



REPUBLIC OF TURKEY
MARMARA UNIVERSITY
MEDICAL SCIENCES INSTITUTE

**IN VITRO EVALUATION OF FRACTURE RESISTANCE OF
CROWN RESTORATIONS FABRICATED FROM DIFFERENT
HYBRID CERAMIC MATERIALS**

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MASTER THESIS

DEPARTMENT OF PROSTHODONTICS



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ISTANBUL 2019

THESIS APPROVAL FORM


Institute : Marmara University Institute of Health Sciences
Programme : Master of Science (MSc.)
Department : Department of Prosthodontics
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Exam Date & Time : 06/09/2019 10:00
Title of the Thesis : In Vitro Evaluation of Fracture Resistance of Crown
Restorations Fabricated from Different Hybrid Ceramic Materials

This study has been approved as a MSc. Thesis in regard to content and quality.

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Qutada Ismael Kadhim KADHIM



I. ACKNOWLEDGEMENT

I would like to thank Professor Yasemin ÖZKAN, the dean of Marmara University Faculty of Dentistry. She shared with me her knowledge and experience and supported me in personal and professional levels.

I would like to begin by thanking Assoc. Prof. Buket EVREN my thesis supervisor she shared with me her knowledge and experience, and supported me in personal and professional levels. I always saw her as our mother, not just as a professor. It has been an honor working with her.

I also would like to thank Professor Şebnem Begüm TÜRKER the Head of the Prosthodontics Department at Marmara University, for all her professional support and passion in teaching all the time.

My deep thanks for all prosthodontics Department's doctors, Assoc. Prof. Rifat GÖZNELİ, Assoc. Prof. Coşkun YILDIZ, Assistant Professor Erkut KAHRAMANOĞLU, Assistant Professor Ceren KÜÇÜK, Assistant Professor Dr. Umut ASLAN for the support, knowledge and experience they shared with me. They were my second family throughout my years in Marmara. And special thanks to Zeliha ŞANIVAR for always having time to help me.

Last but not least, I would like to thank all my colleagues for making my journey colourful and full of joy.

I would like to Thanks for being the best. My dear wife, I'm so blessed of having you. Thank you for your love, care, support and every little effort you are doing for me is simply amazing.

Finally, I would like to express my deepest gratitude to my father, my mother, and my family. Words cannot express my appreciation enough for their sacrifices and continuous support. I would not be here if it wasn't for them.

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III. ABBREVIATIONS AND SYMBOLS

CAD: Computer Aided Design

CAM: Computer Aided Manufacturing

CEREC: Chairside economical restoration of esthetic ceramics or ceramic reconstructions.

3D: Three-Dimensional

ANOVA: Analysis of variance

FDPs: Fixed dental prostheses

LSD: Least significant difference

P: Probability value

SD: Standard deviation

Sig: Significance

SPSS: Statistical package for the social sciences

SEM: Scanning electron microscopy

µm: Micron

PICN: Polymer-infiltrated ceramic-network

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1. ÖZET

Farklı Hibrit Seramik Materyalleri İle Hazırlanan Restorasyonların Kırılma Dirençlerinin in Vitro Olarak Değerlendirilmesi

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Amaç: Bu çalışmanın amacı, CAD\CAM sisteminde farklı hibrit seramik malzemelerden üretilen kron restorasyonların kırılma direncini değerlendirmektir.

Gereç ve Yöntemler: Çekilmiş 45 molar diş, her biri 15 örnek içeren, rastgele 3 gruba ayrıldı. Çıkarılar dişler, otopolimerize edici akrilik reçine bloklarına yerleştirildi. Tüm dişler standart diş kesim prosedürlerine göre chamfer bitiş çizgisile hazırlandı. CAD/CAM sistemi (CEREC Omnicam Sistemi, Salzburg, Österreich) ile dijital ölçüler alındı. Taramadan sonra, 45 diş 3 gruba ayrıldı. kron restorasyonları 3 farklı CAD / CAM bloğundan (IPS e.max CAD, Vita Enamic ve GC Cerasmart) üretildi. Restorasyonların simantasyonundan sonra kırılma direnci universal test cihazı (Shimadzu product, Kyoto 604-8511, Japan) ile ölçüldü. Veriler toplandıktan sonra sonuçlar istatistiksel olarak değerlendirildi.

Bulgular: Sonuçların analizi tüm gruplar arasında istatistiksel olarak anlamlı fark gösterdi ($P < 0.05$). CeraSmart grubu, E-max (2614.47 ± 578.79) ve VitaEnamic gruplarına (1687.90 ± 570.91) kıyasla en yüksek ortalama kırılma yükü ortalamasını (3135.74 ± 860.91) göstermiştir. Sonuçların analizi Cerasmart ve E-max gruplarının istatistiksel olarak benzer kırık yüklerine sahip olduklarını ve Vita grubundan daha yüksek olduğunu gösterdi.

Sonuç: CAD \ CAM sistemiyle üretilen hibrit malzemeler mükemmel kırılma direnci gösterdi.

Anahtar kelimeler: CAD\CAM, Hibrit seramikler, kırılma direnci

2. SUMMARY

In Vitro Evaluation of Fracture Resistance of Crown Restorations Fabricated from Different Hybrid Ceramic Materials

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Aim: Compared to conventional materials, polymer/ceramic hybrid composites have the potential to tailor the desirable properties that individual component can offer.

The aim of this study is to evaluate the fracture resistance of crown restorations fabricated from different hybrid ceramic materials in CAD\CAM system.

Materials and Methods: 45 extracted molar teeth were divided into 3 groups randomly, each group containing 15 specimens. All teeth were placed in autopolymerizing acrylic resin blocks and they were prepared according to standard tooth preparation procedures with a chamfer finish line. Digital impressions were taken with CAD/CAM system (CEREC Omnicam System, Salzburg, Österreich). After scanning crown restorations were fabricated from 3 different CAD/CAM blocks (IPS e.max CAD, Vita Enamic, and GC Cerasmart). After cementation of the restorations, fracture resistance was measured with a universal testing machine (Shimadzu product, Kyoto 604-8511, Japan). After collecting the data, the results were evaluated statistically.

Results: Analysis of the results showed statistically significant difference between all the groups ($P < 0.05$). CeraSmart group exhibited the highest mean fracture load mean (3135.74 ± 860.91) compared to E-max (2614.47 ± 578.79) and VitaEnamic groups (1687.90 ± 570.91). Analysis of the results showed that Cerasmart and E-max groups had statistically similar fracture loads and higher than Vita group.

Conclusion: Hybrid materials fabricated with CAD\CAM system showed excellent fracture resistance.

Keywords: CAD\CAM, Hybrid ceramics, Fracture resistance.

3. INTRODUCTION

For years, full crown restorations were used to preserve the function and aesthetic appearance of damaged natural teeth. Metal-ceramic crowns have been considered as the gold standard for dental full coverage restorations (Pjetursson et al., 2007), due to their high strength, precise fit, marginal integrity and favorable long-term survival rate (Pjetursson et al., 2007, Reitemeier et al., 2013). However, biological complications like periodontitis (Lucas and Lemons 1992, Pjetursson et al., 2007), ceramic chipping/debonding (Marklund et al., 2003) and lack of natural tooth appearance are disadvantages in metal-ceramic restorations (Anusavice 1993). Hence, the interest and demand for metal-free biocompatible restorations from both clinicians and patients have encouraged researchers to seek changes. To accomplish this need, all-ceramic restorations with the benefits of soft tissue biocompatibility (Sjogren et al., 2000), improved wear resistance, colour stability, and excellent light transmitting properties (Gallucci et al., 2007) were developed. In 1965, McLean (McLean and Hughes 1965) presented an alumina-reinforced feldspathic core ceramic, which was used for the restoration of anterior teeth. After that, other systems have been developed and become available in the market.

Hybrid ceramics (Polymer infiltrated glass- ceramics) are materials consisting of two penetrated phases that have more flexural strength when compared to the one-phase materials. Hybrid ceramics were developed according to this idea. Hybrid ceramics are formed by a combination of inorganic and organic components. Inorganic and organic structures were consisting of ceramics and polymers, respectively. Due to their hybridity with the combination of ceramic and polymer materials and the main goal to combine the positive effect of ceramics and resin-based materials, this material family is referred to as hybrid materials. This materials family may be further divided into materials that are based on resins, which will be suggested to as CAD/CAM composite resin, and those that are based on ceramics, which will be referred to as hybrid ceramic. (Ceren et al., 2016).

Computer Aided Design/Computer Aided Manufacturing (CAD/CAM) was first introduced to dentistry in the mid-1980s. Both chairside and chairside—laboratory

integrated procedures are available for the fabrication of CAD/CAM restoration. Esthetic demands, chairside time, laboratory costs, number of visits, convenience, and return on investment associated with CAD/CAM equipment should be considered in selecting the following procedure. Leucite-reinforced ceramics, lithium disilicate, zirconia, hybrid ceramic and composite resin blocks are available for CAD/CAM restorations (Bindl et al., 2005, Coelho et al., 2009b, Al-Amleh et al., 2010).

Fracture resistance tests have been used to know the failure of ceramic restorations under the influence of the preparation design. Non-destructive experimental methodologies, such as the strain gauge test, and finite element analysis should be combined with conventional mechanical tests to better explain the failure of the ceramic restorations (Preis V et al., 2015). The stresses generated by bite loading cause structural strain; if such stresses become excessive and exceed the elastic limit, structural failure may result (Schwindling FS et al., 2017). To avoid the high incidence of failure of dental restorations, several ceramic brands and processing systems found their way to the dental industry. Another proposed technique to resist crown failure in service is the addition of grooves on the proximal surfaces of the abutment tooth after preparation to receive a prosthetic crown. It has been suggested that when the rotational force arc moves away from one wall of the groove, it hits the other wall, so resistance is substantiated one way or the other (Fasbinder DJ et al., 2010).

Fracture tests quantify the influence of restorative material, bonding procedures, and preparation characteristics on tensile strength when specimens are subjected to a concentrated and increasing load. These tests usually produce failure loads that exceed the load limit exerted by regular stomatognathic system movements. However, higher loading during these tests is comparable, for example, to the grinding of a small solid body that concentrates force on the occlusal surface of a single posterior tooth. (Kale E et al., 2017).

3.1. Aim of the Study

Compared to conventional materials, polymer/ceramic hybrid composites have the potential to tailor the desirable properties that individual component can offer. While ceramic materials show excellent mechanical, biomechanical, tribological, and high temperature stability properties, polymers are an example of materials with higher ductility and low elastic modulus. Therefore, the development of polymer infiltrated

ceramic composites tailoring individual components' performance offers a promising dental material. The aim of this study is to evaluate the fracture resistance of crown restorations fabricated from different hybrid ceramic materials in CAD\CAM system. Up to date many studies were conducted about the mechanical properties of hybrid ceramics. In the present study, the newly introduced hybrid ceramic materials will be compared regarding the fracture resistance. The results of the present study may have effect on the clinical choice and use of these materials.

3.2. Research Hypothesis

The null hypothesis for this study was that fracture resistance of posterior crowns would be similar for different materials.

4. GENERAL INFORMATION

4.1. CAD\CAM System

Computer-aided design (CAD) and computer-aided manufacturing (CAM) are popular recently. These digital techniques afford several advantages in dental practice (Mously HA et al., 2014). Taking images of prepared, adjacent, and opposing teeth, which is the first step of CAD/CAM process, removing the need for making an impression using silicon impression material. Therefore, worries about the dimensional stability of impression materials and the pouring of the stone cast can be removed, and the impression process can be significantly simplified (Karlsson S, 1993). The design and milling steps of the CAD/CAM process would reduce manufacturing costs by decreasing the time spent by technicians and allowing clinicians to fabricate chair-side restorations (Renne W et al., 2012).

