بسم الله الرحمن الرحيم

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The Effect of Two Margin Designs on Fracture Resistance of Different Ceramic Crown Materials

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By

Iman Jaber Mohammed Ahmed El-Mashali

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Faculty of dentistry

Ain Shams Unversity

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Supervisors

Dr. Marwa Mohamed Wahsh

Professor of Fixed Prosthodontics Department
Faculty of Dentistry, Ain Shams University

Dr. Maged Mohamed Zohdy

Associate professor of Fixed Prosthodontics
Faculty of Dentistry, Ain Shams University

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List of Contents

Title	Page No.

List of Contents I

List of Tables II

List of Figures III

Introduction 1

Review Of Literature 3

Aim of the Study 28

Materials and Methods 29

Results 51

Discussion 58

Summary 67

Conclusions 70

References 71

Arabic Summary .... -

List of Tables

Table No.	Title	Page

Table (1): List of material used 29

Table (2): Physical and mechanical properties of Zirconia re-enforced Lithium Silicate....31

Table (3): Physical and mechanical properties of High Translucent zirconia 32

Table (4): Physical and mechanical properties of (PICN)....33

Table (5): Physical and mechanical properties of Total-cem 33

Table (6): Samples Grouping....36

Table (7): Descriptive statistics for fracture resistance *(N)* of different groups 51

Table (8): Effect of different variables and load test and their interactions on fracture resistance *(N)*....52

Table (9): Mean ± standard deviation (SD) of fracture resistance (N) for different materials despite the finish line design 53

Table (10): Mean ± standard deviation (SD) of fracture resistance (N) for different preparation designs regardless of the ceramic material....54

Table (11): Mean ± standard deviation (SD) of fracture resistance (N) for different materials and preparation designs. 56

List of Figures

Fig No.	Title	Page
Fig (1):	Celtra Duo blocks	30
Fig (2):	High translucent zirconia (zolid ht+)	31
Fig (3):	Ceramill zolid ht+	31
Fig (4):	Vita enamic blocks	32
Fig (5):	Totalcem resin cement	34
Fig (6)::	Samples Grouping	36
Fig (7):	Prepared maxillary premolars to receive ceramic crowns	36
Fig (8):	Impression index of prepared teeth	37
Fig (9):	Epoxy resin die	38
Fig (10):	Software design	39
Fig (11):	Scanning the sample	39
Fig (12):	digital scanner (shinning 3D)	39
Fig (13):	Milling process	41
Fig (14):	Milled crowns fixated in milling machine	41
Fig (15):	Milling machine (Redon Hybrid machine)	41
Fig (16):	Vita supprinity polishing set technical	42
Fig (17):	Vita Enamic Polishing set technical	42
Fig (18):	Sintering machine	43
Fig (19):	Checking marginal thickness using manual caliper	43
Fig (20):	Hydrofluoric Acid etching	44
Fig (21):	Rising after acid etching	44
Fig (22):	Chalky white appearance	45
Fig (23):	Silanation	45
Fig (24):	Air abrasion of Zirconia Crown	45
Fig (25):	Rinsing of Zirconia Crown	45
Fig (26):	Crown is ready for cementation	46
Fig (27):	Applying resin cement	47

Fig (28): Light curing..47
Fig (29): Finishing and polishing..47
Fig (30): Monitor showing number of cycles 48
Fig (31): Thermo cycler 48
Fig (32): Universal testing machine...49
Fig (33): load application..49
Fig (34): Fractured sample..49
Fig (35): Box plot showing fracture resistance (N) values for different groups 51
Fig (36): Bar chart showing average fracture resistance (N) for different materials...53
Fig (37): Bar chart showing average fracture resistance (N) for different preparation designs 54
Fig (38): Bar chart showing average fracture resistance (N) for different materials and preparation designs (A) 56
Fig (39): Bar chart showing average fracture resistance (N) for different materials and preparation designs (B)...57

Introduction

Advancements in computer system technologies have revolutionized the field of dentistry through the introduction of CAD/CAM systems. The popularity of these systems over the past 25 years is attributed to their efficiency and precision of designing and manufacturing. [1,2].

The CAD/CAM restorative materials are either ceramics, composite or hybrid ceramics.

The ceramic materials include feldspathic glass ceramics, leucite re-enforced glass ceramics, Lithium di-silicate glass ceramics (LS2), yttrium tetragonal zirconia, zirconia oxide (ZrO2) and lithium silicate re-enforced glass ceramics (ZLS), translucent zirconia and high translucent zirconia (HTZ).[3] whereas Resin materials such as PMMA and Resin composite blocks. The hybrid ceramics ***(resilient ceramics)*** includes, polymer infiltrated ceramic network ***(PICN)*** in addition to Nano-ceramics ***(LAVA Ultimate)*** and ***(Cerasmart)***.

