fabricated using CEREC 1 and placed by a single practitioner. The authors reported a 97.8% survival rate. Reasons for failure were noted as porcelain surface defects requiring replacement, tooth fracture, and defective margins. In this study, the operator who placed the restorations was also the examiner through 9.5 years of follow-up.[40]

In a retrospective study, Zimmer et al, stated the survival rates of 23 ceramic onlays and 203 inlays placed using CEREC 1 in a private practice between 1992 and 1994. A total of 23 failures were noted over 10 years. Reasons for failure included seven cases of secondary caries, ten restorations lost, four restorations fractured, and two teeth fractured. Overall survival rate at 10 years was 85.7%.[41] These studies present there are fracture problems and marginal wear concerns in ceramic crowns in spite of the fabrication method.

The studies cited above point to CAD/CAM survival rates exceeding 85% up to 10 years post placement. [38,41,43,46]However, researchers here cited called for more investigations about the survival rates of dental restorations comparing to conventional fabricated methods.

1.3. Clinical Performance of Conventional Ceramic Restorations

The most common failures reported in clinical studies are associated with fracture of the ceramic restoration and degradation of adhesive interface. [42-45] Internal and external dental restoration defects are in many case the origin of cracks, which can spread and prompt calamitous failure. [46, 47] Other vital factors, for example, the design of the cavity preparation, the shape of the restoration (least thickness: 1.5 mm) and the inner fit, impact the strength of the ceramic restoration. Careful selection of the best dental restoration approach for patients with conditions such as bruxism increases the probability for ceramic onlay success. Furthermore, preparation dimensions have a critical effect on the fracture resistance of all-ceramic restorations.[47]

Inability to accomplish essential cavity measurements may contribute more to failure by fracture than the nature of the ceramic system. Wear of the resin cement in the luting gap results in marginal deterioration of ceramic restorations, particularly in

the primary years after restoration placement. [48, 49]Moreover, deterioration of the marginal integrity has been associated with luting agent wear, which tends to rise over time due to high differences in modulus of elasticity between ceramic and resin luting materials.[50, 51]

Fracture has been related to crack propagation through the ceramic restoration due to the fragile characteristic of the ceramic material. The long-term performance rates of adhesively bonded ceramics restorations have been reported to range from 76% to over 90%, [52, 53] with bulk fracture and marginal discoloration as the most common results of failures. [54]

Ortorp et al, assessed the clinical performance of 205 Nobel Procera zirconia crowns placed in private office from 2004 to 2005 with a five-year follow up. The crown was considered as failure in this study when the crown lost the retention that means could not be re-cemented, restoration fractures, and presence of secondary caries. A total of 143 restorations had been evaluated at the full 5- year follow up, 126(88%) had no any issues, 40 crowns had some issues (19%) included root fracture, endodontic problem, porcelain fracture, and loss of retention. According to this study, zirconia crowns are recommended in the premolar and molar regions.[55]

1.5. Current Study

1.5.1. Purpose of The Study

Failure of dental restorations is a major issue in dental practice, especially in the treatment of adults. As new technologies are developed and used for manufacturing dental restorations, the literature points to concerns about ceramic restoration failures from cyclic loading, material flexure, and propagation of fractures inherent in the ceramic material [9, 10] Furthermore, ceramics made by different laboratory techniques,

while the composition is similar, prompts the possibility of encountering manufacturer differences.[5] As such, the purpose of this study was to compare the survival rates of CAD/CAM and conventional ceramic crowns placed in patients at Operative Postgraduate clinic in Nova Southeastern University from 2012 to 2018.

1.5.2. Specific Aims

I. To describe demographical and clinical characteristics of patients who received these crown/onlay restoration(s) at the clinic from 2012-2018.
II. To determine the number of failed ceramic crown/onlay restorations placed by PG Operative residents from 2012-2018.
III. To compare the survival rates of CAD/CAM and conventional ceramic crowns placed in patients at Operative Postgraduate clinic from 2012 to 2018 controlling for demographical and clinical characteristics.

1.5.3. Null Hypotheses

I. There are no significant differences in the survival rates of CAD/CAM ceramic restorations over conventional ceramic restorations.
II. There are no significant differences in the survival rates of dental restorations by demographical or clinical characteristics.