An extensive range of esthetic CAD/CAM ceramic materials has recently been introduced ranging from relatively weak feldspathic and leucite-reinforced glass ceramics to high-strength lithium disilicate glass ceramics, zirconia, and new hybrid ceramics. The mechanical properties of some of these materials have been investigated (Awada A et al., 2015). However, there is little information about the marginal and internal adaptations of CAD/ CAM ceramic materials in the literature; moreover, such studies have been limited to lithium disilicate and zirconia. The marginal and internal adaptations of CAD/CAM fabricated lithium disilicate crowns have been comparable or better than that of conventionally fabricated crowns. Zirconia copings have also exhibited marginal and internal adaptation values falling within the clinically acceptable range. To the best of our knowledge, there are no studies about the adaptation of recently introduced CAD/CAM materials (e.g., monolithic zirconia and hybrid ceramics).

4.1.1. Chairside system

With the chairside system, all components of the CAD / CAM system are located in the dental office, which offers the dentist the ability to manufacture in one appointment a tooth-colored restoration (Beuer et al., 2008). Various dental ceramic

material blocks are accessible for chairside friction. Two CAD / CAM chairs are currently available, CEREC (Sirona dental system, Bensheim, Germany) and on the market E4D (D4D, Texas, USA). The most commonly used CEREC scheme is discovered to be well documented scientifically.

4.1.2. Lab-side system

All the components and production steps of a CAD/CAM system are located in the laboratory (Beuer et al., 2008). To generate three-dimensional data of the preparation, a conventional dental impression is used to produce a master cast, which is later digitally scanned, or chairside digitally scanned data can be sent or mailed from the dental office to a laboratory. Many of the lab-side systems, such as Lava (3M ESPE, St.Paul, USA), Everest (KaVo, Biberach, Riss), or Cerec inLab (Sirona, Bensheim, Germany), produce monolithic restorations and copings and frameworks which later require veneering with either manual or CAD/CAM techniques.

4.2. CAD/CAM materials used for the fabrication of permanent dental crowns

4.2.1. Monolithic materials

Brittle dental ceramics have traditionally been backed by a powerful metal substructure. Today, monolithic restorations have been launched into dentistry with developments in CAD / CAM techniques (Fischer and Marx 2002).

4.2.1.1. Glass ceramics

Glass ceramics are composite materials with a crystalline component and a glass matrix.

4.2.1.1.1. Feldspathic glass ceramics

Feldspathic ceramics are silica-based ceramics with low to moderate crystalline leucite filling ($K_2O \cdot Al_2O_3 \cdot 4SiO_2$) of approximately 5-25% by volume created by firing feldspar at 1150oC (Denry et al., 1996, Giordano and McLaren 2010). The high glass content in the feldspathic ceramics results in excellent aesthetic properties resembling the natural tooth substance (Pjetursson et al., 2007). Leucite particles are used to provide high translucency and alter the coefficient of thermal expansion, as well as to improve the material strength by inhibiting crack propagation. However, the original feldspathic ceramics have a random distribution and large size of leucite

Leucite particles are used to provide elevated translucency and change the thermal expansion coefficient, as well as to enhance material strength by inhibiting the spread of crack. The original feldspathic ceramics, however, have a random distribution and large size of leucite particles, contributing to the low fracture strength of the material, ranging from 70 to 100 MPa (Fischer et al., 2008). It is therefore widely used as a veneering ceramic for powder / liquid-shaped metal material restorations (Giordano and McLaren 2010).

4.2.1.1.2. Leucite-reinforced glass ceramics

The glass matrix is based on an alumino-silicate glass in leucite-reinforced ceramic. A large percentage of leucite crystal varying from 35% to 45% by volume (Deany 1996) is used to strengthen the ceramic glass and enhance its biomechanical characteristics. Adding extra leucite filler may boost glass ceramic's flexural strength to 105-120 MPa (Campbell 1989, Seghi et al., 1990). Leucite-reinforced glass ceramic restorations are highly translucent (Heffernan et al. 2002). The leucite-reinforced ceramic was initially introduced as VITA VMK 68 ceramic (VITA Zahnfabrik, Bad Säckingen, Germany) in 1968 in powder/liquid form as a metal-ceramic veneering material (Strub 1992, Guess et al. 2011).

4.2.1.1.3. Lithium disilicate glass ceramics

In order to be able to construct anterior three-unit all-ceramic bridge restorations, a glass ceramic based on lithium disilicate ($\text{Li}_2\text{Si}_2\text{O}_5$) has been introduced. Solidly arranged needle-like lithium disilicate crystals at a concentration of 70% by volume (Guazzato et al., 2004) with a length of 4 μm and a diameter of 0.5 μm are evenly dispersed in a glass matrix. This interlocking structure prevents crack propagation and increase the flexural strength of lithium disilicate ceramic to 300-400 MPa (Quinn et al., 2003), which is more than twice the strength of leucite-reinforced glass ceramic (Holand et al., 2000, Denry and Holloway 2010). Lithium disilicate crystals have a comparable refractive index to that of the glass matrix, which imparts the translucent properties of this ceramic type even with high crystalline content (Giordano and McLaren 2010). Ivoclar Vivadent introduced the first lithium disilicate ceramic (IPS Empress II, Ivoclar Vivadent, Schaan, Lichtenstein) in 1998 in ingot form to be used with the press technique at approximately 920°C. Several clinical studies

have shown a high survival rate of IPS Empress II single crown restorations range between 95.24% and 100% after observation periods between 5 and 10 years (Marquardt and Strub 2006, Toksavul and Toman 2007, Valenti and Valenti 2009).

Further improvement in physical properties and translucency of lithium disilicate glass ceramic was provided with the introduction of IPS e.max Press (Ivoclar Vivadent, Schaan, Liechtenstein) (Stappert et al., 2006). Pressable ingots are available in a variety of opacities, including high opacity, medium opacity, low translucency, and high translucency. The use of this material is recommended for the fabrication of monolithic inlays, onlays, and posterior crowns, or as a core for crowns and anterior three-unit FDPs (Holand et al., 2000). A survival rate of 97.4% after 5 years and 94.8% after 8 years of single crown made from IPS e.max Press was clinically reported (Gehrt et al., 2013). As CAD/CAM production of dental restorations has become more common, an innovation in lithium disilicate glass ceramic was developed in 2005 under the name of IPS e.max CAD (Ivoclar, Schaan, Liechtenstein) for milling techniques. The CAD/CAM processing provides the advantages of saving time and cost, and increasing the reproducibility of a restoration. The IPS e.max CAD block is a partially crystallized block that consists of 40% lithium meta-silicate crystals, permitting the material to be easily milled. After processing the blue block into the desired dental restoration, a recrystallization process takes place at 850°C for 10 minutes, through which the lithium meta-silicate is transformed into lithium disilicate crystals. This transformation provides the restoration with its final mechanical and aesthetic properties. According to the manufacturer's data, the flexural strength of fully crystallized IPS e.max CAD is about 360 MPa.

The material is not only indicated to fabricate monolithic inlays, onlays, single crowns, and anterior FDPs, but also for short-span posterior FDPs (Holand et al., 2008), with either conventional or adhesive cementation (Bindl et al., 2006). Clinical studies have shown 100% survival rates after 24 months for IPS e.max CAD single crowns without any complications (Fasbinder et al., 2010, Reich et al., 2010). Posterior crowns made from IPS e.max CAD had a survival rate of 96.3% after 4 years (Reich and Schierz 2012). Excluding biological complications, bulk fracture was reported in one out of 41 investigated crowns.

4.2.2. Zirconia-reinforced ceramics

Zirconia-reinforced ceramic is a lithium silicate ceramic system reinforced with zirconia. In the fresh material, the mixture of lithium silicate and zirconia containing glass ceramic ensures great material quality, high load capability, and simple friction and polishing. Vita Suprinity (VITA Zahnfabrik, Bad Säckingen, Germany) and Celtra DeguDent (DeguDent, Hanau, Germany) are two fresh products based on this strategy for CAD / CAM processing. Celtra has a flexural strength of 210 MPa after milling, according to the manufacturer's data, Further stain and glaze firing may improve the flexural strength of the material to 370 MPa. For the manufacture of inlays, onlays, veneers and anterior and posterior crowns, this monolithic CAD / CAM material is stated. Celtra DeguDent restorations can be self-adhesive or fully adhesive cemented, depending on the sign

4.2.3. Composite resin materials

CAD / CAM technology advancement in dentistry today has allowed dentists to use fresh products. Simultaneously, comprehensive study has been made available to improve the biomechanical characteristics of dental materials and a fresh generation of millable composite resin blocks (Kunzelmann et al., 2001). These materials are appropriate for temporary and permanent dental restoration manufacturing.

4.2.4. Hybrid ceramic (glass infiltrated ceramic)

Innovative restorative materials have been developed and marketed to meet the esthetic expectations of patients and mechanical requirements. Improved materials ensure conservation of tooth structure as they require less tooth preparation. Metal ceramic systems have adequate fracture resistance but require extensive tooth structure reduction. The ceramic systems more recently introduced also require substantial preparation of the tooth structure to provide sufficient durability. To overcome these challenges, polymer-infiltrated ceramic-network (PICN) materials have been developed for chairside computer-aided design and computer-aided manufacturing (CAD-CAM) systems and recently introduced to clinical dentistry. As hybrid ceramic and resin nanoceramic materials, they consist of a combination of ceramic, polymer (Dirxen et al., 2013), and zirconia-reinforced lithium silicate ceramic (Lauvahutanon et al., 2014). The elastic moduli of these materials (30 GPa) fall between the moduli of

enamel (<94 GPa) and dentin (<25 GPa). Their application along with CAD-CAM systems allows for more durable restorations that can be fabricated in a single visit. PICN ceramics have also emerged as important materials for implant-retained fixed restorations as they provide a protective effect on the bone and implant (Mihali et al., 2013).

4.2.4.1. CeraSmart

Cerasmart is the latest CAD / CAM composite block that comprises a high-strength ceramic and a composite. This system exhibits superior physical properties due to the fully Influence of different composite materials and cavity preparation designs on the fracture resistance of mesio-occlusal-distal inlay restoration (Saridag S, et al., 2013). In addition to the highest degree of flexibility, strength, and breaking energy, this innovative hybrid nano ceramic helps ensure the best marginal integrity and high strength after bonding (Elhomiamy E et al., 2015).

Cerasmart is ideally suited for later, previous, inlay, onlay, and implant restorations and also enables minimum tooth reduction for minimally invasive restorations. The superior reliability of cerasmart, as well as its unmatched aesthetics, milling accuracy, fastest mill time, and self-polishing properties, are also excellent features. (Peampring C, 2014). Only cerasmart has the amazing natural opalescence and fluorescence of natural teeth. (Lambert H, et al., 2017). Due to the dynamic proprietary nano ceramic matrix, and its complete homogeneous nature, Cerasmart is a true self-polishing material. Not only does it stay polished longer, but it is proven to gain luster even after being roughened. Because of its specially formulated nano-filler technology, it is extremely wearing resistant and made to last. The renowned nano-filler technology gives the restoration high wear resistance, for a long-lasting gloss with a high discoloration resistance. (Li RW et al., 2014).



