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ISTANBUL YENİ YÜZYIL UNIVERSITY

HEALTH SCIENCES INSTITUTE

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MASTER THESIS

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Supervisor

Associate Professor Funda Erol

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FRACTURE RESISTANCE AND FAILURE MODES OF ENDOCROWNS CONSTRACTED WITH DIFFERENT MATERIALS

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İSTANBUL YENİYÜZYIL ÜNİVERSİTESİ

SAĞLIK BİLİMLERİ ENSTİTÜSÜ

Protetik Diş Tedavisi Anabilim Dalı Yüksek Lisans Tezli Programı çerçevesinde yürütülmüş olan bu çalışma Yüksek Lisans tezi olarak kabul edilmiştir.

Tez Savunma Tarihi: 31.08.2016

Doç. Dr. Evrim Eligüzeloğlu Dalkılıç

Yrd. Doç. Dr. Funda Erol

Yrd. Doç.Dr. Işıl Turp

Abstract

Purpose: The purpose of this in vitro study is to compare the fracture resistance and modes of fracture or failure between different endocrown restoration materials as lithium disilicate ceramic (IPS e max press) and indirect composites (Solidex &Gradia) performed for endodontically treated mandibular molars.

Materials and Methods: Forty sound human mandibular first molars (N =40, n = 10 per group) were selected and randomly divided into four groups.Group1was left intact (control). Group 2 endodontically treated teeth (ETT) restored with endocrown made of lithium disilicate ceramic (IPS e.max press, Ivoclar Vivadent, Schaan, Liech-tenstein). Group 3: ETT restored with endocrown made of Solidex indirect composite (Shofu inc. Japan) Group 4: ETT restored with endocrown made of Gradia indirect composite (GC Corporation, Japan).Fracture resistance (N) was measured using a universal testing machine. Load was applied parallel to the long axis of tooth till failure. Fractures or failures were divided into two groups repairable (favorable) and irrepairable (unfavorable). The mean loads of fracture of each group were statistically compared using ANOVA $p<0.001$.

Results: The mean fracture strength (N) of IPS e.max group had significantly higher mean fracture resistance value **(3320±961)** when compared to Solidex **(2222±938)** and Gradia **(2366±420)** indirect composite groups. There was no significant difference between mean fracture resistance of Solidex composite and Gradia composite groups. As regard to failure modes the results showed that **80%** of the Solidex composite groups exhibited repairable failure, also that **60%** of Gradia composite groups exhibited repairable and only **10%** of IPS e.max press group exhibited repairable failure.

Conclusions: The lithium disilicate ceramics endocrowns exhibited higher fracture resistance when compared to indirect composite endocrowns. Indirect composite endocrowns exhibited more repairable failure mode when compared to lithium disilicate ceramics endocrowns.

Dedication

This thesis is dedicated to:

My father and mother:

They always encouraged and inspired me. Without him I wouldn’t have ever

Achieved what I did. They are always supporting me with their best wishes

My wife:

She always cheering me up and stood by me through the good times and bad.

Acknowledgements

I would like to first thank my wife, for all of her support during this residency and research project.

I would like to thank my thesis supervisor; Associate Professor Funda Erol for standing by me and helping me constructs and executes this study. Thank you so much for giving me an opportunity to work with you and for you always support, encouraging and helping me see the true value in research.

To my parents, Abdoulhakim and Mryam, I would like to first and foremost thank you both for the amazing love and support you have given me throughout the years. Thank you for encouraging me endlessly to pursue higher education and explaining to me how through education and knowledge comes enlightenment and humility.

I would like to also thank all my faculty members at Yeni Yüzyil University for educating me.

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1. Introduction and aim:

The classical method for restoring severely damaged coronal structure of endodontic treated teeth is post, core and extra coronal full coverage crowns with ferrule, the preparation of a post space inside root canal increases the risk of accidental root perforation(1). With development of all ceramic materials, improvement resin composite materials and increasing popularity of adhesive dentistry a change in treatment decisions toward more conservative treatments has been observed, and the need for conventional post and cores has become less clear, limiting the risk for root fracture or failure and improving the long-term prognosis. Inlays, onlays, and endocrowns without cores and root posts have been introduced as alternative restorations for endodontic treated molars depending on the remaining coronal tooth structure (2). Enducrown is a new restorative option for endodontic threated tooth consisting of the entire core and crown as a single unit mono block made out of ceramic (reinforced acid etch able ceramic such as lithium disilicate ceramics and leucite ceramic) or resin composite which uses the surface of the pulp chamber to obtain stability and get the retention through adhesive cement. It consists of central cavity inside the pulp chamber with supra cervical circumferential circular margin. The endocrown enters inside the pulpal chamber without entering the canals. The retention principle of endocrown includes the macromechanical retention form of pulp chamber and micromechanical retention from adhesive resin cements. The preparation of endocrown should be supra-gingival to improve visibility, facilitate taking impression and retention of endocrown is increased due to optimal use of the margin located on the enamel to ensure adhesion (3). The first study on endocrown was published in 1995 by Pissis; he described the mono block porcelain technique for restoration of teeth with extensive loss of the remaining coronal structure (4). The terminology of endocrown was named for the first time by Bindl and Mörmann in 1999(5). Endocrowns are used in situations of posterior teeth with curved or short and calcified root canals that make post application difficult, also may be indicated in cases with excessive loss of remaining tooth structure and insufficient inter occlusal space that make impossible to find adequate thickness for post and core and crown, also the endocrown indicated when extensive loss of coronal tooth structure that do not allow the use of an adequate ferrule(6).Endocrowns are more biocompatibility, more conservative, easy and quick to perform, low cost, and more aesthetic properties when compared to traditional single crowns with posts and cores (6). Different materials can be used for fabrication of endocrown lik reinforced glass ceramic e.g. lithium disilicate ceramic (IPS eMax Ivoclar vivadent), hybrid composite resin, and resin matrix ceramics (Lava ultimate, 3M ESPE, Enamic, Vita).

With increased popularity of endocrown restoration the endocrowns is new and suitable option for restoration of endodontically treated teeth especially molar teeth, the endocrown is simple, lower cost, lower chair time need and more conservative with removing lower amount of sound tooth structure compared to conventional treatments with root post and crown, the many literature study found that endocrowns may perform similarly or better than the conventional treatments using root posts, direct composite inlay ,onlay restorations, also endocrown seem to have better fracture strength than conventional crown restoration (7). Because the endocrowns are usually prepared without ferrule, in contrast the conventional crown require ferrule preparation that cause the loss of sound enamel and dentin tooth structure that would be important for cementation of the restoration, in addition occlusal thickness of endocrowns varies from 3 to 7 mm greater than occlusal thickness of conventional crown that varies from 1.5 to 2 mm. The material chosen, i.e. ceramic or composites may also have influence on the performance of endocrowns, the restoration may become more rigid than the dental structure when ceramic material was used or biomechanically similar to the tooth when composites were used.

In this study we used the lithium disilicate ceramic and indirect composite materials for fabrication the endocrowns for that the aims of this study is to compare the fracture resistance and modes of failure between lithium disilicate ceramic and indirect composite endocrowns.