Chapter 2: Materials and Methods

2.1. Background Information

Following is background information about the procedures that were employed in the selected clinic for this study to create the patient treatment plan and/or plan of service for the patients serviced from 2012-2018. After an oral examination and detailed evaluation of the patient was completed, a determination was made by the attending resident indicating the type of dental restoration, specifically, all-ceramic CAD/CAM (crown/onlay) restoration or ceramic conventional (crown/onlay) restoration. The decision of the type of restoration was based on: location of tooth, remaining tooth structure, position of the margins (subgingival or supragingival). Furthermore, additional information was collected to determine if the patient preferred a one-appointment visit, no temporary restoration, and further patients' demands. After this information was collected, then the recommended treatment plan was created, presented, discussed and signed by the patient if he/she agreed with the treatment plan. The clinical treatments were performed by postgraduate students who were supervised by faculty members at Operative Department Clinic. According to the Operative Department Clinic protocol, patients are required to schedule check-ups every 12 months. During the follow-up appointments a clinical examination are performed and radiographs are taken.

2.1.1. Tooth Preparation

The tooth preparations followed the general principles for adhesive ceramic onlays (CAD/CAM and conventional), including isthmus width between 1.5 and 2.5 mm; minimum occlusal reduction of 1.5 (nonfunctional cusps) to 2.0 mm (functional cusps); 1.25-mm modified shoulder margin around the preparation; round internal line angles; and divergence of walls at approximately 10 to 15 degrees with no bevel.

For all ceramic crowns (CAD/CAM and conventional), occlusal reduction is from 1.5mm to 2 mm, 1.5mm for axial reduction, and chamfer finish line is 1 mm, with rounded internal angle margins.

2.1.2. Cementation Protocol

All the ceramic crowns/onlays were placed using the following cementation protocols: etched with 10% hydrofluoric acid (Prosthetic Etchant Gel; Dentsply Sirona) for 20 seconds, washed, and dried; silane agent (Monobond S; Ivoclar Vivadent AG) applied for 1 minute; prepared tooth, acid etched with 35% phosphoric acid, rinsed with water, and gently air dried; dentin bonding agent (Multilink Primer or Excite DSC; Ivoclar Vivadent AG or Scotchbond Universal Adhesive; 3M ESPE) applied over dentin and enamel. If Scotchbond were used, the silane agent was omitted as Scotchbond Universal contains a silane agent.

The crowns were cemented with a dual-polymerizing resin luting material (Variolink II; Ivoclar Vivadent AG or RelyX Ultimate; 3M ESPE) according to the manufacturer's instructions.

2.2. Data Collection

In this retrospective study, an AxiUm search was performed to retrieve data from the clinical records of patients who received all ceramic CAD/CAM crowns (D2740C), CAD/CAM onlays (D2643C), all ceramic conventional crowns (D2740), all ceramic conventional crown onlays (D2643) at the Postgraduate Operative clinic at Nova Southeastern University from 2012 to 2018. The participant inclusion criteria for this study were the patients who received all ceramic CAD/CAM crowns/onlays and all ceramic conventional crowns/onlays restorations in a postgraduate Operative clinic from 2012 to 2018 on posterior teeth.

The following data fields stored in AxiUm were collected from the patients' records who met the criteria for inclusion in this study: for each case (each restoration): gender, age at crown placement, location of the restored tooth (maxilla/mandible, anterior/premolar/molar region), self-reported use of high fluoride treatment, self-reported tobacco use, self-reported, self-reported chronic diseases, specifically, diabetes, gastroesophageal reflux disease (GERD) and hypertension. Additionally, patients' caries risk level, restoration type (crown or onlay), date of placement and if applicable, date of replacement, and operator – 1st or 2nd year resident. For each dental restoration the fabrication method variable, CAD/CAM or conventional, was created using the procedure code information prior to data analysis.

Proper IRB protocol, along with proper HIPAA procedures to protect patient confidentiality was adhered to. A form was added to the patient's chart after the PI accessed information from the patient's record. The note stated the chart was accessed for research purposes. The deidentified information acquired from AxiUm was electronically stored in a computer located at the College of Dental Medicine. The file was encrypted and password protected. All data acquired during this research will be deleted following the policies of the Nova Southeastern University Institutional Review Board office.