A comparison between the characteristics of the main 3 groups of CAD/CAM materials ***(ceramics, composite and hybrid ceramics)*** regarding their mechanical, physical and esthetic properties shows that ceramics are considered the hardest and the most resistant to wear among them all. They are Biocompatible and provide superior esthetic qualities [4]. Yet, they are very brittle and highly susceptible to fracture. They don't accept add on adjustments and cause excessive wear to the opposing natural dentition. [5]

On the other hand, composite shows different behavioral features. They are the most resilient and the least resistant to wear. They have easy finishing and polishing properties and can easily be repaired and altered. Besides, they are less abrasive to the opposing natural teeth. [5]

An attempt to merge both ***(ceramics and composite)*** together in order to boost their qualities and improve their drawbacks, had resulted in the production of hybrid ceramic materials. Their mechanical properties are similar to enamel and dentine. They have inferior brittleness, hardness and rigidity comparing to ceramics, moderate fracture toughness. In terms of machine handling properties, they are superior to ceramics. Therefore, they can provide more precise results at areas of thin margins as post milling procedures such as firing or finishing and polishing are not necessary .[5]

There are different marginal designs applied for various types of fixed restorations, they can be classified into: horizontal finish line designs ***(shoulder or chamfer)*** and vertical finish line designs ***(feather edge)*** or without finish line **(prepless)** [6, 7].

Mostly the recommended and favorable margin design for ceramics is the deep chamfer finish line because it allows for better marginal fitting, improved esthetics and increased fracture resistance of the restoration in order to attain long-term durability. [9, 10, 11]

Feather edge design, which is one of the vertical preparations designs, in which an acute angle is formed with the restoration [12]. It is commonly indicated in periodontally compromised patients or cases with severe erosion [13]. Vertical finish line is considered a biologically oriented preparation technique ***(BOPT)***[8].

This approach is the least invasive when it comes to the terms of tooth reduction, comparing to the common horizontal margin designs [14]. As it permits for pulp tissue protection since the cervical zone is the most sensitive area for the pulp integrity. [15]

This study investigates the fracture strength property when applying conservative preparation design (feather edge preparation design) with ceramic materials.

Review of Literature

CAC/CAM technology has offered through digital milling and sintering an efficiently fabricated 3D designed ceramic restorations, achieving the ultimate goal of strength, esthetics and durability [16].

It enabled dentists to use new treatment modalities, create new restoration designs, expand the application limits and allow for more preservations of the natural tooth structure [17,18].

There is a wide range of ceramic materials, this classification of ceramic materials helps making the appropriate selection of the suitable restorative material easier for the operator [19].

Classification of ceramic materials:

1. **Glass-matrix ceramics**: nonmetallic inorganic ceramic materials that contain a glass phase
2. **Polycrystalline ceramics**: nonmetallic inorganic ceramic materials that do not contain any glass phase
3. **Resin-matrix ceramics**: polymer-matrices containing predominantly inorganic refractory compounds that may include porcelains, glasses, ceramics, and glass-ceramics. [20]

Feldspathic porcelain

Feldspathic ceramics comes in form of powder and water which are mixed together. A plasticized ceramic mixture is pressed and extruded through a nozzle to give its form. The blocks are then dried over several days before sintering.[21] Glasses in dental ceramics derive principally from a group of mined minerals called feldspar which are based on silica ***(silicon oxide)*** and alumina ***(aluminum oxide)***, hence feldspathic porcelains belong to a family called aluminosilicate glasses. Glasses based on feldspar are extremely easthetic and biocompatible.[22]

Leucite re-enforced:

It is also named IPS Empress ***(Ivoclar Vivadent, Liechtenstein)***. It is a particle-filled glass with leucite fillers incorporating the glassy matrix forming its microstructure, the leucite particles added two benefits to microstructure, one is the high translucency and the other is the selective etching to creat a micromechanical bonding with the resin cement and the tooth structure [22, 23]. It has a flexural strength of 100-150 Mpa. The restoration of this material is fabricated by the lost wax technique or by milling using CAD/CAM. It is indicated for veneers and single crowns in the anterior region.[24, 25]

Although feldspathic porcelain and leucite re-enforced ceramics have different micro structure, they share similar properties. Their distinctive aesthetic qualities prevail over other ceramic materials [26] by mimicking the optical properties of natural enamel and dentin [20] yet fail to mask any tooth discolorations. Their mechanical properties are considerably low comparing to other ceramic materials. [27,28]

Lithium disilicate:

It is a higher strength glass based ceramics, the incorporated fillers within the glassy matrix are a result of crystalline growth following heat treatment allowing for the precipitation of crystals within the glass[20, 29], the proportion of glass is reduced to 30% allowing the crystalline proportion to increase [22,23]. This type of ceramics could be filled with Lithium disilicate ***(LS2)*** or Lithium silicate and or zirconium dioxide ***(ZrO)***.