2. Review of literature

2.1. Endodontically Treated Teeth (ETT):

The endodontic treated teeth (ETT) are more subject to loss of tooth structure and changes in physical properties such as a decreased modulus of elasticity and increase susceptible to fracture when compared to vital teeth. One of the main reasons for this increased weakness of ETT is the loss of tooth substance after the pathological process and endodontic treatment procedures of the tooth. This biomechanical alteration causes a negative effect on the long-term prognosis of ETT. Therefore when considering to the restoration of endodontic treated teeth the dental restoration materials should be able to restore the loss of tooth structure in order to ensure mechanical and functional properties (8, 9).

2.1.1. Failure of endodontically treated teeth:

Improper restorative treatment is that the most cause of ETT failure, retrospective clinical study that analysis the causes for all failure of ETT over a period of 1 year in clinic, it was reported that the 60% of these were un restorable teeth fracture, 32% were failure of extracted teeth due to periodontal disorder and 7% were failure due to endodontic disorder (10). The most common teeth that exhibit endodontic failures were mandibular molars, a possible reason for ETT failure is recontamination of the root canals by oral microorganism through micro leakage of restoration by time, so the successful restoration is important to prevent failure the ETT (11). Torbjorner et al reported the rate of failure was 2.1% per year (12) and Mentink et al found 18% failure after 10 years (13).

Endodontic- ally treated teeth require extra coronal protection to prevent fracture and failure of endodontic treated teeth when masticatory forces are presented on them. The extra coronal crown is usually not indicated for anterior endodontic teeth, restoration with bonded resin is quite enough. The prognosis of ETT (posterior teeth) is improved with placement of extra coronal crown (14, 15). Placement of extra coronal coverage can improve the fracture resistance of posterior teeth and decrease the incidence of failure for posterior ETT (16). Aqualino et al reported the ETT without crown are 6 times more failed than crowned teeth (14).

2.1.2. Restoration of endodontically treated tooth:

A final restoration is very important for ETT treatment success, the literature review assessment by using radiographs showed that, ETT with good restorations plus good endodontic treatments, the results were 91.4% absence of periapical inflammation, ETT with bad restorations plus bad endodontic treatments, the result were 18.1% absence of periapical inflammation, ETT with poor endodontic treatment plus good restorations the ratio was 67.6% success rate (17).

The treatment plan of endodontic treated teeth depending on amount of remaining tooth structure (10). The loss of coronal tooth structure will determine whether the ETT can be restored only with restoration materials or using a core or post-core and crown .When minimal loss of coronal structure usually treating conservatively with only permanent filling restoration such as composite resin or amalgam restorations (18). But when is the case of patients with Para- functional habit which may need occlusal coverage because endodontic treated teeth become more brittle and will fracture when subjected to high Para-functional forces (19). When the crown of ETT less than 50% are missing (one missing axial wall) the adequate amount of remaining tooth structure to support the restoration, teeth require only root canal treatment and final restoration without a post and core (20). When crown of ETT is missing more than 50% are missing (two or more axial walls missing) the suitable coronal structure are limited for traditional restoration, the treatment need use of root posts to retain a core and extra coronal cast restoration, root posts are used only for retention of cast restoration through the core and distributes the stresses to the bone through the root. Ferrule is a 360 degree cervical collar, the finish line of the crown must extend 2 mm apical to tooth: core junction to preventing the failure of (tooth**:** core junction) which is the mechanically weak point and increase fracture resistance of the ETT.

2.1.3. Post & core and crown:

The ETT with large amount of coronal structure missing has restored with the post, core and extra coronal crown. The role of post and core is to support the weakened tooth by replace coronal tooth structure missing and provide anchor for extra coronal cast restoration. The post doesn't strengthen the endodontic treated teeth, and the post shouldn't be used for the tooth with adequate amount of tooth structure that able to support the restoration (21, 22, 23, 24). Previously many researchers believed in the past that posts may increase the fracture resistance in endodontic treated tooth and support the root, nowadays it is known that preparation of space in the root for post can weaken the root and may increase the possibility of root perforation, root weakness and fracture, so the use of root post undergoing to reduce (25). While knowing the use of posts to increase the weakness of the root, they are still used for premolar and anterior crowned teeth (26).

2.1.3.1-Post use for anterior teeth:

For anterior teeth if amount of tooth structure remains is large, bulky it is generally not necessary to use the post, only adhesive restoration used for filling access cavity (25). If the anterior with inadequate of coronal tooth structure remains to support filling restoration, the post, core and crown is necessary. Endodontic anterior teeth restored conversely with only restoration without post, core and crown should more fracture resistance under static loading in vitro than endodontic anterior teeth with post, core and crown (27).

2.1.3.2. Post use for posterior teeth:

The restoration of endodontic posterior teeth require extra coronal crown, because increase the incidence of teeth fracture, the treatment of endodontic premolars teeth generally require root posts, because of their smaller dimension and exposure to high shear stresses (28). The common site of ETT failure is maxillary premolar, extra-coronal crown are necessary to support these to decrease tooth fractures (29).

Mandibular premolar are more suspect to vertical load , the necessity for crown coverage depended on the amount of coronal structure lose .The tooth that has wide pulp chamber like molar teeth may be restored only with core with no need use of post. The molars may be treated without a post except if there is significant loss of coronal structure, the core made up with amalgam or bonded composite using the pulp chamber with 2 mm extension in root canal (30, 31). This core required adequate amount of tooth structure with minimum of 1.5-2 mm height for ferrule preparation (32). When a pulp chamber is narrow and restricted, a root post is necessary. However the post should be placed in the largest and straightest such as the palatal canal of upper molars or distal canal of lower molars (33).

2.1.4. Amalcore (Nayyar core):

Amalcore was introduced by Nayyar et al in 1980; Nayyar cores are useful in posterior teeth as amalgam can be packed 2-3 mm into the canal orifice and avoiding the need for a post and providing an orifice seal. In this restoration amalgam was packed inside the pulpal chamber, getting in the canal 2 to 3 mm. Amalcore restoration require wide and deep pulp chamber to give adequate support and retention (30).

2.2. All ceramic restoration

Different new types of ceramic materials have been introduced in recent years for fabrication indirect cast restorations, ceramics originally in naturally occurring fledspathic form. John Mclean's introduced of aluminous porcelain in 1960, which have been continuous improvement in esthetics , methods of fabrication , and strength of ceramics. The classification systemic of ceramic materials should be useful to giving clinical data about side to use the ceramic material (anterior or posterior) for which type of restoration (partial or full, short or long span) and how to cement it. Different classification system have proposed according to clinical indication ,composition ,sensitivity to etching , methods of fabrication , firing temperatures , microstructure , fracture resistance and translucency (34).