2.3. Power Analysis

The sample size for this study was determined using the guidelines provided in Hsieh, F.Y., Block, D.A., and Larsen, M.D. (1998) and PASS 16 software (NCSS, LLC) functionality. Results from the PASS 16 analysis for the following parameters: a power of .80 and an alpha of .05, for a Cox Regression analysis indicated a recommended sample size of approximately 650. Refer to Figure 1 below.[56]

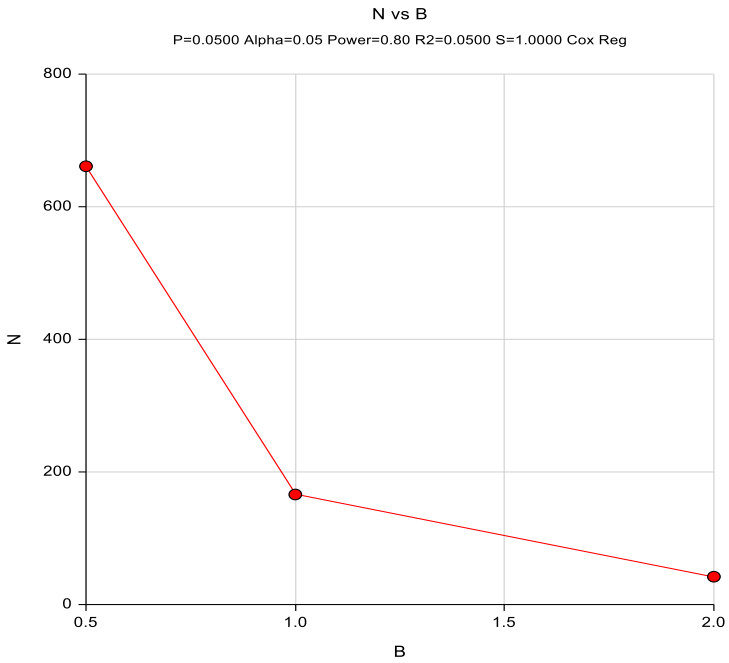

Figure 1: Sample Size Estimation

The AxiUm query of patients who received all ceramic CAD/CAM crowns (D2740C), CAD/CAM onlays (D2643C), all ceramic conventional crowns (D2740), all ceramic conventional crown onlays (D2643) at the Postgraduate Operative clinic at Nova Southeastern University from 2012 to 2018 returned 78 CAD/CAM all ceramic crowns/ onlays and 429 all ceramic conventional crowns/ onlays, for a total of 507 crowns.

2.4. Variables

2.4.1. Dependent Variable

To determine the survival rates of ceramic CAD/CAM versus conventional fabricated crowns and onlays, information from the dental records of patients attending the clinic from 2012-2018 were employed to determine the survival time of the crown(s) or onlay(s) by fabrication method. Specifically, patient's records stored in AxiUm were searched to identify all patients who received the restorations of interest from 2012-2018 and examined, across time, to determine if a restoration(s)

had been replaced or scheduled for replacement. Restorations replaced or scheduled for replacement were coded as failed restorations. This information was added to the data file, described in the Data Collection segment in this manuscript, showing that the restoration(s) failed and the date of replacement if replaced.

For cases where the record showed that the patient was noted as needing a replacement but has yet to receive the replacement, time of failure was the date stamped on the follow-up radiograph showing any of the conditions previously mentioned.[37] This information was included in the data file, by case, coding the restoration as either failed or not and the time of failure if applicable.

2.4.2. Independent Variables and/or Covariates

Following is a list displaying all the explanatory variables employed in this study:

1. Location of the restored tooth maxilla/mandible, premolar/molar region (categorical variable).

2. Demographics: Age at crown placement (continuous variable), gender (categorical variable), race: Hispanic, White, African American, Asian and other (categorical variable).

3. Use of high fluoride treatment (yes or no).

4. Tobacco use (yes or no).

5. Chronic diseases (hypertension, diabetes, GERD).

6. Provider/Operator – 1st or 2nd year residents.

7. Caries risk (low, moderate, high, extremely high).

8. Fabrication methods (CAD/CAM, conventional).

2.5. Statistical Analysis

Deidentified AxiUm data, the fields of information were described in the Data Collection section of this manuscript, were downloaded into a Microsoft Excel™ file. Data was transferred to SPSS V.25 software for analysis. The analytic plan included univariate, bivariate and survival analysis. The univariate analysis includes descriptive statistics for the sociodemographic variables and other characteristics of the subjects included in the study (means and standard errors, or frequencies and proportions). Also, descriptive statistics were reported overall for all the restorations and by fabrication method. For the bivariate analysis a Chi square test of Independence was employed to determine the significance and the magnitude of the association between crown status, failure or not, and each independent variable. Odds ratios, with 95% confidence intervals, were reported for each association.