Figure 4.1: CeraSmart

4.2.4.2. Vita Enamic

The new VITA ENAMIC material combines the properties of ceramic and polymer. It consists of a hybrid structure with two interpenetrating networks of ceramic and polymer, a so-called double network hybrid (DNH). Due to the structure of the feldspar ceramic and the acrylate polymer network, this material has a similar abrasion, high flexural strength, and elasticity close to dentin (Hamdy A, 2015). In 2013, Vita Enamic (VITA Zahnfabrik H. Rauter GmbH) was introduced for CAD-CAM restorations. Vita Enamic is a polymer-infiltrated ceramic network material (PICN) that contains a dominant porous feldspathic ceramic network (86 wt %) and is infiltrated with a copolymer (14 wt %). (Bruna Salamoni Sinhori et al., 2018). More than 90% of the Vita Enamic restorations in the present study were well matched in color and had high marginal adaptation. (Salamoni Sinhori B, et al., 2017).

The restorations were cemented with adhesive resin cement since the hybrid ceramic, which contains a glassy matrix, can adhesively bonded to the resin cement by using silane solution. The previous study showed that adhesively cemented glass containing restorations exhibited higher fracture loads compared to the restorations, which were cemented with conventional cement (Jae-Hong Kim et al., 2016). This material consists of a fine microstructure of a feldspathic ceramic matrix and an acrylate-based polymer network (Zainab M et al., 2018).

"Hybrid ceramic provides a new definition of load capacity. In this dental material, the dominant ceramic network is strengthened by a polymer network, with both networks fully integrated. (Mounajjed R et al., 2015).

Vita Enamic Block is a hybrid dental ceramic with a dual-network structure (Peampring C, 2014). VITA Enamic is composed of a ceramic part (75% by volume) and a polymer part (25% by volume) (Li RW et al., 2014).



Figure 4.2: VitaEnamic

4.2.4.3. IPS e.max

The IPS e.max system is an all-ceramic system that comprises lithium disilicate (LS2) glass-ceramic and zirconium oxide (ZrO₂) materials for the press and CAD/CAM technologies. Additionally, there is a universally applicable nano-fluorapatite glass-ceramic available for veneering all IPS e.max components.

Since the beginning of its development until today, the IPS e.max system was monitored by the scientific community and many renowned experts have contributed to a unique database with their studies. The worldwide success story, the ever-growing demand, as well as over 70 million fabricated restorations, are testament to the success and the reliability of the system (Koizumi H et al., 2015).

The components of the press technology include the highly esthetic IPS e.max Press lithium disilicate glass-ceramic ingots and the IPS e.max ZirPress fluorapatite glass-

ceramic ingots for the fast and efficient press-on-zirconia technique. Depending on the case requirements, two types of materials are available for CAD/CAM techniques:

- The innovative IPS e.max CAD lithium disilicate blocks and the high-strength zirconium oxide IPS e.max
- ZirCAD. The nano-fluorapatite layering ceramic IPS e.max Ceram, which is used to characterize/veneer all PS e.max components – glass or oxide ceramics – completes the IPS e.max System (Mounajjed R et al., 2016).

The shades and translucency levels of the IPS e.max CAD blocks are based on the overarching IPS e.max shade system. The system has a flexible design and can be used in conjunction with the A-D, Chromascop as well as Bleach BL shade guides. The shades of the Press ingots and CAD/CAM blocks offered in the IPS e.max System are all coordinated with each other. They are available in different degrees of opacity and/or translucency. The selection of the translucency level is based on the clinical requirements (shade of the prepared tooth, desired tooth shade) presented by the patient, as well as the desired processing technique (layering, cut-back, staining technique) (Flury S et al., 2016).

Achieving this success, required excellence in several areas, along with a clear vision of how the market could evolve with this product system. The various technical hurdles that occurred were overcome with intensive developmental work over many years. (Hamdy A, 2015).

Glass-ceramics were first developed by Corning Glass Works in the late 1950s. Over time, manufacturers started adding filler particles to the base glass composition to improve mechanical properties, such as strength and thermal expansion and contraction behavior. Crystalline filler particles can be added mechanically to the glass, for example by mixing crystalline and glass powders before firing (F. D. Oz and S. Bolay, 2018)

The mean observation period was 121 months. FDPs' survival rate (survival being defined as remaining in place either with or without complications) was:

- 100% after five years and 87.9% after ten years.

Their success rate (success being defined as remaining unchanged and free of complications) was:

- 91.1% after five years and 69.8% after ten years

Conrad (2007) reported longevity of ceramic restorations to range from:

- 88 - 100% after 2-5 years in service
- 84 - 97% after 5-14 years in service (Ahmadzadeh A et al., 2015)



Figure 4.3: E-max CAD

4.3. Fracture Resistance

Fracture strength is an essential mechanical property that has been shown to influence the clinical success of dental restorations. Dental ceramics are brittle materials with a high elastic modulus. In brittle materials, fracture often begins from a single location such as a flaw or a defect that has developed from mechanical, chemical, or thermal processing where defects act as a localized stress concentrator. Applied stress can cause cracks to originate from the flaws and propagate, leading to catastrophic failure. (Seydler B et al., 2015).

The fracture strength of a clinical crown is influenced by several factors, such as cementation, loading condition, and the elastic modulus of the supporting die. If natural teeth were used as the supporting model, the fracture strength of the copings might have been lower. As for the other factors of loading condition and cementation, they were the same for all the specimens in this study (Franco et al., 2014).

Fracture strength can be described as stress at which material tends to fracture. The most critical factors restricting the resistance to fracture are the size and distribution of load and fracture toughness. Nevertheless, fracture strength is an essential parameter in the evaluation of the fracture resistance of ceramic materials. (Zainab M et al., 2018).

It is well known that fractures always proceed from the area that is subjected to the highest tensile stress. Porosities and microcracks are sites of fracture initiation. They can considerably increase internal stress, which initiates to crack that progresses from the inner surface and finally damages the restoration. (Willard A et al., 2018).

Retrieved crowns analyzed by fractographic methods reveal several modes of fracture. One standard fracture mode causes the crown to split in half from cracks that propagate upward from a margin, in response to hoop stresses on the margins. The location of the fracture origins is usually in the approximal area. The reason that the fractures start there is not yet evident from the available evidence. Other standard fracture modes are chipping and delamination starting from worn or damaged surfaces in the veneering ceramics (Bakeman et al., 2015).

Most in vitro tests of crown shaped specimens load the crowns on the occlusal surface until a fracture occurs from contact damage cracking created directly under the loading device. Several investigations of in vivo failures indicate that this is not a standard clinical failure mode.

Also, using adhesive cementation can balance the fracture resistance of higher strength ceramic to be comparable to that of lower strength ceramic crowns. Today, ceramic is the standard material for CAD / CAM inlay restorations. Clinical failure rate, esthetic outcome, and stabilization of tooth substance are favorable for ceramics, whereas direct composite fillings exhibit lower marginal integrity in clinical practice and produce a lower stabilization effect on remaining tooth substance. (S.D. Heintzea et al., 2018).

The formation of an adhesive "monoblock" probably contributed to increasing the resistance to fracture, letting the cement act as an elastic stress absorber and compensating for the stiffness of the glassy component of lithium disilicate ceramic. Effective adhesion could strengthen the restorative system, allowing to dissipate the occlusal forces on the entire intaglio surface of the crowns; conversely, imperfect adhesion, voids and/or bubbles within the cement layer could negatively affect the

effectiveness of adhesion (Weyhrauch M et al., 2016).

On the other side, brittleness is a frequently recognized drawback, especially when faults and tensile stresses coexist in the same area of restoration. Small faults tend to open and propagate cracks when tensile stress is applied. The defect could be a microcrack on the surface produced by a diamond burr while adjusting ceramic, corrosion and surface diversification or a subsurface porosity due to handling flaw and mistake during firing cycles. (Sieper K et al., 2017).

Discontinuities or any irregularities in the porcelain body, or abrupt shifts in restore form, encourage stress and serve as an inducer of stress. The quantity of the enhanced pressure relies on the irregularity form. According to Griffith's theory of fracture, the primary cause of such faults are stress concentrations created around tiny faults and are high around cracks as ceramics lack the ductility to deform and decrease sharp angles. (Della Bona et al., 2014).

5. MATERIALS AND METHODS

5.1. Sample Selection

Forty-five human mandibular molars were selected for this study (Figure 5.1). The teeth selection criteria were:

- Intact and free of caries teeth.
- Unrestored teeth without any amalgam and composite filling.
- Teeth extracted for periodontal reasons.

Immediately after extraction, the teeth were scaled using a ruler to ensure that all the teeth were same almost the same size (1,5-2 cm). After that, the teeth were immersed in a germ-free 0.1% thymol solution at room temperature for one day. Then the teeth were stored in distilled water for no longer than three months before using them. Prior to testing, the teeth were cleaned by an ultra-sonic scaler to remove any attached soft tissues or pigments.



Figure 5.1: Human mandibular molars

5.2. Sample Preparation

The teeth were mounted individually in auto polymerizing acrylic resin blocks (Meliodent, Heraeus Kulzer, Berkshire, UK) (Figure 5.5). Every tooth was attached to a dental survey (Kavo EWL, Typ 990, Kavo Elektrotechnisches Werk GmbH, Leutkirch im Allgau, Germany) (Figure 4.2) using red laboratory wax while inserting it to the block to ensure that the long axis of tooth was perpendicular to the top surface of acrylic resin block.