2.2.1. Classification of ceramic according to microstructures:

Kelly and Benetti describe ceramic materials according to glass content in to: 1-esthetic ceramics (predominantly glass), 2-structural ceramic or Particle-Filled glasses (low glass) and 3-polycrystalline ceramics (no glass). This classification does not involve the modern industrial improvements in ceramic technology, furthermore Kelly and Benetti classifications does not include Resin-Nano ceramic materials, these materials considered as ceramic materials by American Dental Association (ADA), the resin Nano ceramic have high mechanical properties similar to ceramic (34). The new classifying of ceramic material in to three families'1-Glass-matrix ceramics, 2-Polycrystalline ceramics. 3- resin-matrix ceramics Figure (1).

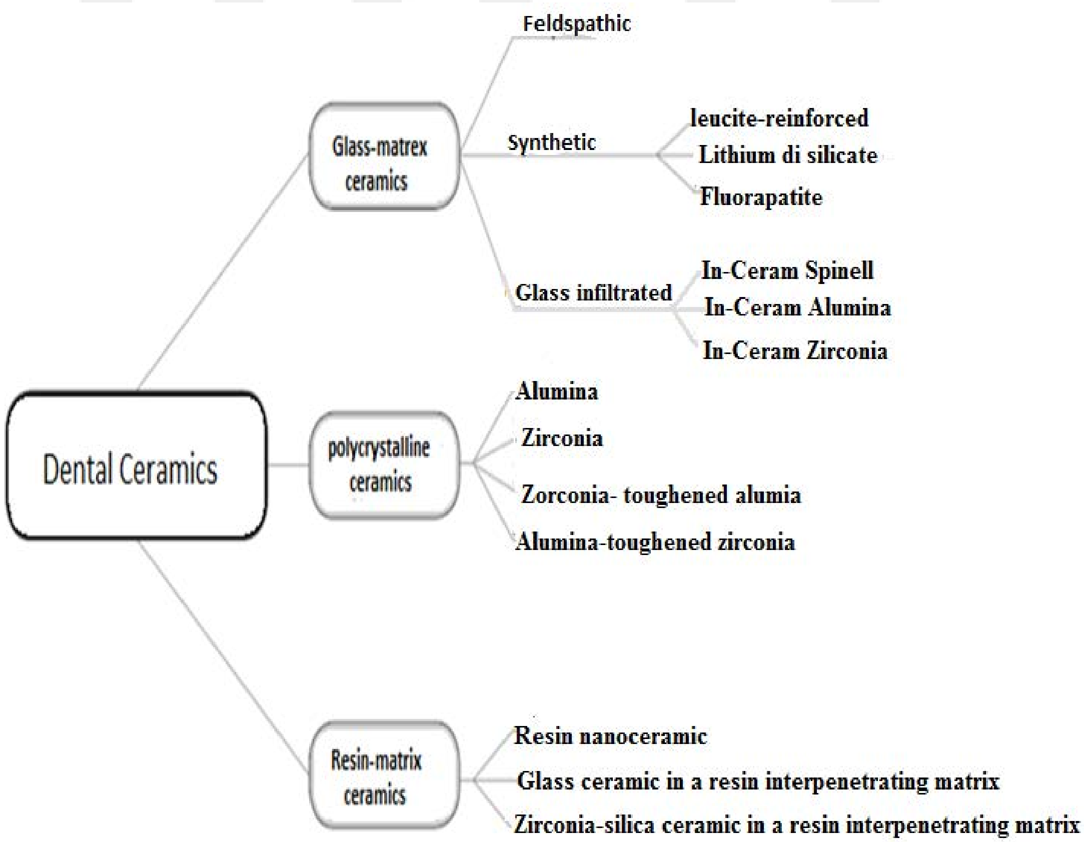

Figure1: Classification of ceramics

2.2.1.1. Glass matrix ceramics:

It is type of ceramic material that contains glass, glass-matrix ceramics are sensitive to acid etching by hydrofluoric acid **(**etchable ceramics**)** creating areas of micro retention. The glass matrix ceramics subdivided in to three sub group:

2.2.1.1.1. Feldspathic:

Traditional group of ceramics materials which contain clay (hydrates aluminosilicate), quartz (silica), and feldspar (potassium and sodium alumina silicate), the most important property of feldspar tendency to forms leucite crystals when melted that increase the strength of restoration and control of coefficient of thermal expansion below that of metal substructure, The feldspathic ceramics have low mechanical properties and low flexural strength 60–70 MPa , this ceramic utilized as veneering materials for ceramic or metal substructure (35).

2.2.1.1. 2. Synthetic:

This is a modification to feldspathic porcelain that the amounts of different crystals (leucite crystals or lithium disilicate crystals or fluor apatite crystals) have been added in the glass matrix (36).

2.2.1.1.2.1. Leucite reinforced glass ceramics:

The leucite crystals have been commonly used as a component of ceramics in dentistry to control the coefficient of thermal expansion that enhance the ceramic to be fused onto metal. Lucite ceramic utilized in the construction of metal–ceramic restorations, the new products of these materials have finer leucite crystals (10 µm to 20 µm) and all crystals distribute throughout the glass. These materials has adequate mechanical properties which able to be used now for resin-bonded ceramic restorations, the leucite-reinforced glass–ceramics have flexural strengths of up to 120 MPa. Leucite-reinforced feldspars used for veneers, anterior crowns and posterior inlays, the method of fabrication of these ceramic restorations can be done either by Sintered: e.g. Mirage, Fortress, Optec-HP, or hot-pressed: e.g. Empress I or CAD–CAM: e.g. Procad (37).

2.2.1.1.2.2. Lithium disilicate ceramics:

The lithium disilicate ceramic was introduced by Ivoclar vivadent as IPS Empress II and now in the form of IPS e.max press and IPSemax CAD. The lithium disilicate crystals form about 70% of the volume of the glass ceramic that improve the mechanical properties of ceramic because the plate -like crystals that prevent and stop the propagation of cracks. The lithium disilicate ceramics have greater mechanical properties than leucite ceramic with a flexural strength 350–450MPa, the fracture toughness of lithium disilicate is about three times higher than the leucite ceramic. For the dentist, lithium disilicate ceramics have adequate aesthetic and mechanical properties also these ceramic sensitive to acid etching that can improve the adhesion properties. Lithium disilicate ceramics can be utilized in any area of the mouth .The fabrication technique of lithium disilicate either by hot press technique or CAD/CAM system technique. Lithium disilicate ceramic is now considered as one of the best restorative materials available today for fabrication single unit indirect cast restorations (crown, onlays, inlay, endocrown, veneer).The lithium disilicate not only strong, but also it supplied with different translucencies and can be veneered to improve the aesthetic properties in some cases (38).

2.2.1.1.2.3. Fluorapatite ceramics:

The fluorapatite crystals in glass matrix may considered as veneering porcelain. The amount and the form of crystals improve the flexural strength in to 360 MPa**,** approximately three times more than leucite. The fluorapatite Ceramic materials are translucent even with present of high amount of crystal. The fluorapatite crystals improve the optical properties of the veneering porcelain (36).

2.2.1.1.3. Glass infiltrated ceramics:

The core substructure was sintered on a porous refractory die and then applying of slurry based molten glass on sintered coping or framework at 11000C for about 4 hrs, the glass infiltrate into all the pores by capillary action to produce the dense more strength ceramic. The glass infiltrated ceramics can be fabricated by one of three core ceramics, In-Ceram Alumina, In-Ceram Zirconia and In-Ceram Spinell. They have adequate flexural strength and ability to be etched by acid etching (36).