A Cox (proportional hazards or PH) model was used as the multivariate approach for analyzing the survival time data expressed as a hazard function and a set of covariates.[57] The covariates were presented in the previous section of this manuscript and include patient demographics, restoration type, tooth type (molar or premolar), and patient behaviors such as tobacco use and use of high fluoride treatments previously know to cause crown failure. This study employed Fixed Type I censoring where time is prespecified, in this study August 2018, and is the same for all individuals.[58]

Chapter 3: Results

3.1. Case Summary

In total, 507 all ceramic restorations that met the inclusion criteria were placed in 225 patients at the postgraduate Operative clinic from 2012 to 2018. A total of 429 (84.6%) restorations were fabricated conventionally, and 78 (15.4%) restorations were fabricated via CAD/CAM system.

3.2. Descriptive Statistics

Following are highlights from the descriptive statistics analysis and results from this study, refer to Table 1 and 2 for more detailed information. The majority of the patients were female (n=149, 66.2%), while 33.8% (n=76) were male. The mean age of the patients was 57.4 years (SD=13.2). Caucasian/White Non Hispanic was the most represented racial group (n=124, 57.4%) followed by Hispanic/ Latino (n=67, 31%).

Approximately 94% (n=211) of the patients reported that they were non-smokers. In regards to chronic diseases including diabetes, hypertension and gastrophageal reflux disease (GERD), 74.2% (n=167) of patients did not report having chronic diseases, while 25.8% (n=58) of patients reported having at least one chronic diseases.

Most of the patients were designated as high caries risk (44%) followed by moderate (33.3%), low (16.9%), and extremely high was (2.2%). Most patients reported (53.8%) that they were not using high fluoride mouthwash and/or tooth paste. Molar teeth were most frequently restored (59.5%) while (40%) were premolar restorations. Furthermore, 48% (n=108) of the patients had multiple restorations placed at the clinic.

Summary statistics based on the total number of restorations, to include the number of failed restorations by fabrication mode, either conventional method or CAD/CAM systems are presented on Table 2. From March 2012 to August 2018, according to AxiUm records, there were 19 failed restorations that is equivalent to an overall failure rate of approximately 3.7%. Of the 19 failed restorations only two were CAD/CAM fabrications. Overall, the failed restorations, not patients, these were proportionally higher in males, specifically, 88.2% (n=15). Open margins were the most frequent reason for failure (33.3%) followed by porcelain fracture and recurrent carries (22% each). Chipping and esthetics accounted each for 11.1% of the failures. These are valid percentages representing the percent failure from the total number failures.

3.3. Bivariate Analysis

The highest amount of failed crowns by race/ethnic group was noted in the Caucasian/White Non Hispanic group with 15 failed crowns. All failed crowns belonged to the non-smoking group (n=19) and the majority of failed crowns (n=15) were reported among patients who did not report chronic diseases (Hypertention/ Diabetes/ GERD). Furthermore, approximately 94.7% (n=18) of the failed restorations were found among patients who received multiple restorations at the clinic.

The majority of the failed cases were found among individuals who belonged in either the high risk or low risk for caries groups. Specifically, there were 10 failed restorations in the low caries risk group and 6 failed restorations in the high caries risk group. In addition, the majority of patients with failed restorations (n=18) were initially done by second year residents, noted is that residents from the second year restored 459 cases, while only 46 cases were restored by first year residents.