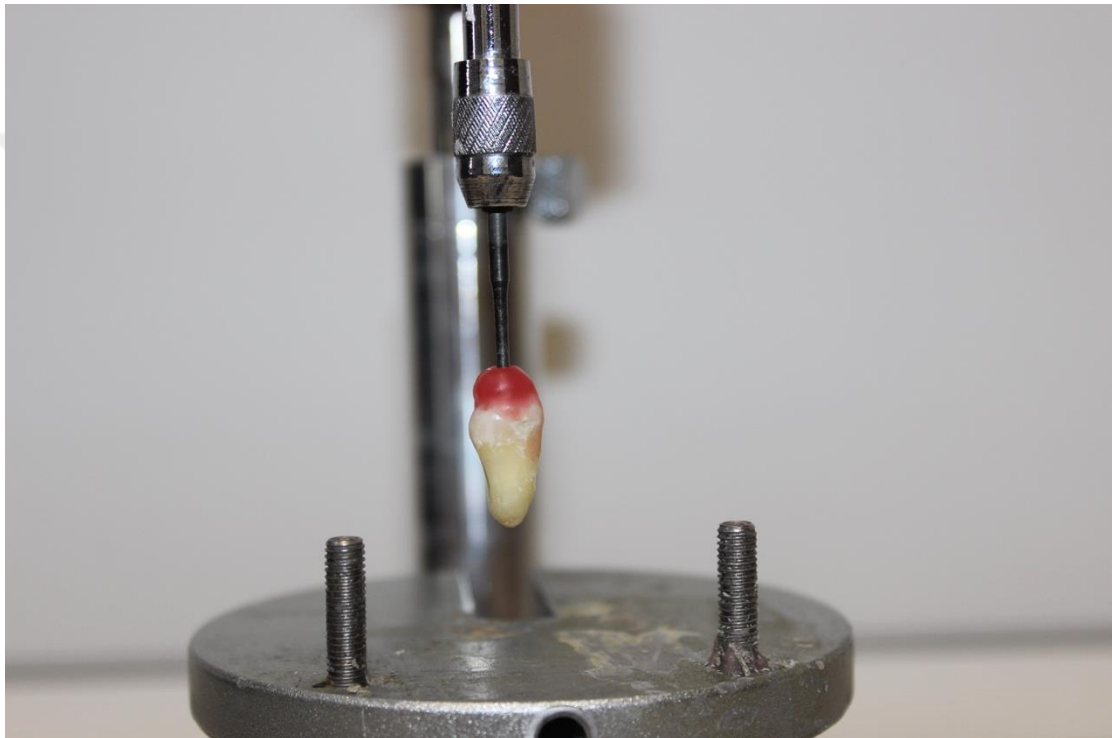


Figure 5.2: Tooth in dental survey

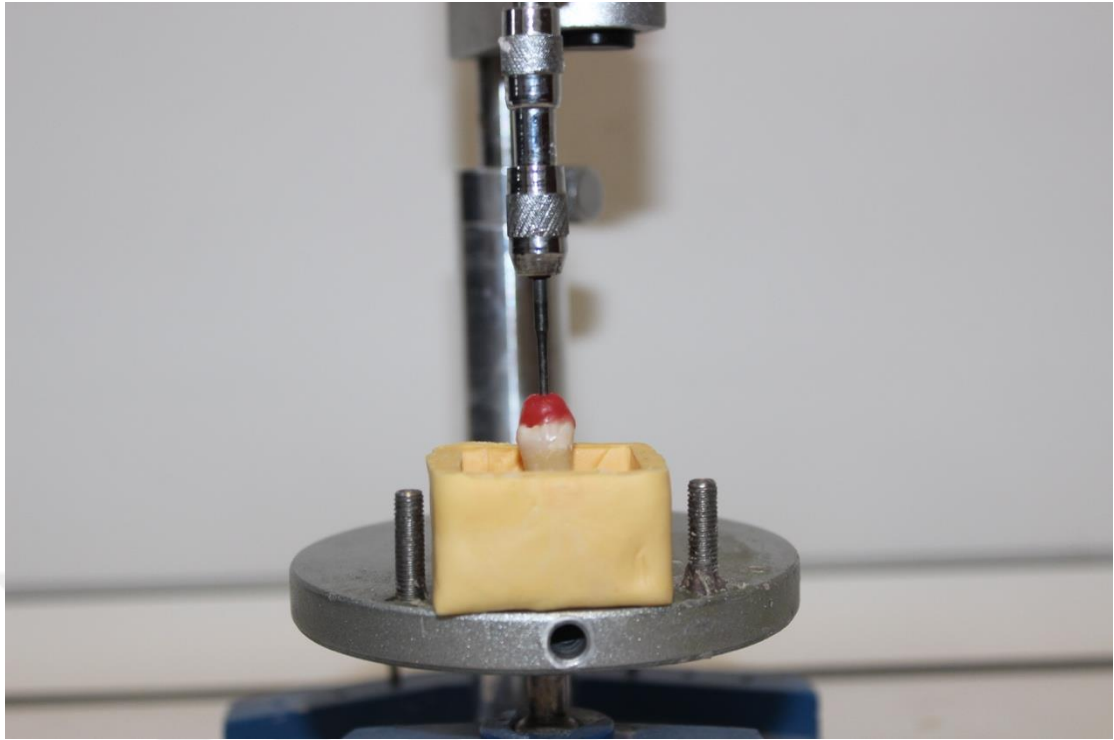


Figure 5.3: Tooth in model base

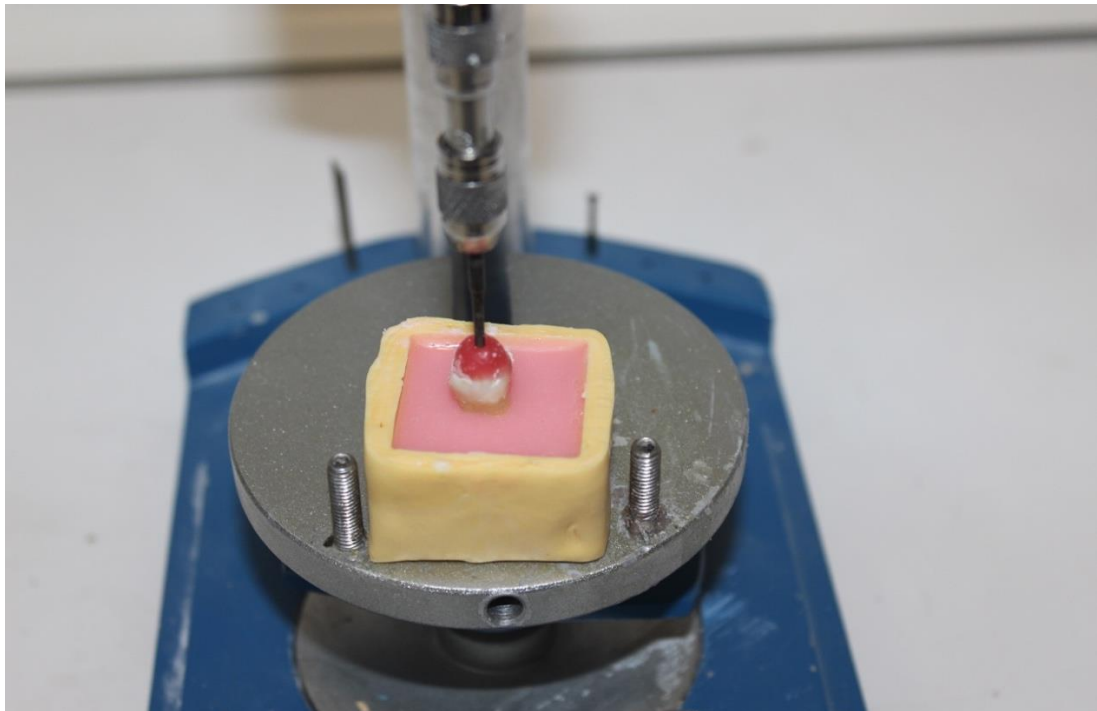


Figure 5.4: Tooth in acrylic resin



Figure 5.5: Tooth mounted in acrylic resin block

All the teeth were prepared according to a standardized protocol as follows:

- A chamfer finish line was 1mm above the cementoenamel junction (CEJ).
- Minimum layer thickness of each material was prepared by the respective manufacturer's instructions for all crown restorations as follow (1,5-2 mm occlusal reduction and 1-1,5 mm axial and marginal reduction and 6 to 10 degrees of total convergence angle).
- The preparation was done by diamond tapered burs (Meisinger, Germany).
- All teeth were prepared by one dental practitioner and standardized crown preparation was accomplished by fixing the dental handpiece in a parallelometer (Degussa F1; DeguDent, Hanau, Germany) (Figure 5.6).
- All sharp or internal line angles were rounded and the preparation margins were not beveled.
- All the prepared teeth were polished with fine polishing burs (Meisinger, Germany).

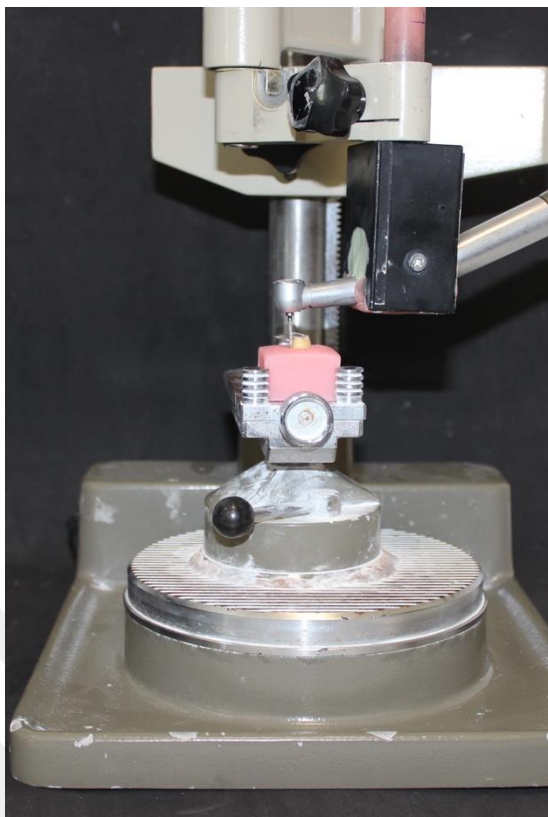


Figure 5.6: Standardized crown preparation using dental parallelometer

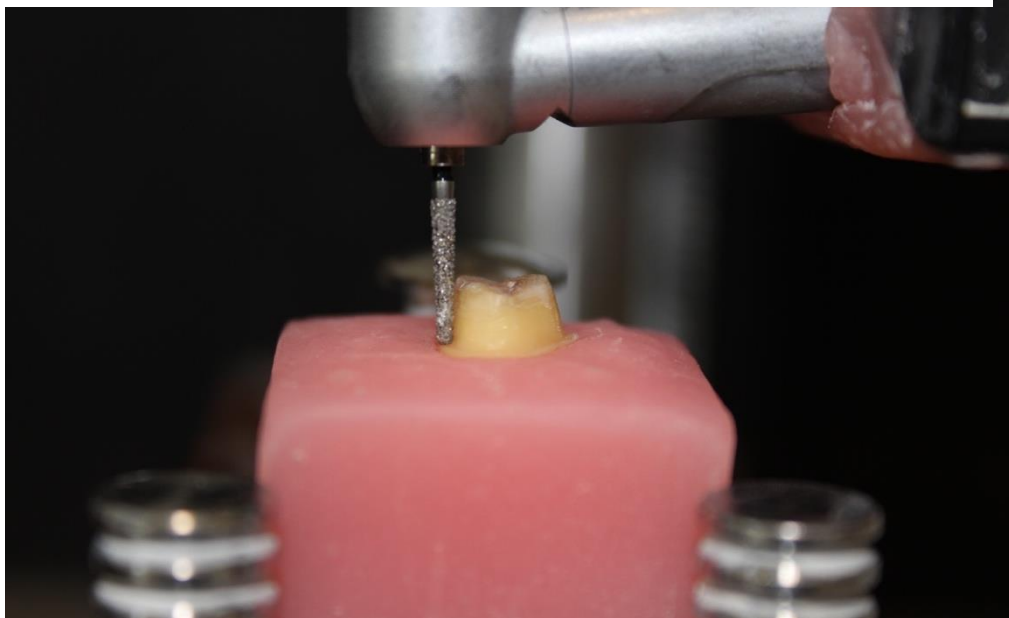


Figure 5.7: Diamond tapered burs

5.3. Fabrication of the Crowns

The master die of each specimen was used individually for laboratory fabrication of forty-five restorations using CAD/CAM (CEREC Dentsply Sirona, Germany, Bensheim) system from three different materials; CERASMART (GC America Inc, Chicago, USA), VITA ENAMIC (VITA Zahnfabrik, Germany) and IPS E Max CAD (Ivoclar Vivadent, Schaan, Liechtenstein). The teeth were divided into three groups randomly, each group containing fifteen specimens (n=15).

- Group A: CERASMART (GC America Inc, Chicago, USA).
- Group B: VITA ENAMIC (VITA Zahnfabrik, Germany).
- Group C: IPS e Max CAD (Ivoclar Vivadent, Schaan, Liechtenstein).

5.3.1. Restorations design:

Digital impressions were taken for all the prepared teeth using CAD\CAM intra-oral scanner (CEREC Omnicam, Sirona Dental Systems, Bensheim, Germany) to generate a 3D cast to design the master dies for the three ceramic blocks. The scan process was conducted following the manufacturer's guidelines, before which the teeth were dried and each tooth was scanned from the occlusal, buccal, mesial, distal and lingual surfaces. The camera tip was 5-10 millimeters away from the tooth. The camera head was slid over the teeth in a single direction gently to generate the successive data into a 3D model. Each crown was designed with CEREC MC XL software, according to the manufacturer instructions (1,5 occlusal thickness and 1mm axial thickness). Then and the digital information was sent to the accompanying milling unit.