2.2.1.1.3.1. In-Ceram Spinell (alumina-magnesia matrix):

Introduced in 1994, the in-Ceram spinell, is the highest translucent with moderate strength, the flexural strengths is 350MPa, which can be used to fabricate anterior crowns (36).

2.2.1.1.3.2. In-Ceram Alumina (alumina matrix):

In-Ceram alumina has high strength and moderate translucent properties, which can be used to fabricate crowns of anterior and posterior teeth .In-Ceram alumina flexural strength is 450MPa (36).

2.2.1.1.3.3. In-Ceram Zirconia (alumina-zirconia matrix):

Ceramic with very high strength and low translucent and is utilized for posterior bridges. Flexural strength is 650MPa (36).

The glass infiltrated ceramics are also supplied in a block form for CAD-CAM system. The use of glass infiltrated ceramic is decrease due to increase zirconia and lithium disilicate publicity (34).

2.2.1.2. Polycrystalline ceramics:

Dense, non-glass polycrystalline structure enhancing mechanical properties and lowering translucent properties, Polycrystalline ceramics are subdivided in (alumina,

Al_2O_3) or zirconium oxide (ZrO_2), these ceramics un etchable ceramic (difficult to etch with hydrofluoric acid) (35).

2.2.1.2.1. Alumina:

Either all Ceram alumina was first introduced by noble biocare in 1990 with strength of approximately 600 MPa. E.g. procera allceram, the alumina powder is pressed and milled on a die and sintered at 1600C° (35).

2.2.1.2.2. Zirconia:

Zirconia has specific physical features that make it much stronger than alumina-based ceramics, with flexural strength about 900 MPa to1100 MPa, this is zirconia, partially stabilized with small amounts of other metal oxides .Partially stabilized zirconia able to be used for fabricate long span bridge of posterior bridge (35).

2.2.1.3. Resin matrix ceramics:

The modulus of elasticity of resin matrix ceramic materials are more closely to modulus of elasticity of dentin when compared to ceramics, these material are easier to milling and adjusting than glass-matrix ceramics or polycrystalline ceramics, also resin-matrix ceramic materials easy to repair or modification with composite resin**.** Resin-matrix ceramic composition varies substantially, but they are only fabricated for CAD/ CAM system**.** Resin-matrix ceramic materials can be subdivided according to their inorganic composition into three subgroups as follows: 1-Resin Nano-Ceramic (e.g., Lava Ultima, 3M).2-Glass ceramic in a resin matrix (e.g. Enamic, Vita). 3- Zirconia-silica ceramic in a resin matrix (34).

2.2.2. Surface treatment of ceramic restorations before cementation:

Table1: Surface treatment of ceramics before cementation

materials	Brands	Procedures
Feldspar ceramics	Duceram, DegussaDental GmbH,Hanau, Germany	1. Sandblast with 30- to 50-µmAl2O3 particles (at 80 psi). 2. Use 9% hydrofluoric acid for 2–2.5 min, then clean and dry. 3. Use silane for 60 sec
Leucite-reinforced ceramic	IPS Empress, Ivoclar-Vivadent,Schaan, Liechtenstein	1. Sandblast with 30- to 50-µm Al2O3 particles. 2. Use 9% hydrofluoric acid for 1min, then water spray clean and dry. 3. Use silane for 60 sec.
Lithium disilicate reinforced ceramic	IPS Empress 2, Ivoclar-Vivadent	1. Sandblast with 30- to 50-µm Al2O3 particles. 2. Use 9% hydrofluoric acid for 20 s, then clean and dry. 3. Use silane for 60 sec and dry
Glass-infiltrated aluminum oxide ceramic	In-Ceram alumina, Vita, BadSackingen,Germany	Sandblast with synthetic diamond particles or 30- to 50-µmAl2O3 particles (at 80 psi).
Zirconium reinforced ceramic	In-Ceram alumina, Vita	1. Sandblast with Sandblast with 30- to 50-µm Al2O3 or synthetic diamond particles.
Aluminum oxide ceramica	Procera, Nobel Biocare, Goteborg,Sweden	1. Sandblast with 30- to 50-µm Al2O3 or synthetic diamond particles.

2.2.3. Classification of ceramic according to method of fabrication:

2.2.3.1. Powder condensation:

This is considered the traditional way for fabrication of an all-ceramic restoration. This technique involves applying moist porcelain using a special brush. Then compact the porcelain by removing the excess moist. The porcelain is then fired under vacuum allowing further compaction. Ceramics fabricated by this technique have a great amount of translucency and are highly esthetic, and are used mainly as veneering layers (39).

2.2.3.2. Slip casting:

It is supplied as one of three core ceramics: In-Ceram alumina, In-Ceram spinell, In- Ceram zirconia. Slurry (slip) of one of these material's applied on a refractory die the water of slurry is absorbed by the capillary action leaving layer of either alumina, spinell or zirconia on the surface and sintered for 10 hours at 1120°C. This makes a porous framework of core particles which is infiltrated with molten lanthum glass by capillary action during a second firing for 4 hours at 1100°C.This procedure is done to remove porosities, increase strength, and limit crack propagation sites (39, 40).

2.2.3.3. Hot pressing:

Preheat of wax pattern to form the mold that filled with pressable dental ceramics. Pressable ceramics are found as glass-ceramic ingots which are supplied from manufacturers. The ingots have a similar composition of powder porcelains. The ingots are heated to a high temperature where they become extremely viscous liquid, and then pressed into the formed mold. This technique attaining good accuracy of fit using the lost wax method, the pressible ceramic technique used for fabriaction all ceramic crowns, inlays, onlays, endocrowns and veneers. IPS Empress and IPS Empress 2 (Ivoclar vivadent) are representatives of materials utilizing hot pressing technique for fabrication the restoration (41).

2.2.3.3.1. IPS Empress:

IPS Empress is a leucite- glass ceramic. IPS Empress has a low flexural strength of 112±10 MPa limiting its use to single unit complete-coverage restorations in the anterior region (41).

2.2.3.3.2. IPS Empress 2:

IPS Empress 2 is a lithium-disilicate glass ceramic and it was introduced in1998,a flexural strength of IPS Empress in the range of 400±40 MPa which is much higher than that of IPS Empress, increased flexural strength makes it suitable for the usage for fabrication of FPDs in the anterior region, and can extend to the second premolar (42).