A Chi-square test of Independence was employed to assess all bivariate associations between the nominal variables and failure status (yes or no). The obtained associations, p values, measures of association, Cramer's V, and odds ratios are reported on Table 3. Outcomes from the analysis revealed that crowns placed in female patients were significantly less likely to fail (OR=0.922, 95% CI: 0.878-0.968) than crowns placed in male patients. Furthermore, crowns that were placed in patients who did not have multiple restorations were more likely not to fail by a small but significant margin (OR=1.040, 95% CI: 1,012-1.069) than crowns that were placed in patients who had multiple restorations. The odd ratios for smoking, chronic disease, race, age, high fluoride, tooth position, resident year in the program and fabrication method were not statistically significant. The association between crown status and high fluoride and caries risk met the Bendel and Afifi (1977) recommendation of a p-value of 0.25 or less for the selection of explanatory variables to be included in regression model building.[61]

3.4. Survival Analysis

The Cox proportional-hazards model regression analysis (Cox, 1972) was employed to determine the association between the survival time of crowns by fabrication method and all available predictor variables as presented on Table 4. The Cox proportional hazards regression analysis, works for both quantitative predictor variables and for categorical variables. Furthermore, the Cox regression model extends survival analysis methods to assess simultaneously the effect of several risk factors on survival time. An obtained hazard ratio (HR) of greater than one, indicates a covariate that is positively associated with the event probability, which is restoration survival, and thus negatively associated with the length of survival.[58]

The first model included all variable confounding and covariates: gender, multiple restorations, smoking, chronic disease, race, age, high fluoride, tooth position, resident year and time. For the analysis, Fixed Type I censoring was employed where time was prespecified, August 30, 2018, for every case that did not have the failure event observed during the course of the study. Results from the Cox proportional hazards regression analysis for the first model, displayed on Table 4, revealed that gender and high fluoride as significant predictors of survival time. Specifically, the hazard risk ratio for females was 8 times higher than for males (HR= 8.105, CI 95%, 2.199 to 29.882). The hazard risk ratio for individuals who used oral high fluoride products was lower than those who did not use oral high fluoride products. (HR = 0.291, CI 0.094 to 0.899). Again, although not statistically significant (p= 0.063), those with multiple restorations were 7.4 times more likely to have a failed restoration. Similarly, those with chronic diseases were 1.8 times more likely to have a failed restoration.

Once the first model was completed, backward elimination was employed testing the deletion of each variable that did not meet the stated criterion, a p value of .05 and below, and repeating this process until no further variables could be deleted without a statistically significant loss of fit.

The resulting final model included only two variables, that is, gender and high fluoride as significant predictors of survival time and forced entered into the model were the variables multiple restoration, yes or no, and fabrication method, CAD/CAM or conventional. The obtained hazard risk ratio for gender was 5.7 (95% CI: 1.8 to 17.4), in other words, the length of survival for females was negatively associated with the length of survival. The obtained hazard risk ratio for high fluoride 0.356 (95%CI: 0.12 to 0.98). The length of survival for cases with high fluoride was positively

associated with the length of survival.

In regards to the quality of the fit of the model, the obtained Nagelkerke R-square for the final model was 0.172. In spite of the low value obtained for the Nagelkerke R-square, further assessment of the quality or fit of the model was performed by applying the model to the collected data and evaluating if the model was able to classify the cases according to crown status. The overall classification rate for the model was approximately 96%.

Chapter 4: Discussion

This retrospective study evaluated the clinical performance of 507 all ceramic CAD/CAM versus conventional fabricated crowns and onlays placed on either premolar or molar regions as restorations that were placed at the Nova Southeastern University Operative clinic from 2012 to 2018. The results from the analysis of the data revealed that there are no significant differences between the survival of these CAD/CAM over conventional restorations. Hence, the first null hypothesis was retained.

Furthermore, analysis of the data revealed that the overall of the crowns placed by residents from 2012-2018 survived 96%. The results of this study are in agreement with the results from other studies that evaluated the clinical performance of all ceramic CAD/CAM versus conventional ceramic restorations.[38,42] For example, a retrospective study by Felden, where forty nine IPS-Empress all ceramic onlays were evaluated from 1992 to 1999, two crown fractures and one recurrent caries were found and a survival rate of 95% over a period of 7 years was reported. [59] Similarly the three-year prospective clinical study was conducted by Guess et al, to assess the longevity and clinical outcomes of presseable and CAD/CAM onlay ceramic crowns in a splitmouth design. Eighty crowns were fabricated and placed on posterior teeth (40 IPS e.max conventional crowns and 40 ProCAD which are CAD/CAM crowns) showed a high survival rate for IPS e.max (100%) and ProCAD (97%) at three years. One ProCAD crown had a ceramic fracture and the fracture happened after 9 months service.[31]