Figure 5.8: CEREC CAD\CAM intra-oral scanner



Figure 5.9: Digital impression

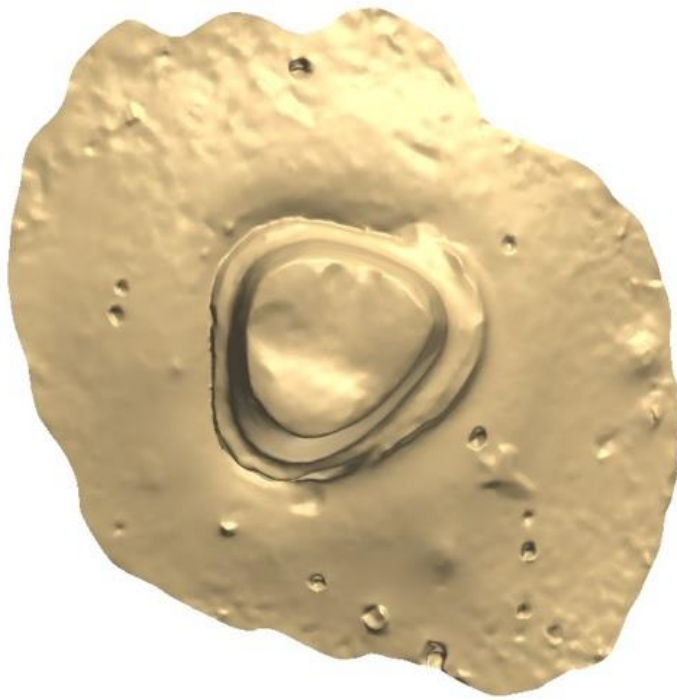


Figure 5.10: Final model

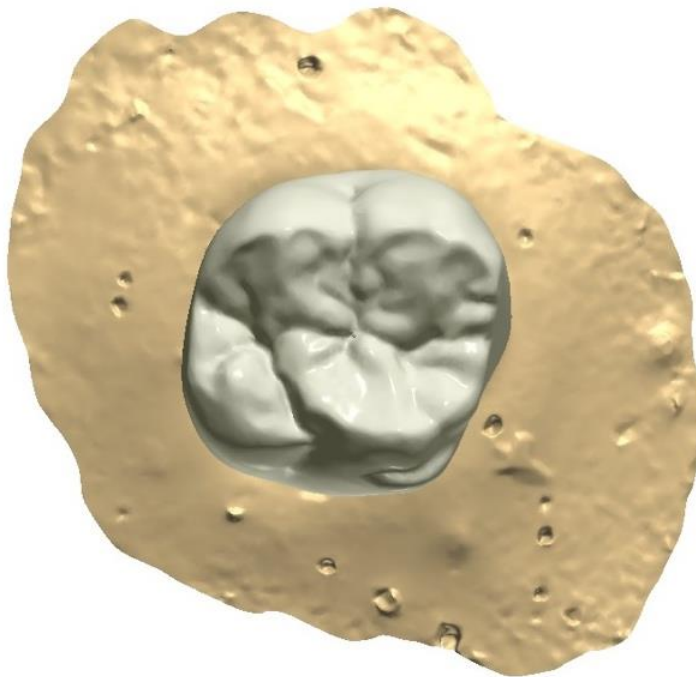


Figure 5.11: Restoration design

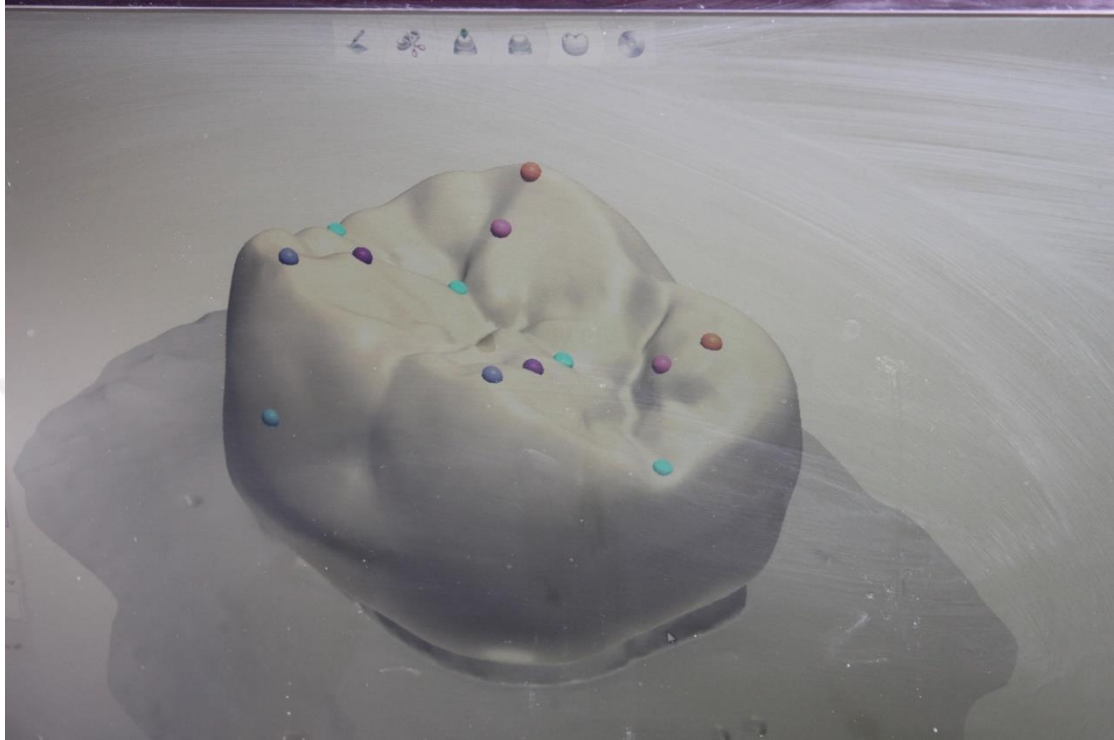


Figure 5.12: Final design

5.3.2. Milling, sintering

After designing the restorations, they were sent to a milling unit (inLab MC X5, Dentsply Sirona, Germany, Bensheim) and new set of CAD/CAM milling burs was used for each group. Then sintering was carried out for all groups with classic program using (inFire HTC speed, Dentsply Sirona, Germany, Bensheim) according to the manufacturer instructions. Both CAD/CAM scanner and milling machine were calibrated at the beginning of the study, and then recalibrated as prompted by the computer software.



Figure 5.13: Milling unit

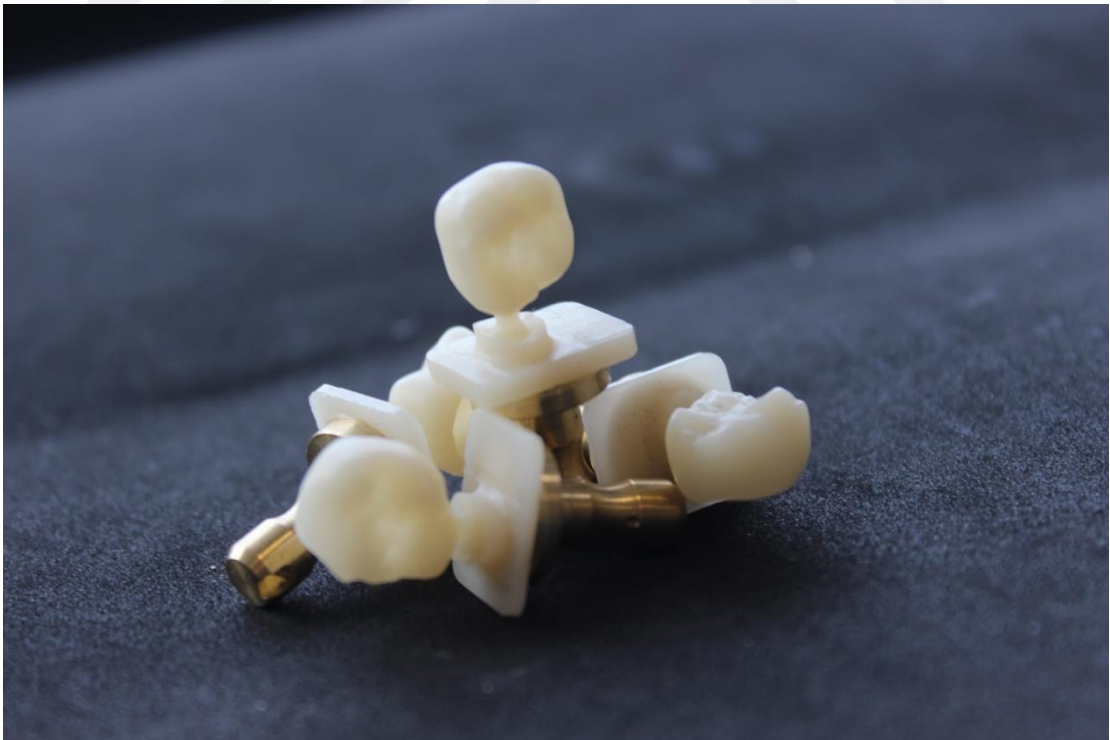


Figure 5.14: Final restorations



Figure 5.15: Measurement of the crown thickness

5.4. Cementation of CAD/CAM Crowns

Fit of crowns was evaluated by the same dental technician, and internal adjustments were performed using diamond finishing burs when needed. All crowns were seated on their respective prepared tooth and manipulated, when needed, to ensure complete seating. Before cementation, the internal surface of all specimens was sandblasted using sandblasting unit (Renfert, Hilzingen, Germany).

All specimens were dried with oil free compressed air and cemented using dual-cure self-adhesive resin luting cement (G-Cem LinkAce, GC, Tokyo, Japan). A2 shade was chosen. Cementation was carried out individually to all crowns according to the manufacturer instructions as following: each restoration was coated with sufficient amount of cement then immediately seated on the prepared tooth and firm finger pressure was applied in the direction of insertion. Excess cement was removed using a surgical blade (AESCULAP no. 12, Aesculap AG & Co, Tuttlingen, Germany) after curing 1-2 seconds, then each surface was light cured using LED curing unit (Elipar S10, 3M ESPE, Seefeld, Germany) for 20 seconds and left for self-cure for four minutes.