2.2.3.3.3. IPS e.max Press:

An advanced press ceramic material called IPS e.max Press (Ivoclar –vivadent) and it was introduced in 2005 with advanced mechanical and physical properties and improved aesthetics. IPS e.max Press is supplied as pressable ingots that contains lithium disilicate glass-ceramic with different opacity (HT, LT, MO, HO). The ingots are adequate for the fabrication of frameworks or single indirect restorations. The IPS e.max press contains lithium disilicate glass ceramic similar to that of IPS Empress 2 but the characteristics are altered by a various firing process. The IPS e.max Press framework can be veneered by fluoroapatite ceramic that has nearly the same coefficient of thermal expansion as framework has. In comparison with IPS Empress 2, it has better physical properties and improved esthetics (43). Accordıng to manufacture the IPS e.max Press material used to fabricate inlays, onlays, veneers, partial crowns, anterior and posterior crowns, short span anterior bridges that can be extend to premolars, telescope primary crowns, and implant restorations. In some cases, minimal tooth preparation is desirable (e.g. thin veneers) and lithium disilicate (IPS e.max Ivoclar Vivadent) allow laboratories to press veneer as thin as 0.3 mm while still ensuring a strength of 400 MPa, if sufficient space is available without any preparation. Clinically IPS e.max press crowns showed very good survival rate at 96.6% after 3 years (44).

2.2.3.4. Computer-aided design/computer-aided manufacturing (CAD-CAM):

Machinable ceramics are available as prefabricated glass-ceramic ingots. They are cut by tools that are controlled by the computer. After the tooth is prepared, an optical impression is taken for the preparation by a special scanner the image is then transferred to the system's software, then the software designs the restoration and sends the data to the computer controlled milling machine that grinds the ceramic block according to the desired shape. Many of materials available for the CAD/CAM technology such as, Silica based ceramics: IPS e.max-CAD. Infiltration ceramics: Vita In-Ceram, Oxide high performance ceramics and Blocks of aluminum oxide and zirconium oxide (45).

2.3. Composite restoration:

The composite structures have been continuously developing after the Bis-GMA was introduced to dentistry in 1962 by Bowen .New developments in material that reinforced the mechanical and physical properties of resin-based composites and increased their clinical indications. Dental composite materials can be classified into direct (directly placed into the oral cavity and cured) and indirect resin composite (IRC) (extra oral fabricated and cured by means of light and / or heat). IRC are also named as prosthetic composites or laboratory composites (46).

2.3.1. Classification of composite according to technique:

2.3.1.1. Direct composite:

Restorative dentistry has been modified with the introduction of resin composite materials. The material was introduced nearly four decades ago and was widely used for restoration both anterior and posterior teeth as a direct restorative material. The use of direct composite has been restricted to small lesions and less stress bearing areas because of the materials has low wear resistance, weak strength, inadequate of marginal integrity and polymerization shrinkage. They are also more sensitive technique when compared to other different restorative materials like amalgam. When increasing the filler content of composite increase the strength, hardness, compressive, and stiffness, and reduced the polymerization shrinkage and water absorption. This increased the materials efficiency to be used in posterior areas but it has difficulty in building the proximal contacts and contours of restoration directly in the oral cavity (47).

2.3.1.2. Direct-indirect composite:

The composite increment is condensed into the cavity after application of a separating medium (e.g., agar solution or glycerin) to the prepared tooth, the separating medium helps to removal of the restoration after the initial intraoral curing. The restorative resin pattern was formed, light-cured, and removed from the cavity preparation. After initial curing the restoration is exposed to additional light for approximately 4 to 6 minutes or heat-activated at approximately 100 °C for 7 minutes (addition polymerization), after which the prepared cavity is etched, the composite restoration cemented into place with a dual-cure resin, and the restoration is then polished. The direct-indirect/semi-indirect composite excludes the need of the impression of the prepared cavity and the procedure can be completed as one step (46).

2.3.1.3. Indirect composite:

Indirect composites utilized for fabrication of onlays, inlays and endocrown. The restorations are polymerized externally and then cemented to the tooth with composite resin cement, indirect composite restoration decrease wear and leakage, adequate dental contour and overcome some of the disadvantages of direct resin composite restorations such as polymerization shrinkage, inadequate polymerization in interproximal areas (48). The Indirect composite resins need an impression, die and a dental laboratory technician to construct the indirect restoration. In addition to conventional light- and heat-curing, laboratory processing may employ heat (e.g., 140 °C) and pressure (e.g., 0.6 MPa for 10 minutes).In the laboratory the impression poured in to die then the indirect restoration is made directly on a die. Once the separating medium is putted to the die, composite increments are condensed into the cavity and light cured for forty sec for each surface then the restoration removed and addition cured by light or heat. The advantage of these materials is that a significantly increase degree of polymerization is attained, that improves physical properties, proximal contours can be achieved appropriately .and resistance to wear. The polymerization shrinkage does not occur in the prepared teeth, so decrease stresses on bond and failures of bonding, which reduces the potential for leakage. Furthermore, these composite resins are repairable in the mouth and are not as abrasive to opposing tooth structure like ceramic restoration (49). Several studies on the clinical quality of composite restoration have been performed by Rammelsberg et al reported that composite crowns (68 posterior and 46 anterior crowns) showed very good survival rate of 96% after 3 years (50) . Vannorbeek et al, reported a survival rate of for composite crowns (40 posterior and 19 anterior crowns) was 87.9% after 3-year (51).

2.3.1.3.1. First-Generation indirect composite:

The earlier version of indirect resin composites which were also termed as 1st generation indirect composites, the first generation of these indirect composites were introduced in the1980's, these materials was made of micro filled with an average size of 0.04 µm , the 1st generation indirect composite has flexural strength around 60 to 80 MPa, and elastic modulus around 2000 MPa to 5000 MPa, the resin volume percentage of inorganic filler higher than 50% and micro particles , these materials showed un acceptable mechanical properties like low wear resistance and poor color stability and high occurrence of bulk fracture, marginal gap or micro leakage and adhesive failure, low mechanical properties of 1st generation due to a low percentage of filler particles and a high percentage of resin and inadequate bonding between matrix and fillers (52).

2.3.1.3.2. Second-Generation indirect composites:

Many clinical failures associated with first-generation composites led to improvement of second-generation composites. The developments happened mainly in composition, structure, polymerization technique, and fiber reinforcement. The second generation indirect composite introduced in 1990's, these materials are micro -hybrid composite, filler diameter of 0.04–1 μ, with inorganic fillers percentage about 66%, the mechanical properties and wear resistance was increased with increasing the filler load, and the polymerization shrinkage was decreased by decreasing the organic resin matrix, resulting in development mechanical properties with flexural strength about 120 to 160 MPa and elastic modulus of 8500 to 12,000 MPa (4). Also the specific heat, vacuum, pressure, and oxygen-free environment are may be used for additional polymerization of second-generation composite to increase the degree of polymerization and the wear resistance (53).The fiber reinforcement of second generation composite act as crack stopper and improve the mechanical property of composite. The resin matrix acts to maintain the fiber (54).

2.3.2. Second-Generation composites products:

2.3.2.1. Solidex indirect composite:

According to manufacture the Solidex is a light curing, ceramic filled, micro-hybrid composite with organic matrix in its composition. This specific structure is highly homogeneous and high wear-resistance with elasticity, and aesthetic requirements. The specially designed filler particles enable the restoration transmit light like porcelain which is hard to differentiate from ceramic restoration, the Solidex light-curing micro-hybrid composite with a ceramic portion of more than 53 % , Figure (2) .The Solidex Introduced by Shofu, It is produced as metal primers, cervical, incisal , body, opaque and translucent shades. According to manufacture with these properties the Solidex is suitable for making of Crowns and bridges ,Telescopic crowns ,Precision attachment work , Implant-supported restorations , Long-term temporary restoration , Occlusal covering , inlay ,onlay, endocrown and laminate veneer. The Solidex composite properties flexural strength 75 N/mm²; flexural modulus 5700 N/mm²; compressive strength 314 N/mm²; diametral tensile strength 48 N/mm²; Vickers hardness 422 N/mm²; polymerization shrinkage 2.5 % by volume.