Another prospective clinical study that reported results similar to the findings from our study was conducted by Otto et al in 2002. The purpose of this study was to evaluate the performance of Cerec inlay and onlay at 10 years service. The 200

restorations were placed in a private office between 1989 and 1991. Results from this study revealed that the survival rate of Cerec inlays and onlays was 90.4% after 10 years. A total of 15 (8%) failures were found, 73% were caused by either ceramic fractures (53%) or tooth fractures (20%). The other failures were related to caries (20%) and endodontic problems (7%). [37] In our study, Open margins was the most frequent reason for failure (33.3%) followed by porcelain fracture and recurrent carries (22% each). Chipping and esthetics accounted each for 11.1% of the failures.

Moreover, the 2005 study from Kramer, N. and R. Frankenberger and the 2014 study from Gherlone revealed that the most common failures were attributed to fractures of the restoration or tooth, secondary caries and endodontic problems.[38,42] Similarly, in spite of the small amount of crown failures found in our study, recurrent caries was the most frequent cause of failure followed by open margin and porcelain fracture, and chipping.

The results from our study confirm that dentists' decision to use a CAD/CAM or conventionally made dental crown or onlay should not reside on concerns about the duration of the crown by fabrication method since the results of our study and the here cited literature point to no differences in the longevity of crowns by fabrication method. Instead, decisions about the best option for the fabrication of the restoration should be made according to the location of the dental restoration, patient's demand, esthetics and appointment frequency preference. The literature points that CAD/CAM is more beneficial to the dentists and patients because it eliminates the need for a temporary crown; therefore, it provides a faster option for treatment completion.[8]

Whereas there were no significant differences in the survival time of crowns across fabrication method, there was a significant difference in the survival time by gender and oral use of high fluoride products. Results from the Cox regression

analysis indicated that gender and high fluoride were associated with survival time, specifically, gender was negatively associated with survival time and high fluoride was positively associated with survival time. Precisely, the crowns in females were 5.7 (95% CI: 1.8 to 17.4) times more likely to fail than for males and the cases indicating the use of oral high fluoride products were more likely to survive than for the group who did not use oral high fluoride products. It is important to note that the bivariate analysis indicated that crowns that were placed in patients who did not have multiple restorations were more likely not to fail by a small but significant margin (OR,1.040, 95%CI: 0.6 to 38.4) than crowns that were placed in patients who had multiple restorations. Therefore, this variable, while not significant according to first Cox regression analysis, was included in the final model and should be taken into consideration in treatment planning.

There are several unanticipated outcomes in this study. First, proportionally the amount of males indicating the use of high fluoride treatments was higher than the female group, that is, approximately 46.4% (n=78). Secondly, the proportion of females (47.9%, n=158) coded as high caries risk level was higher than the proportion of males (32.9%, n=53) as presented on Table 6. The use of fluoride treatments and the caries risk level patient designation has been cited in the literature as significantly associated.[60] The literature about the effectiveness of the use of high fluoride treatments indicates that using high fluoride vehicles such as mouth wash and toothpaste is necessary for caries prevention and treatment of the patients with high caries risk.[60] Therefore, it is plausible to consider that the higher likelihood of crown failures in females found in this study could be related to the fact that proportionally the use of high fluoride treatments reported by females was smaller than the proportion of males who reported using prescribed high fluoride treatments. Moreover,

the proportion of females designated as high caries risk level was higher than the proportion of males in this study.

4.1. Limitations

Among the limitations of this study is the time reviewed for the determination of the durability of the dental restorations. Specifically, in this study we accrued patient dental restoration data from 2012 to 2018. Whereas the data reviewed spans a 6 year period, that does not reflect the time that a given patient had a restoration. The data covered restorations placed from 2012 to 2018, therefore, the length of time after the placement of the restoration varied from patient to patient.

A purposive sample was employed in this study; therefore, generalization of the findings from this study to a population is not appropriate. Furthermore, the amount of cases analyzed in this study, 507, was below the sample size estimated in the power analysis (refer to section 2.3 in this manuscript), thus result need to be interpreted with care, because of the reduced power.

4.2. Future Studies

We recommend other studies further explore other predictors, for example, other aspects of patient clinical history and oral habits as predictors of survival of dental restoration. Moreover, there is a need to further examine any potential associations between gender and dental restoration survival rate. Furthermore, there is need to compare survival rates for anterior dental restorations.