Figure 5.16: Self Adhesive Resin Cement

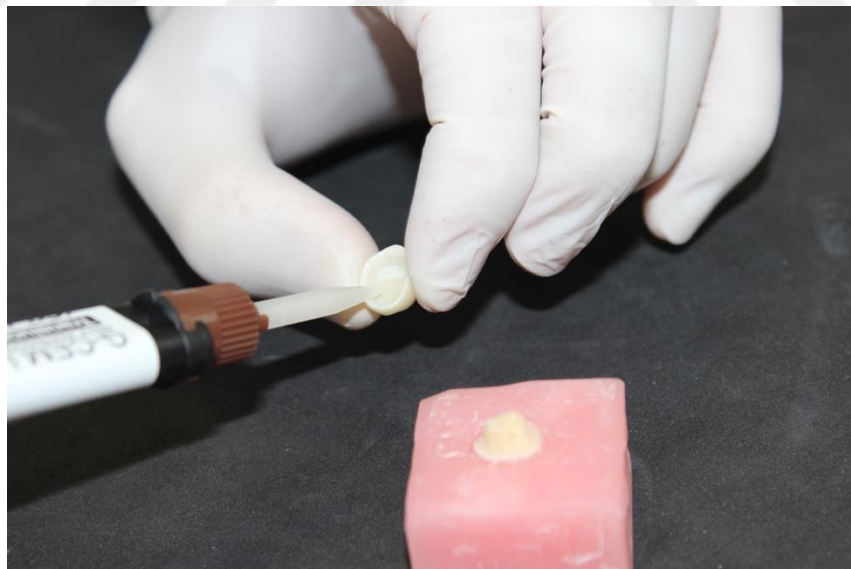


Figure 5.17: Filling restoration with resin cement

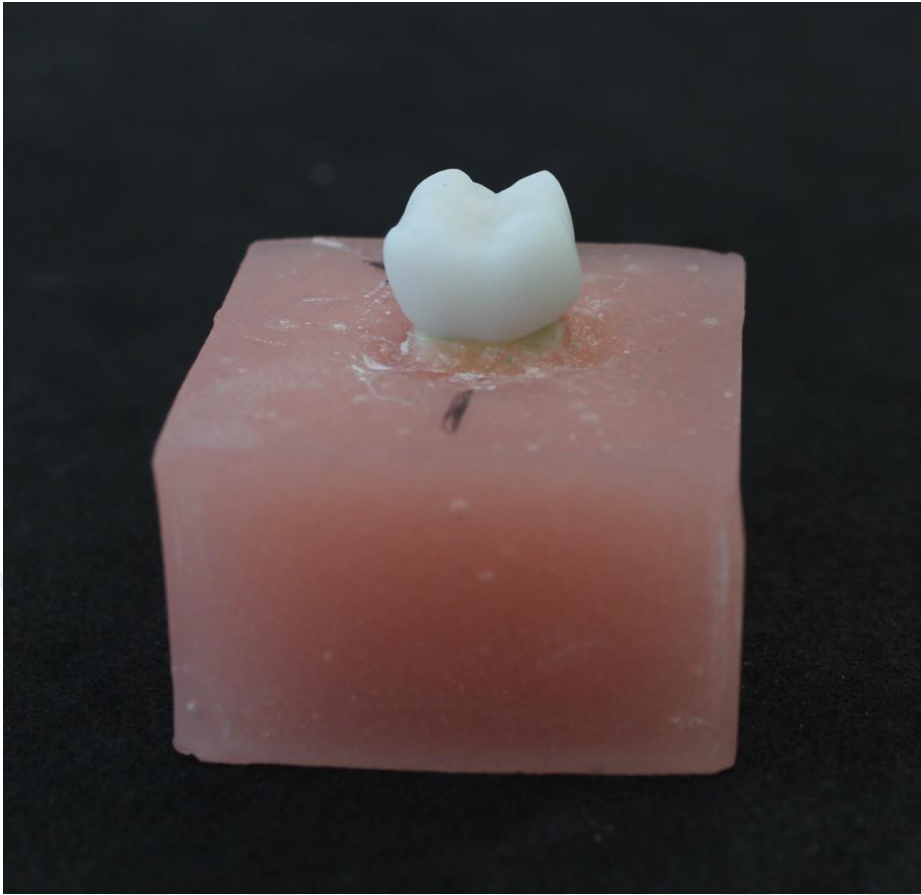


Figure 5.18: Cemented crown

5.5. Fracture Resistance Evaluation

The fracture resistance test was performed with a universal testing machine (Shimadzu, model no:133064800195, Kyoto, Japan). All specimens were individually mounted on a testing machine and fixed with screws. A steel ball of 6 mm diameter mounted in a screw-driven was used to vertically apply compressive load to the central fossa at a crosshead speed of 0.1 mm/min. All samples were loaded until fracture and the maximum breaking loads were recorded in Newtons (N) by computer software (Trapezius X SHIMADZU Software) and fracture modes were registered.



Figure 5.19: Universal testing machine (Shimadzu, Kyoto, Japan)

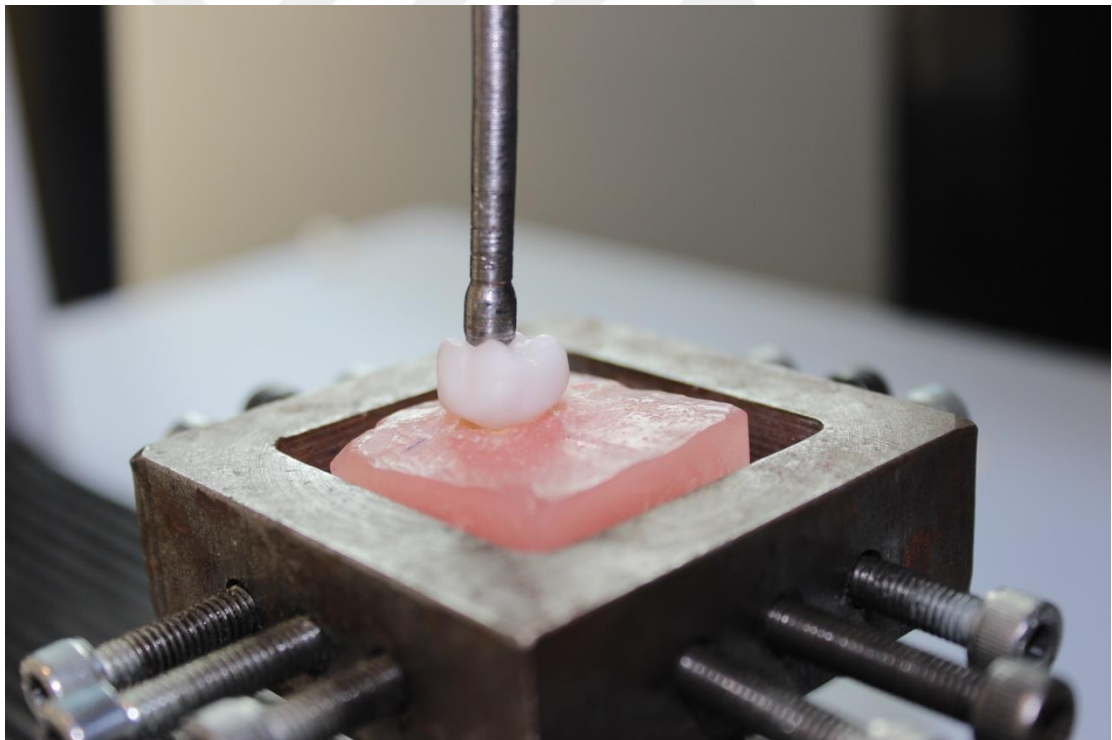


Figure 5.20: Steel ball of testing machine applying compressive load to the central fossa.

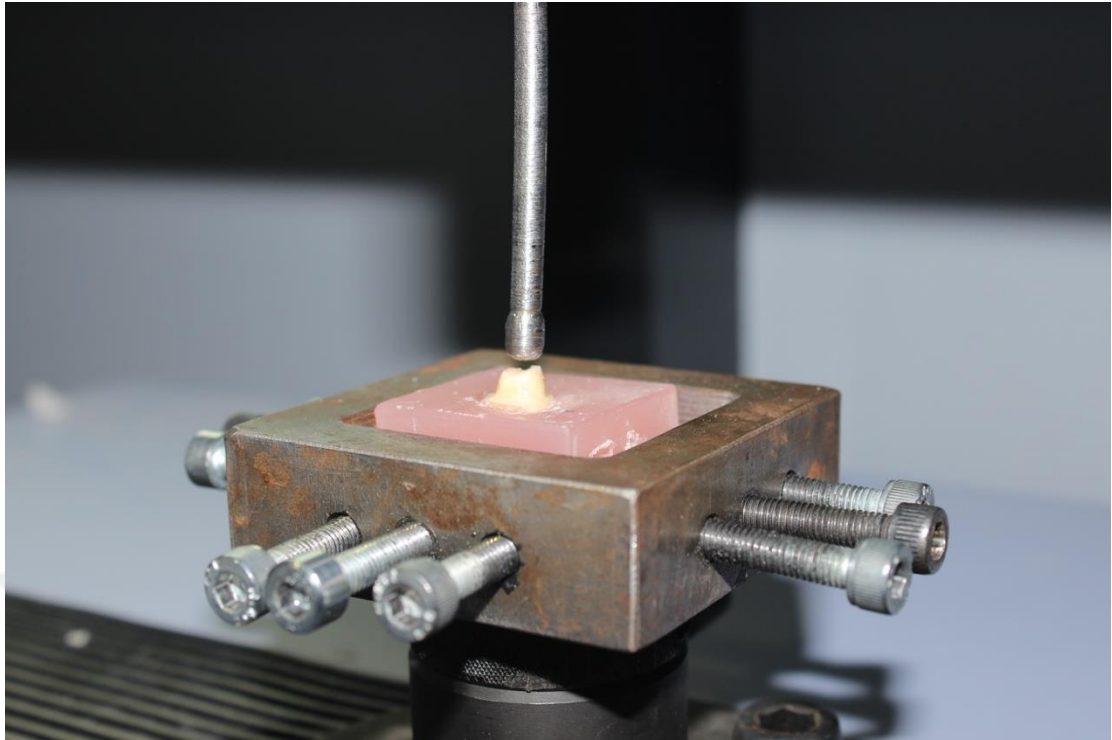


Figure 5.21: After applying compressive load to the central fossa, the fracture occurred

5.6. Statistical Analysis

In this present study, statistical analysis was performed with SPSS statistic software (version 21.0, SPSS Inc., Chicago, Illinois, United States). For each group classification, the mean value, the standard deviation (SD), the minimum and the maximum was calculated. For analyzing two- and three-dimensional deviations, one-way ANOVA was performed. LSD (least significant difference) test for post hoc comparison was conducted. The statistical significance was set at ($p < 0.05$).

6. RESULTS

Fracture resistance: Analysis of the results showed statistically significant difference between all groups ($P < 0.05$). Cerasmart group exhibited the highest fracture load mean (3135.74 ± 860.91) compared to E-max group that exhibited a fracture load mean of (2614.47 ± 578.79). As for VitaEnamic group, it showed a fracture load mean of (1687.90 ± 570.91) (Table 6.4).

Cerasmart group showed a mean value of (3135,74) compared to E-max (2614,47), and VitaEnamic (1687,90) (Table 6.1).

Standard deviation was the highest in Cerasmart group with (860,91), followed by E-max group (578,79), and the lowest was VitaEnamic group which registered a value of (570,91) (Table 6.4).

The minimum value in Cerasmart group was (1908,75) and the maximum was (4806,85), in Addition, VitaEnmaic group showed a minimum value of (1203,54) and a maximum value of (1825,14). Furthermore, E-max group exhibited a minimum value of (3180,26) and a maximum of (4225,41) (Table 6.1).

Analysis of the results showed that Cerasmart and E-max groups had statistically similar fracture loads and higher than VitaEnmaic group.

Failure pattern: in the present study all specimens exhibited total crown fracture and tooth fracture occurred only in two specimens of vitaEnmaic group.

Anova test revealed that there is a significant difference in between groups (table 6.2).

There was a statistically significant difference when comparing Cerasmart group with VitaEnmaic group ($P = 0,000$). However there was no significant difference between Cerasmart and E-max groups ($P = 0,105$). Furthermore, a statistically significant difference was found in the intergroup comparison between VitaEnmaic and E-max groups ($P = 0,002$) (Table 6.3).