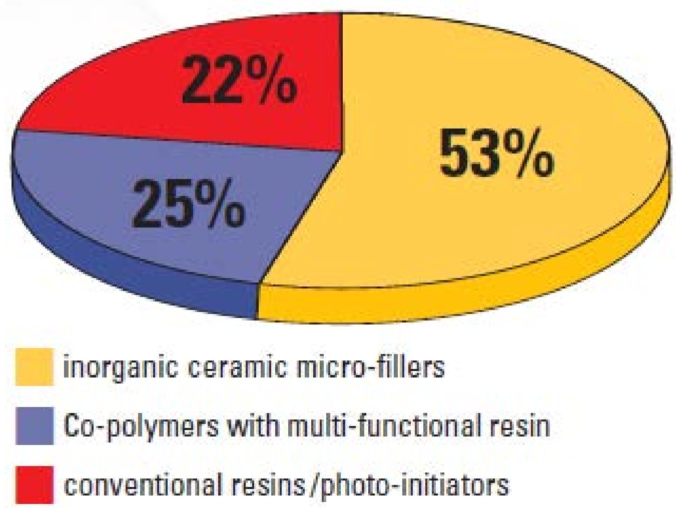

Figure2: Composition of Solidex

2.3.2.2. Gradia indirect composite:

According to manufacture GC contain of Matrix- UDMA, Filler – silica powder, silicate glass powder, pre polymerized filler (75wt %), the Gradia is micro-hybrid composite with the high strength, brightness and translucency like porcelain, indicated for fabrication the inlays, veneers and crowns and endocrown .Gradia characteristics bright color that preforms it like to the best ceramic now available .The shade of Gradia locks like the human tooth. Gradia has adequate mechanical properties such as surface smoothness and abrasion-resistance. It is bio-compatible and less abrasion to opposing natural teeth. The Gradia indirect composite can be used for crowns and bridge, implant superstructures, jacket crowns, inlays and onlays, laminate veneers.

There are many indirect second generation products such as (Artglass, Belleglass HP, Sinfony: Targis (Ivoclar Vivadent), Sculpture plus (Pentron), Tescera Atl (BISCO

INC): Paradigm MZ100 (3M ESPE), Vita ZetaLC (Vita Zahnfabrik), Pearleste E2 (Tokuyama Dental Corp), and Estenia C&B (Kuraray). That can be used in various clinical applications such as inlays and onlays, endocrown laminated veneers and jacket crowns, implant-supported restorations, for progressive loading of implant-supported prosthesis and for easier repair directly into the mouth.

2.3.3. Surface treatment of indirect composite restoration:

The hydrofluoric acid should not be used for surface treatment of indirect composite because the acid may causes structural change of the composite due to the dissolving of the inorganic particles (55). The most effective different technique to increase the surface energy is by sand-blasting with Al2O3 particles for 10 sec (56) .This makes a micro pores on the surface of composite and improve adhesion, after sand-blasting the sand was removed with alcohol and dried with oil-free, moisture-free air, after surface treatment by sand-blasting application of silane to improve the bond strength.

2.3.4. Clinical advantages of indirect composite restoration:

When the indirect composited resin compared to the direct composite techniques, the indirect composite has better possible for giving proper anatomic form, proximal contacts, contours, excellent occlusal morphology, less polymerization shrinkage and excellent marginal adaptation (57).When compared the indirect composite with ceramics the strength and mechanical properties of the indirect composites are lower than ceramics. However the indirect composites supplement and compliment rather than replace ceramic restorations as suitable alternatives in some clinical situations like dental implants superstructure. The ceramics has a high modulus of elasticity and less absorb of the masticatory load, large amount of the mastication forces are transmitted from implant to bone and increase of implants failure, polymeric resin composite become the best restoration material in this case because they more absorb of the occlusal forces, the patients with poor periodontium who need occlusal coverage, stress-absorbing restoration such as indirect composite restoration are suggested also the indirect composite restoration were both cheaper and more user friendly than ceramic restoration (57) .The advantages of composite is less transfer of masticatory forces ,Composite materials have shown a greater ability to absorb occlusal compressive loading forces and decrease the impact forces by 57% more than porcelain and the indirect composite material has ability to maintain the marginal integrity to occlusal loading (58). Tsitrou et al reported that composites have a less occurrence of marginal chipping than ceramics (59). A Ramı´rez-Sebastia et al were compare the marginal adaptation between ceramic and composite Cerec crowns they observed the marginal adaptation crowns fabricated from millable composite resin more greater than all-ceramic crowns (60). Because of the identical structure of the luting cement and composites, the marginal adaptation of composites is greater than that of ceramics; indirect composite resins were observed to overcome the disadvantages of all-ceramic restoration related to clinical failure.

3. MATERIALS AND METHODS

3.1. Specimens preparation:

Forty sound intact, non-carious, unrestored extracted mandibular molars (N = 40 n = 10 per group) of nearly same dimensions. Calculus and soft-tissue remnants were removed, the nearly same size and shape were selected by measuring its buccal-lingual, mesial- distal crown width and tooth length in millimeters using a digital caliper, the average buccal- palatal and mesial-distal mean widths were 10 ±1mm and 9.30 ±1mm, respectively .The teeth were cleaned and stored in distilled water at room temperature until further processing to avoid dehydration during storage. The teeth were randomly separated into 4 groups. Group1: Control, intact teeth. Group 2: endodontically treated teeth (ETT) was restored with endocrown made of lithium disilicate ceramic (IPS e.max press, Ivoclar vivadent, Schaan, Liech-tenstein).Group 3: ETT was restored with endocrown made of Solidex indirect composite (Shofu inc. Japan). Group 4: ETT restored with endocrown made of Gradia indirect composite (GC Corporation, Japan).