4.3. Clinical Recommendation

The results from this study point to better odds for crown survival for cases that were using high fluoride oral products. Therefore, in addition to the prescription of high fluoride oral products for patients that are at a higher risk for developing caries,

the dentist should consider prescribing these products to patients who have crowns especially those who have multiple restorations.

Chapter 5: Conclusion

Consistent with the findings from previous similar studies, we found that there were no significant differences in the longevity of CAD/CAM restorations over conventional restorations.[34, 36]Moreover that the overall survival rates, approximately 96%, of the restorations placed by residents from 2012-2018, matched findings from studies that examined a 10- year period.[34, 36] However, unique to this study is that the dental restorations examined in this investigation were placed by residents in a university dental clinic setting. The fact that the findings from this study and from previous studies that examined dental restorations cases outside a dental residency program are similar points, possibly, to akin clinical procedures with the same levels of effectiveness.[34, 36]

Another finding from this study was that the risk for crown failure for cases using high fluoride oral treatments was lower than for the group who did not use high fluoride treatment. This is another instance in this study where the findings are consistent with the evidence reported in many studies about the effectiveness of high fluoride in the treatment of caries.[60]

In our study, the final Cox regression model revealed that gender was associated with survival time, particularly, the risk of crown failure for females was 5.7 times (95% CI: 1.8 to 17.4) higher than for males and thus negatively associated with the length of survival. A thorough research of the extant literature did not locate any reference that has examined dental restorations survival rates by gender. This finding merits more research.

Appendix A

Appendix A

Table 1. Descriptive Statistics for Overall

Variables		Count	Column N %
Multiple Rest			
	No	117	52.0%
	Yes	108	48.0%
Gender			
	Male	76	33.8%
	Female	149	66.2%
Smoking			
	No	211	93.8%
	Yes	14	6.2%
Race/Ethnicity			
	Caucasian/ Non Hispanic white	124	57.4%
	Hispanic	67	31.0%
	African American	14	6.5%
	Asian	3	1.4%
	Multi ethnic	6	2.8%
	American Indian/ Native Alaskan	2	0.9%
High Fluoride			
	No	121	53.8%
	Yes	104	46.2%
Age			
	59 and below	124	55.1%
	60 and above	101	44.9%
Chronic Diseases	No	167	74.2%
	Yes	58	25.8%
Caries Risk			
	Low	38	17.5%
	Moderate	75	33.3%
	High	99	44%
	Extremely High	5	2.2%

Appendix A

Table 2. Descriptive Statistics for Restorations

	Variables	Crown Type							
		Conventional				CAD/CAM			
		Crown Status				Crown Status			
		Not Failed		Failed		Not Failed		Failed	
		Count	Column N %	Count	Column N %	Count	Column N %	Count	Column N %
Multiple Rest	Single	82	20.0%	1	5.9%	37	48.7%	0	0.0%
	Multiple	328	80.0%	16	94.1%	39	51.3%	2	100.0%
Gender									
	Male	124	30.2%	15	88.2%	29	38.2%	0	0.0%
	Female	286	69.8%	2	11.8%	47	61.8%	2	100.0%
Smoking									
	No	393	95.9%	17	100.0%	66	86.8%	2	100.0%
	Yes	17	4.1%	0	0.0%	10	13.2%	0	0.0%
Chronic Disease	None	318	77.6%	13	76.5%	57	75.0%	2	100.0%
	One	67	16.3%	3	17.6%	18	23.7%	0	0.0%
	More than one	25	6.1%	1	5.9%	1	1.3%	0	0.0%
Caries Risk	Low	73	18.2%	10	58.8%	5	7.2%	0	0.0%
	Moderate	138	34.4%	1	5.9%	36	52.2%	2	100.0%
	High	177	44.1%	6	35.3%	28	40.6%	0	0.0%
	Extremely High	13	3.2%	0	0.0%	0	0.0%	0	0.0%
Race Ethnicity	Caucasian/White Non Hispanic	266	66.0%	13	76.5%	33	44.6%	2	100.0%
	Hispanic/Latino	115	28.5%	2	11.8%	27	36.5%	0	0.0%
	African American/Black	10	2.5%	1	5.9%	9	12.2%	0	0.0%
	Asian	4	1.0%	0	0.0%	1	1.4%	0	0.0%
	Multi ethnic	4	1.0%	1	5.9%	3	4.1%	0	0.0%
	American Indian/Alaskan Native	4	1.0%	0	0.0%	1	1.4%	0	0.0%
High Fluoride	No	220	53.7%	5	29.4%	63	82.9%	2	100.0%
	Yes	190	46.3%	12	70.6%	13	17.1%	0	0.0%