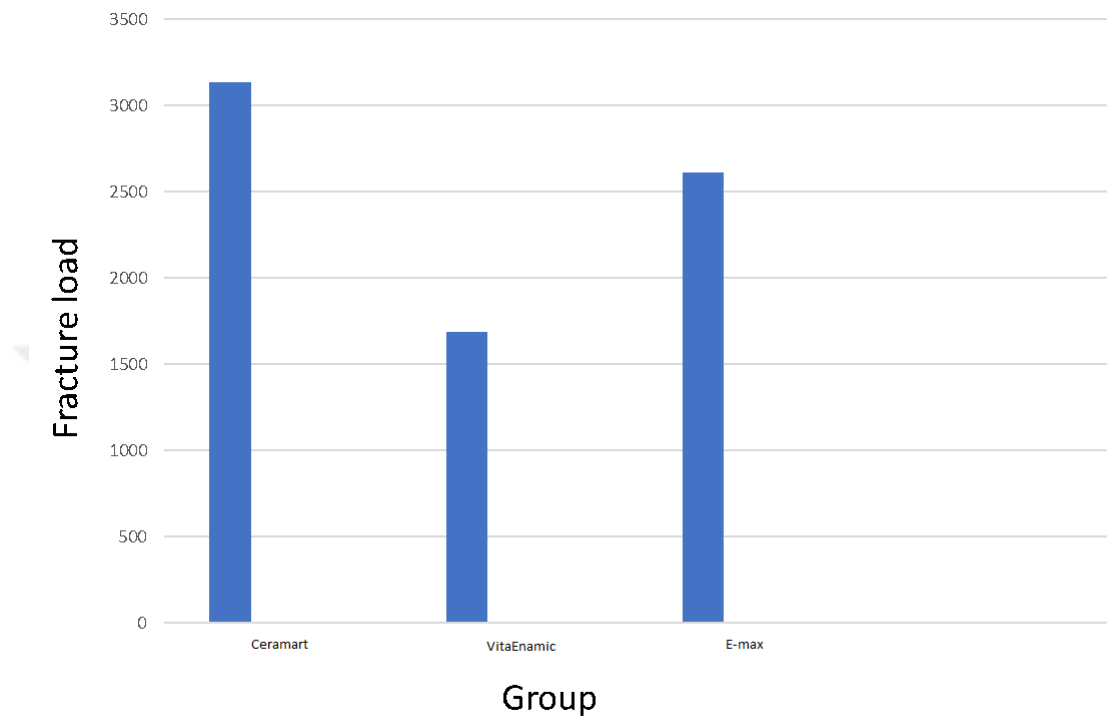


Figure 6.1: Fracture load of all experimental groups.

Table 6.1: mean, SD, SE, minimum and maximum values of fracture loads.

Material	Cerasmart	VitaEnmaic	E-max
1	4806.85	1244.14	3184.07
2	3784.71	1300.42	2991.69
3	4324.98	1984.23	2961.57
4	3794.66	1568.72	2372,00
5	2181.07	1444	2875.88
6	3086.96	1490.98	2261.64
7	2094.76	1520,00	4225.41
8	3599.21	1306.20	2420.05
9	2556.79	2363.22	2327.58
10	3617.41	1418.66	226,259
11	1908.75	1416.30	2378.23
12	2672.51	2509.89	2251.63
13	2252.96	1203.54	2174.68
14	3051.13	3180.26	2704.9
15	3303.48	1368.05	1825.14
Mean	3135,74	1687,90	2614,47
Std. Deviation	860,91	570,91	578,79
Std. Error	222,28	147,41	149,44
Minimum	1908,75	1203,54	3180,26
Maximum	4806,85	1825,14	4225,41

Table 6.2: Anova test.

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	16 132 474 ,452	2	8 066 237 ,226	17,25	,000
Within Groups	19 629 567 ,738	42	467 370 ,660		
Total	35 762 042 ,190	44			

Table 6.3: Tukey tests.

Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
				Lower Bound	Upper Bound
Cerasmart VitaEnmaic	1447,84	249,63	,000	841,36	2054,32
	E-max	521,27	,105	-85,2012	1127,75
VitaEnmaic Cerasmart	-1447,84	249,63	,000	-2054,32	-841,36
	E-max	-926,56	,002	-1533,04	-320,08
E-max Cerasmart	-521,27	249,63	,105	-1127,75	85,20
	VitaEnmaic	926,56	,002	320,0842	1533,04

Table 6.4: mean, SD, SE, minimum and maximum values of fracture loads.

Material	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Cerasmart	3135,74	860,91	222,28	1908,75	4806,85
VitaEnmaic	1687,90	570,91	147,41	1203,54	3180,26
E-max	2614,47	578,79	149,44	1825,14	4225,41

7. DISCUSSION

Comparative Evaluation of Materials used in this study: The discussion part of this research is based on a comparative model. First, an in-depth evaluation is presented based on each material that was used in the study. For purposes of comparison, the use of similar materials is discussed based on other existing research that have been done by other researchers in the same field. The use of a comparative model in scientific research is instrumental in making useful deductions based on the results that have been retrieved from a study. A summary of the materials and methods that have been used in this study are reviewed for the purposes of conducting a substantive comparison with materials and methods that have been adopted in in-vitro research papers.

This research entailed five fundamental steps of applying materials and methods to realize the expected results. The five steps included: sample selection, sample grouping, tooth preparation, fabrication of the crowns and cementation procedure. The specific details and reasons for choosing the steps are described in the preceding section. The choice of materials and methods for the study was conducted in such a manner that each method and material used complemented the functionality of another. In the end, a more streamlined methodology was employed to address the specific requirements and objectives outlined in the research. The results that were yielded from the study were then used to develop fundamental insights on the behavior of fracture resistance in crown restoration processes.

Discussion of Materials and Methods: Separate studies concerned with the evaluation of fracture resistance in crown restoration processes have relied on varied materials and methods to draw substantial conclusions. A study conducted by Sorrentino et al., (2016), sought to analyze the resistance of fracture in the case of a CAD/CAM Cerasmart using the crowns of molar tooth that have varying occlusal thicknesses. The study entailed the use of materials and methods that were specific at addressing the actual requirements of the study. A total of 30 human molar teeth were extracted for the study. Only teeth that were experimentally sound were selected for the experiment. This implied that the teeth that had carries were subsequently rejected. By use of an ultrasonic scaler, the teeth were scrubbed off to remove any external debris.

Before the materials could be subjected to mechanical tests, they were kept in an incubator set at a humidity factor of 0.9 and a temperature of 37°C to mimic the oral environment. With the aid of a CAD software, the restorations were grouped in three categories with varying occlusal thicknesses. A luting agent was used to cement the restorations before fracture tests.

In a separate study carried out by Saridag, Sevimay and Pekkan (2013), an in vitro study was conducted on “Fracture Resistance of Teeth Restored with All-Ceramic Inlays and Onlays”. In that study, 50 teeth were extracted freshly from the human mandibular teeth region. Subsequent cleaning was carried out with pumice water and a rubber cleanser. Only intact and carries-free teeth were used in the study. The teeth were kept in distilled water to mimic actual oral conditions. The roots of the teeth were covered in a layer of polyether to mimic the ligament in the periodontal region before being subjected to mechanical fracture tests.

Comparing these independent studies, some deductions can be made. In all the three studies, the fracture resistance tests were to be determined. However, the number and types of materials used in the study were different. For instance, this study relied on 45 teeth while the other studies relied on 50 and 30 teeth. The presence of a large sample in this study provided an opportunity to establish reliable and accurate results. In addition, the selection criteria for these studies relied on a selective model that required experimentally sound teeth. As a result, only teeth that were free from carries were used in the studies. One fundamental difference was however observed. While the two studies utilized methods to mimic oral conditions, this study failed to develop a substantial technique for mimicking oral similar conditions. More importantly, the findings of the three studies were all in agreement.

The present study was concerned with an evaluation of the fracture resistance of crown restorations fabricated from different hybrid ceramic materials in CAD/CAM system. Until present day, several dental studies have been conducted to investigate the mechanical properties of hybrid ceramics. A key aspect of the present-day hybrid ceramics is their fracture resistance. Accordingly, the study was designed in a procedural manner including the selection of samples, the preparation of samples, fabrication of the crowns, cementation of CAD/CAM crowns and evaluation of fracture resistance. In the end, a statistical analysis was carried out with the aid of the SPSS

statistics software to illustrate the findings of this study. The use of the SPSS statistical software in the analysis of the data from the study was instrumental in providing a concrete illustration for easy interpretation hence facilitating factual conclusions. Consequently, the results that have been retrieved from this study have the potential of impacting the clinical choice and use of the ceramic hybrid materials in dental practices across various environments.

To begin with, the process of selecting samples for the study was carefully done. The selection of samples was a significant part of the study as it determined the quality of materials to be used in the study. According to Gracis et al., (2015), the choice of samples in scientific studies is critical in meeting the objectives of the study that are set out. In line with the expectations of the study, determining and evaluating the fracture resistance of hybrid ceramic materials, a large sample size of 45 molar teeth was selected. A selection criterion was used to ensure that the teeth that were selected for the study met the standards that were required. For instance, it was important to select a sample size that is free from dental caries and other defects. In addition, the extraction of the teeth was done exclusively for the purposes of orthodontic studies. Next, the samples were taken through a grouping process. A random technique was used to divide the specimen into three groups each containing 15 specimens. The process of grouping is important as it exposes the specimen into different states. For instance, one group of the specimen is utilized as a control experiment for the purposes of comparative analysis.

The teeth samples were then taken through a preparation process to allow for optimal and hence accurate observation of experimental results. The preparation process involved the mounting of the teeth on automatic polymerizing acrylic resin blocks by attaching every tooth to a dental survey. Most importantly, the preparation process of the teeth played a fundamental role in ensuring that the CAD/CAM requirements of the study are met. For instance, the axial positioning of the teeth was to be specifically aligned in a way to optimize the accuracy of the process and hence the results. The fabrication of the crowns was done with the aid of the CEREC digital scanner. In order to realize a standardization in the designs of crowns, strict adherence to the instructions of operating the CEREC digital scanner was done. In addition, a design procedure was used to conduct the stages of restoration parameters including the

restoration design, sintering and milling. Finally, a cementation procedure was done on the teeth specimens. Every crown was carefully cemented to firmly fit into position. The cementation stage was a final and critical stage as it marked the completion of the methods before fracture resistance tests could be conducted. A compressive axial loading was then subjected to the teeth samples with the aid of computer control. The optimum breaking load was tabulated for each tooth sample. Apart from statistically analyzing the recorded data with the aid of SPSS software, a one-way ANOVA was used to analyze the 2 and 3-dimensional deviations. In addition, Turkey tests were carried out for the three sample groups – Cera, Vita and E-max. The results that were obtained from the study are statistically discussed in the section that follows.

As with existing research, the investigations of the study demonstrate the significance of occlusal thickness in the fractural resistance of hybrid ceramic materials. The possibility of reducing the occlusal thickness of the ceramic material to a safety thickness of 1.0 mm has the effect of limiting the intrusiveness of the preparation stages through the CAM/CAD techniques. According to Spitznagel et al., (2014), the resistance to fracturing of the ceramic materials increases with the occlusal thickness of the ceramic material. Consequently, the failure mode progressively increases. Spitznagel et al., (2014) assert that apart from the material behavior of ceramic materials, the thickness of the cores is a major determinant in gauging the clinical longevity of ceramic restorations. This is due to the fact that the teeth are filled with high density resin that is effective in shock absorption. In addition, the clinical performance of the ceramic restorations is strongly influenced by the type of luting material used as well as the accuracy of the dental restoration procedure that is used. The results of the statistic testing for the study could have been affected by a number of variables such as luting technique used, the type of die material used and the storage of the experimental specimen.