Lithium disilicate was introduced to the market in 1998 as IPS Empress II ***(Ivoclar Vivadent)***. It has a high flexural strength of **(350-440)** Mpa, high fracture toughness **(2-3)** Mpa and high thermal shock resistance ***(30,31)***.

A restoration made by this material is fabricated by the lost wax technique using pre-colored ingot which is heated and pressed.***(32)*** This technique produces a restoration with good marginal adaptation with survival rate reaching 100% for single crown and 70% for 3-unit bridges.***(33)***

IPS E.max was introduced in 2005 as an improved version of IPS Empress II. The manufacturing technology is based on glass technology ***(pressure casting technology)*** in order to fabricate the blocks. This method of manufacturing uses optimized processing parameters to prevent defects formation such as pores and accumulation of pigments. ***(34)***

IPS E.max CAD blocks are produced with 40% platelet-shaped lithium metasilicate crystals in a glassy phase. The final state of IPS E.max CAD consists of 70% fine spindle shaped grains and lithium disilicate crystals with a **(360)** Mpa flexural strength. ***(31, 35, 36)***

Crystals of lithium meta-silicate, in the partially crystallized form are responsible for the good machining properties, moderate strength and improved margin strength edge properties. ***(36)***

It is a highly translucent material that can be used as single crowns for anterior or posterior teeth and as short span bridge.

Zirconia re-enforced lithium silicate *(ZLS)*

Another example of CAD/CAM high strength ceramic based material is zirconia re-enforced lithium silicate ceramic ***(ZLS)*** which is commercially known as Celtra Duo. It was produced as a new class of glass ceramic material in 2012. It has high content of ultrafine glass ceramics (<1.0 um), 10% diluted zirconium dioxide in amorphous glass to create fine grained structure to provide consistent high load capacity and higher qualities. (37, 38)

Specifically, the micro structure of crystallized (fixed) Celtra Duo is formed of 58% silica, lithium meta-silicate, disilicate and 5% phosphorous pentoxide plus and 1.9% Alumina for increased chemical stability, 2% ceria 10% crystalized ZrO_2 .(39-40)

The presence of 10% zirconia dissolved into lithium silicate glass matrix result in 4 times smaller silicate crystals than in lithium di-silicate. Improving the glass content leading to higher translucency and adequate optical properties through various levels of translucency, improved flexural strength and higher compressive strength. The manufacturer provides a fully crystallized state of the material. Hand polishing results in a material that has flexural strength of 210 Mpa, while glaze-fire results in a material with a flexural strength of 370 Mpa (41)

Zirconia *(ZrO_2)*

Over a decade ago zirconia was introduced to the dental field (42). It has offered very high mechanical qualities like no other ceramic material did, due to its nearly pure, dense poly-crystalline and heterogeneous nature, It has favorable mechanical and physical properties, it has low thermal conductivity, low corrosion potential (43), high bio-compatibility and low bacterial surface adhesion(44,45,46). In addition, it has an outstanding ability to counter act crack and crack propagation through the local volume increase of the crystals in stress bearing areas (47). However, it is not susceptible to conventional acid etching techniques consequently and does not take the advantage of conventional adhesive bonding like glass ceramics. (48)

There are three crystalline forms for zirconia which are temperature dependent: the tetragonal phase ***(from 2370 °C to 1170 °C)***, monoclinic phase ***(from 1170 °C to room temperature)*** and the cubic phase ***(from the melting point at 2680 °C to 2370 °C)***. [(49)]. these different allotropic states present with distinct mechanical and optical properties that can be exploited differently in Prosthodontics.[(50,51)] Zirconia ceramics exhibit the highest flexural strength and fracture toughness of all dental ceramics currently available. But its opacity remains a critical draw back requiring veneering or limits its application to the posterior region. [(52)]

Translucent zirconia

A step further towards developing a more esthetic and translucent zirconia was an improved translucent ***(3Y-ZPT)***, which was achieved through several approaches such as: decreasing the amount of alumina from ***(0.25% to less than 0.05%)*** which did not affect the mechanical properties nor significantly enhanced the translucency. Another approach of improving zirconia translucency was by increasing the lanthanum oxide content to 0.2% mol or by improving the processing temperature and techniques to control the grain size, shape and processing density to minimize light reflection and refraction and increase translucency[(52)]. Unfortunately, all of these approaches resulted in a slight enhancement of the translucency and further decrease in the toughness of translucent zirconia compared to tetragonal zirconia, compromising the mechanical properties with values of flexural strength ranging between ***500 and 900*** Mpa due to the dimensions and distribution of the crystals. [(51)] Eventually, the effective approach to increase translucency without hindering the strength of zirconia majorly was done by increasing yttria up to ***4 and 5 mol %*** and retaining alumina content at ***0.05 weight %***, this composition have ***(25-50 %)*** cubic content polycrystals. The