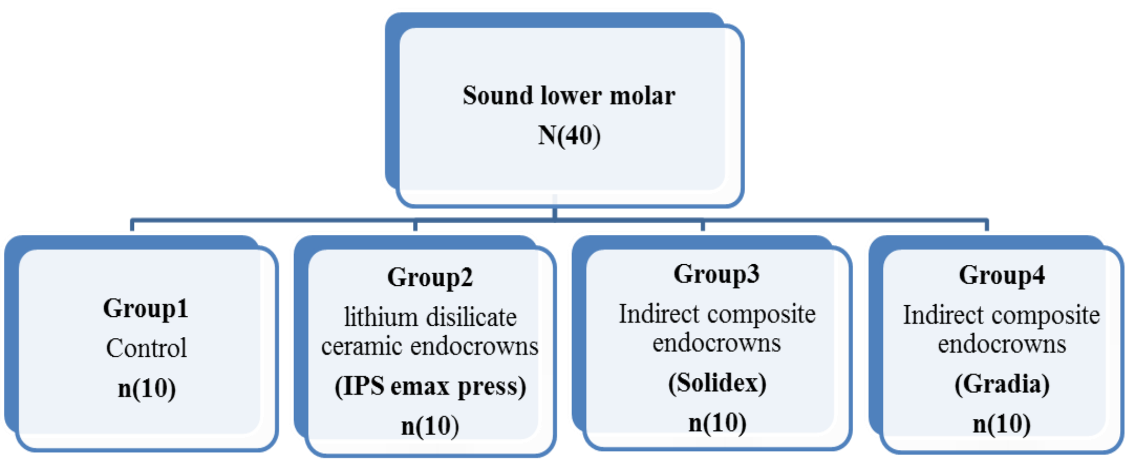

Figure 3: Flow-chart showing experimental groups

Table 2: Materials tested in this study

Brand	Type	Chemical composition	Manufacturer	Batch number
IPSe.max press	Lithium disilicate glass ceramic	SiO_2 57 – 80 % Li_2O 11 – 19 % K_2O,P_2O_5 ,ZrO_2 other oxides and ceramic pigments	Ivoclar vivadent	L19011
SOLIDEX	Light curing ceramic filled, micro-hybrid indirect composite	**Matrix** -25 wt. % co-polymers of multi-functional resins and 22% conventional resins/ light-initiators. **Filler** -53 vol % inorganic ceramic micro filler	Shofu inc. Japan	081331
GRADIA GC	Light cured ceramic filled Micro hybrid indirect Composite	**Matrix**- UDMA, **Filler**- silica powder, silicate glass powder, pre polymerized filler	GC Corporation, Japan.	150804A

3.2. Endodontic Procedures:

All teeth of all groups were endodontically treated except group 1(control group). Triangular shape access cavity was prepared for endodontic treatment using a high-speed cylindrical diamond bur. The measure the initial working length, a K-file (no. 15, Dent Evo, China) was used. It was inserted into the canal until its tip became visible at the apex from a proximal view; this length subtracted by 1 mm was considered the initial working length. The canal was prepared with a step-back method at this length.

The apical section was cleaned until a no. 30 master apical file for mesio bucall, mesio lingual canals and no.35 master apical file for distal canal were reached and the canals was shaped with files up to no. 50. During preparation the canal was irrigated with a normal saline solution after each filing. When the preparation was finished the canal was irrigated with EDTA .After biomechanical preparation the prepared teeth were obturated with lateral condensation technique using gutta-percha (Dent Evo, Chaina) plus endodontic sealer (ADSEAL, Meta Biomed Co. ltd Korea) using lateral condensation technique. The sealer was mixed and prepared on paper pad ,the mesial canals and distal canal were dried with no 30 and no35 paper point respectively then master gutta-percha cone no. 30 was impregnated with sealer and positioned in the mesial canals ,afterward the mesial canals was obturate with lateral gutta-percha cones (no. 20) using a (no. 25) stainless steel finger spreader then the distsl canal was obturated by using a master gutta-percha cone (no.35) was impregnated with sealer and positioned in to the canal, afterward the distal canal was obturated with lateral gutta-percha cones (no. 20) using a no. 25 stainless steel finger spreader. When obturation was accepted, the gutta-percha was cut from 1 mm under the orifice using heated excavator.

3.3. Endocrown Preparation:

3.3.1. Occlusal reduction:

Occlusal preparation can be accomplished by preparing 2-mm-depth orientation grooves as guides figure (4). After that green diamond wheel bur was utilized to connect the orientation grooves and reduce the thickness of occlusal surface, figure (5) .wheel bur held parallel to the occlusal plane to ensures a flat surface of the cervical margin .The position of cervical margin about 2mm above cement enamel junction.

Figure4: Drilling 2-mm-depth orientation grooves

Figure 5: Occlusal reduction by green diamond wheel bur.

3.3.2. Intra coronal preparation:

After occlusal reduction was finished the internal cavity preparation was performed inside the pulp chamber by removal of undercut areas of the pulp chamber and alignment of its axial walls with an internal taper of 8-10 degrees using a green diamond tapered bur with rounded end, figure(6). The bur guided along the long axis of the tooth, and the bur held perpendicular to the pulpal floor and all internal line angles were rounded and smoothed. The axial walls were prepared from the pulpal side to provide for a standardized cavity margin wall wide (circumferential butt margin) of 2 ± 0.2 mm, figure (8). The preparation is completed without excessive pressure on the pulpal floor. The depth of the intra coronal cavity in side pulp chamber was 4 mm measured from the internal cavity margin to the floor of the pulp chamber by using a periodontal graded probe, figure (8).

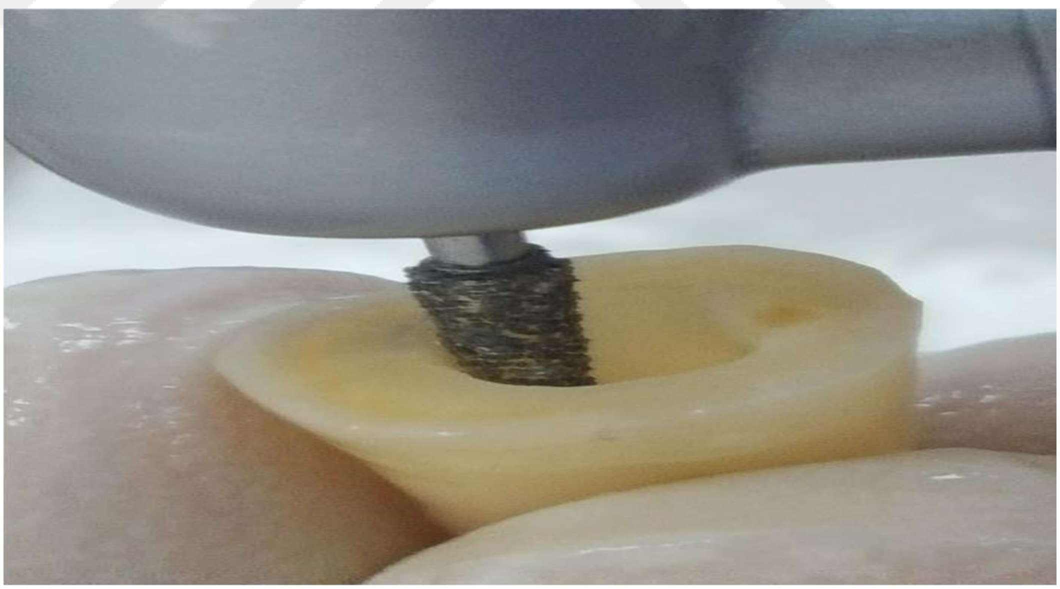

Figure 6: Intra coronal preparation tapering green diamond bur with rounded end

3.3.3. Smoothing the cervical margin:

After that the cervical margin was polished and smoothed by red diamond tapered bur, figure (7). The bur should be directed around the whole surface of the cervical margin to eliminate irregular roughness and produce a flat, smooth polished surface.