Table 2. (Continued)

Variables		Crown Type							
		Conventional				CAD/CAM			
		Crown Status				Crown Status			
		Not Failed		Failed		Not Failed		Failed	
		Count	Column N %	Count	Column N %	Count	Column N %	Count	Column N %
Resident									
	First Year Resident	35	8.5%	0	0.0%	10	13.2%	1	50.0%
	Second Year Resident	375	91.5%	17	100.0%	66	86.8%	1	50.0%
Tooth									
	Molar	236	57.6%	8	47.1%	56	73.7%	2	100.0%
	Premolar	174	42.4%	9	52.9%	20	26.3%	0	0.0%

Appendix A

Table 3. Bivariate Associations Between Crown Status Demographical and Medical History Variables

Variables	Crown status			95.0% CI for Exp(B)	
	Cramer's V	P-value	Odds Ratio	Lower	Upper
Gender (Female)	0.192	0.000	0.922	0.878	0.968
Smoking	0.047	0.291	0.960	0.943	0.978
Chronic Disease	0.030	0.470	0.86	0.315	2.347
Caries Risk	0.057	0.204	0.977	0.944	1.012
Race/Ethnicity	0.065	0.149	0.974	0.942	1.006
Age	0.060	0.175	1.024	0.989	1.061
High Fluoride	0.082	0.064	1.034	0.996	1.073
Tooth Position	0.029	0.516	1.012	0.976	1.049
Multiple Rest	0.086	0.053	1.040	1.012	1.069
Resident Year	0.026	0.553	1.018	0.972	1.067
Fabrication Method	0.027	0.545	0.985	0.946	1.027

Appendix A

Table 4. Cox Regression for First Model

Variables	B	SE	Wald	df	Sig.	Hazard Risk Ratio	95.0% CI for (HR)	
							Lower	Upper
Gender (Female)	2.093	0.666	9.881	1	0.002	8.105	2.199	29.882
Multiple Rest	2.007	1.079	3.463	1	0.063	7.443	0.899	61.646
Smoking	14.231	733.964	0.000*	1	0.985			
High Fluoride	-1.234	0.575	4.603	1	0.032	0.291	0.094	0.899
Resident	-1.136	1.092	1.083	1	0.298	0.321	0.038	2.728
Tooth	-0.545	0.533	1.048	1	0.306	0.580	0.204	1.646
Crown Type	-1.644	0.904	3.308	1	0.069	0.193	0.033	1.136
Caries Risk	-0.356	0.564	0.398	1	0.528	0.700	0.232	2.117
Race	0.298	0.640	0.217	1	0.641	1.347	0.385	4.718
Age	-0.069	0.606	0.013	1	0.910	0.934	0.284	3.064
Chronic Diseases	0.634	0.734	0.746	1	0.388	1.885	0.447	7.946

*Wald statistic =0 no HRR reported

Appendix A

Table 5. Cox Regression for Result Model

Variables	B	SE	Wald	df	Sig.	Hazard Risk Ratio	95.0% CI for (HR)	
							Lower	Upper
Gender (Female)	1.741	0.571	9.298	1	0.002	5.702	1.862	17.458
Multiple Rest	1.624	1.033	2.473	1	0.116	5.075	0.670	38.427
High Fluoride	-1.034	0.520	3.950	1	0.047	0.356	0.128	0.986
Crown Type	-0.671	0.808	0.689	1	0.406	0.511	0.105	2.493

Appendix A

Table 6. Descriptive Statistics for Caries Risk and High Fluoride by Gender

Variables		Gender			
		Male		Female	
		Count	Column N %	Count	Column N %
Caries Risk	Low	47	29.2%	41	12.4%
	Moderate	61	37.9%	118	35.8%
	High	53	32.9%	158	47.9%
	Extremely High	0	0.0%	13	3.9%
High Fluoride	No	90	53.6%	200	59.0%
	Yes	78	46.4%	139	41.0%

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