Discussion of Results: Separate studies concerned with the evaluation of fracture resistance in crown restoration processes have relied on varied materials and methods to draw substantial conclusions. A study conducted by Sorrentino et al., (2016), In its conclusion, the study established that the occlusal thicknesses of the restoration crowns had minimal influence on the resistance of the fractures. In addition, CAD/CAM restorations used in the study demonstrated a substantive proportion of fracture resistance. For this reason, the restorations can effectively be utilized in the molar regions in clinical practice (Sorrentino et al., 2016).

In a separate study carried out by Saridag, Sevimay and Pekkan (2013), it was concluded that the cuspal coverage of the teeth crowns reduced the fracture resistance of the dental restorations (Saridag et al., 2013).

For these studies, it was established that the CAD/CAM restorations made in the studies demonstrated a substantial amount of fracture resistance. The force of fracture resistance was larger than the human biting force. For this reason, the CAD/CAM restorations can be used in clinical practice.

Evaluation of Hybrid dental ceramic: For the present study, the Vita sample group was observed to possess the lowest fractural strength with a numerical mean value of 1687.90 N. For this study, the crowns for the sample teeth were taken through the fabrication process from hybrid ceramic material. Low fracture strength that was recorded for the Vita group can potentially be attributed to the low mechanical properties that characterize the material. Apart from the lower strength characteristics of the hybrid ceramic material, another potential factor that could have contributed to the low mean value of the Vita group is the nature of material that is contained in the hybrid composition of the material. In separate The Vita group comprised of hybrid ceramic materials that has the integration of polymers and unified networks. The impact of the composition of the ceramic material on the strength of the material is that it leads to a difference in the resulting rates of ablation during the processes of surface treatments such as polishing and grinding. The processes of surface treatment may cause the rise of microcracks along the several boundaries of the hybrid ceramic material. In the end, the mechanical properties of the ceramic material are greatly

reduced. Hybrid ceramic materials still present several problems that directly impact on their fracture resistance in crown restoration applications. According to (Coldea et al., 2013), in hybrid materials, failure could originate from any flaws on the microstructure. For instance, in the case of ceramics that are infiltrated by polymers.

Regarding the failure patterns that were observed in the study, all the specimen that were utilized in the study exhibited signs of total crown fracture. In addition, the tooth structure occurred only in the two specimens of the vita group. According to (Felden et al., 2013), failure in ceramic structures is sometimes attributed to the surface tension that occurs at the surface of the materials. The results of the statistical analysis via the ANOVA test as well as the Turkey tests provided useful insights into the behavior of fracture resistance of crown restorations that are fabricated from different hybrid ceramic materials. Due to the surface tension that is existent on the surface of the materials, flaws propagate slowly leading to massive failures in the end. The flaws that are developed at the surface of the ceramic materials could also be as a result of two variables – the mode of machining and the material itself. These two variables have the capability to increase the possibilities of fracturing which has an effect in the overall fracture resistance of ceramic materials especially in the Vita group. According to a study done by Bakeman et al., (2015), the application of higher fracture loads in the case of CAD/CAM techniques has the potential of producing fractional coverage in dental restorations as compared to glass ceramics of lithium disilicate.

In addition, Bakeman et al., (2015), put forward several reasons that can be attributed to the failure of most ceramic restorations. The principal problems indicated by Bakeman et al., (2015), in their research were attributed to the process of cavity preparation in ceramic restorations. Other reasons include: the type and nature of luting agent used, the thickness of the ceramic material, internal flaws of the ceramic material and patient occlusion. In a different study conducted by Sieper et al., (2017), the failure in ceramic restorations has been attributed to the brittle feature present in ceramics. Moreover, ceramics are associated with a small abrasive impact on opposite dentition. Despite the failure of ceramic restorations, advancements in dental research coupled with luting technologies have led to the creation of hybrid ceramic crowns with adequate resistive features to achieve both the aesthetic and functional needs in dental applications. The impact of the luting agent on the failure of ceramic restoration is

evidenced in the study results. It is shown that the CAD/CAM restorations used in the study had a substantial amount of fracture resistance and can hence be employed in clinical practice.

This section entails an in-depth assessment and evaluation of the statistical results that were obtained from this study. It is important to note that the materials and methods that have been applied in this study were selected and utilized in line with the aim of the study. That is, the overall study was guided by the objectives of the experiment that were set out in the introductory section of the paper. In discussing the results, it is important to note that the three sample groups that have been described under materials and methods were designated into Cera group, the Vita group and the E-max. As a result, the discussions will exclusively rely on the three terminology to evaluate the findings of the research. In order to develop a critical evaluation of the fracture resistance of the crown restorations that are fabricated from different hybrid ceramic materials, the results are discussed under two major sections – fracture resistance and a demonstration of the failure patterns. At the beginning of the study, a null research hypothesis was formulated stating that the fracture resistance posterior crowns would be similar for different materials. Based on the results of the research, the null hypothesis was accepted owing to the fact that the fracture resistance of the different hybrid ceramic materials showed no major differences under the CAD/CAM system. Conversely, the null hypothesis was rejected based on the significant differences that were observed on the mode of failure patterns of the different hybrid ceramic materials. The reasons for accepting and rejecting the null hypothesis of the research are illustrated in the discussions that follow.

For this present study, the statistics that were recorded demonstrated significant differences across the fractural strengths of the three different groups of specimens. However, it is important to note that for the fracture strength of the fabricated crowns, the mean value that was recorded for each distinct group was more than the normal maximum biting force that is usually recorded along the molar region of the teeth. According to Vanoorbeek et al., (2010), this maximum biting force is usually approximated at 450N in the region of premolars. The finding could be attributed to

two possible sources. On one hand, the process of teeth preparation can be said to have been carried out adequately. Fulfilling of the teeth preparation requirements for the distinct materials specified in the study provided the necessary volume of material to offer resistance to the load that was applied. On the other hand, the finding could directly be attributed to strict adherence to the instructions during the process of cementation. The fact that each tooth was subjected to proper surface treatment before cementation implied that the overall strength was enhanced. The differences in structure for the hybrid ceramic materials for the through groups were dependent on other factors which include the mechanical characteristics of the materials, the chemical composition of the materials and their overall microstructures (Fabbri et al., 2014).

In this present study, an examination of the degree of reliability that is observed on posterior ceramic restoration that was developed from various materials with distinct methods of fabrication. The resistance of the fractures on posterior restorations are appreciably affected by the type of material involved. From the study, it was determined that all the hybrid ceramic materials that were used showed signs of high fractures on the specific materials used. The failure of ceramic restoration was attributed to the tooth structures that remained. In addition, the fractural resistance that was shown for the fabricated crowns was comparable to the fractural resistance of teeth specimen left unprepared. The fractural resistance of unprepared teeth is typically measured at 2905N (Coldea et al., 2013). Owing to the fact that the ceramic has a high concentration of the crystal, the luting agent that is used in the cementation stage offers a more compact interlocking mechanism that stops the spreading of microcracks in the tooth structure. The onset of cracks on the posterior layer results into prompt propagation across the tooth structure. The fracture loads that were observed on all the ceramic restoration processes achieved through the CAD/CAM technique showed near similar mechanical properties between ceramic hybrid materials and lithium disilicate materials (Gehrt et al., 2013).

Both the biomimetic and mechanical properties of hybrid ceramic materials can be thought of to be attributed to effective clinical results in the case of limited prosthetic space. The ability of Cerasmart to be manufactured in smaller thicknesses implies that it can be applied in conditions that are minimally invasive with regards to the strategies

that are applied in treatment. For instance, they could be applied in the case of worn dentition. From the tabulated results, the fractural force values that were recorded for the three sets of sample data exceeded the average maximum biting force in the premolar and molar regions of the teeth. As a result, it is proven that all the three groups of data that were subjected to experimental procedures had the ability to endure the physical occlusal loads that they were subjected to. However, in line with the modes of fractures that were recorded, ultrathin hybrid ceramics are not recommended for use in the premolar region of the teeth (Felden et al., 2000).

In the experimental results obtained for this present study, an evaluation of fracture resistance can be done on two major sections – fracture resistance and the failure patterns. Aspects of these areas of discussion have already been discussed comprehensively in the sections above. To begin with, the results on fractural resistance showed significant disparities in the three groups of data explored in the study. More precisely, the Cera group was shown to exhibit the highest fracture load at a mean value of 3135.74 ± 860.91 N. The E-max group had the second highest fracture load recorded at a mean value of 2614.47 ± 578.79 N with the Vita group registering the lowest fracture load marked at a mean value of 1687.90 ± 570.91 N as indicated in table 1. The graphical representation of the fracture loads shown in figure 1 illustrates the order of sequence for the weighted fracture loads of the three sample groups led by Cera then E-max and finally Vita. Table 1 demonstrates a detailed analysis of the statistical data that was collected for the 45 teeth in their three distinct groups.

8. CONCLUSION

Having assessed, evaluated and discussed the results of the study, the following conclusions can be made on the fracture resistance of crown restorations fabricated from different hybrid ceramic materials:

1. Strength of the fracture of the crowns that were fabricated from different hybrid ceramic materials were found to exceed the normal maximum biting force that is present in the region of the molar teeth.
2. The implication of this observation is that the hybrid ceramic materials could successfully be used in the clinical practice without fracturing.
3. For the three groups of sample data, the highest fracture strength tabulated was the Cerasmart group with a mean value of 3135.74 N, followed by the E-max group with a mean value of 2614.47 and finally the VitaEnamic group which had a mean value of 1687.90.
4. The fractural strength of the crowns that had been fabricated was hugely influenced by the chemical configuration and the physical structure of the ceramic material that was employed in the monolithic fabrication by aid of the CAD/CAM technique.
5. For hybrid ceramic restorations, it is important to consider several factors that affect the fracture resistance of the crown restorations.

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	Duty	Institution	Duration (Year - Year)

Foreign Languages	Reading comprehension	Speaking*	Writing*
English	Very Good	Very Good	Very Good
Turkish	Very Good	Very Good	Very Good
Arabic	Mother language	Mother language	Mother language

Foreign Language Examination Grade#								
YDS	ÜDS	IELTS	TOEFL IBT	TOEFL PBT	TOEFL CBT	FCE	CAE	CPE
			78					

	Math	Equally weighted	Non-math
ALES Grade			
(Other) Grade			

Computer Knowledge

Program	Use proficiency
Microsoft office	Good

*Evaluate as very good, good, moderate, poor.

ENCLOSURE: Other scientific activities (publication, congress proceedings etc.)



T.C.
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Diş Hekimliği Fakültesi
Klinik Araştırmalar Etik Kurulu

Projenin Adı: In vitro evaluation of fracture resistance of crown restorations fabricated from different hybrid ceramic materials

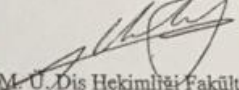
Proje yürütücüsü: Buket Evren

Projedeki Araştırmacılar: Qutada Ismael Kadhim Kadhim

Onay tarihi ve sayısı: 28.03.2019 2019-288

Sayın Doç. Dr. Buket Evren

2019-298 Protokol nolu "In vitro evaluation of fracture resistance of crown restorations fabricated from different hybrid ceramic materials" isimli girişimsel olmayan çekilmiş dişlerle in vitro çalışmanız Marmara Üniversitesi Klinik Araştırmalar Etik kurulu tarafından incelenmiş ve etik yönden uygunluğuna karar verilmiştir.


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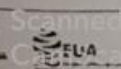
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