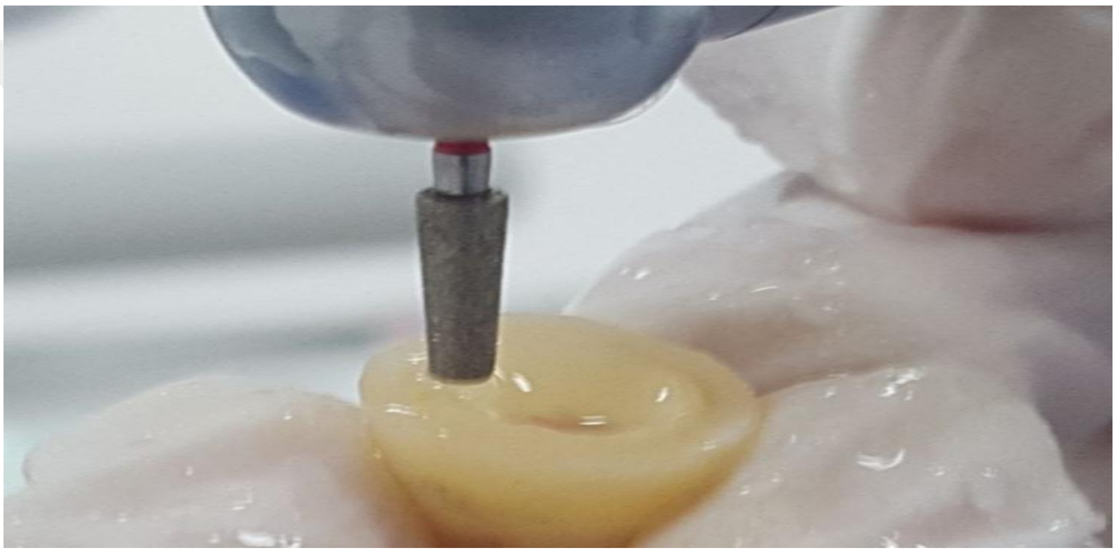

Figure 7: Smoothing the cervical margin using red diamond tapered bur

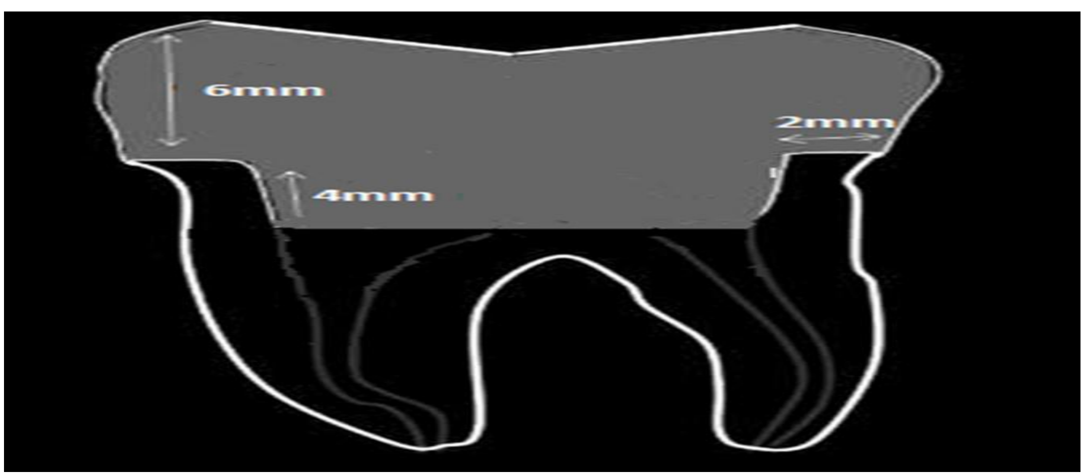

Figure 8: Schematic representation of the endocrown preparation, cavity margin wall thickness 2 ± 0.2mm, the depth inside pulp chamber 4mm, the crown height 6mm

3.4. Sealing of orifice canals:

After the endocrown preparation was finished, the orifice of canal was closed by light curing lining glass ionomer (EVOSEL Dent Evo China.), which filled the canals up to the level of the pulp chamber, figure (9).

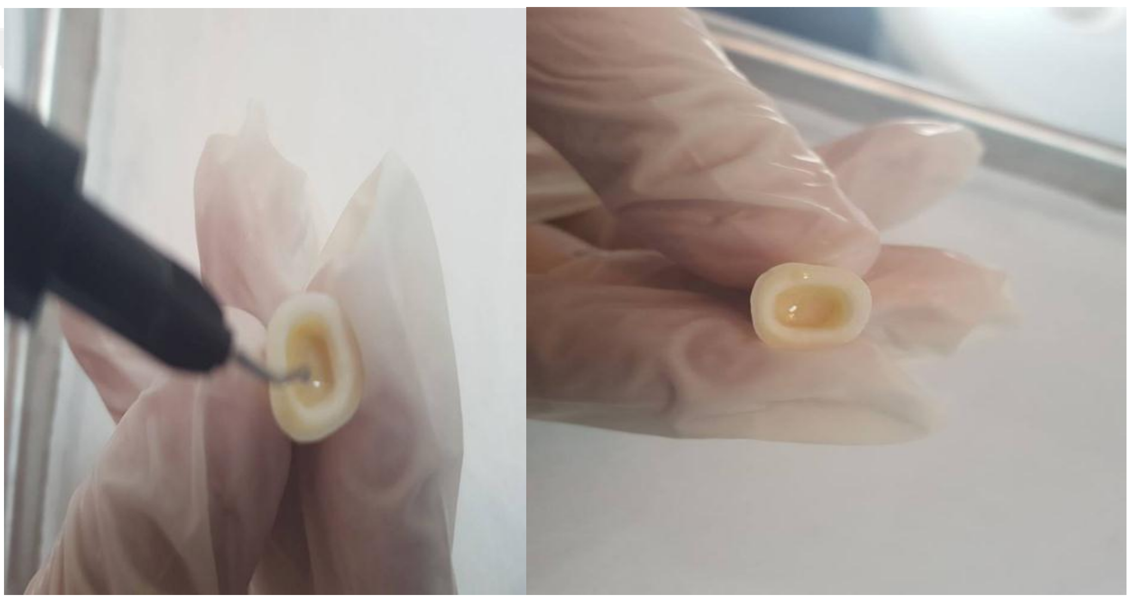

Figure 9: Sealing of canal orifice using light curing glass ionomer lining

3.5. Laboratory Phase:

3.5.1. IPS e.max-press endocrowns:

Laboratory procedures began by making the endocrowns in wax by scanning with CAD-CAM impression, figure (10). The occlusal thickness of endocrown was 6 mm. The wax sprues were attached to each of endocrown before investing in investment material, figure (11). The preheating cycle was accomplished at 850 C for one hour, then the molds were placed to the furnace and press-the mold with IPS e. max Press ingot

(MO1) (Ivoclar vivadent, Schaan, Liechtenstein) material at 915 C for 20 min, after that the endocrown restoration separated and glazed, figure (12).

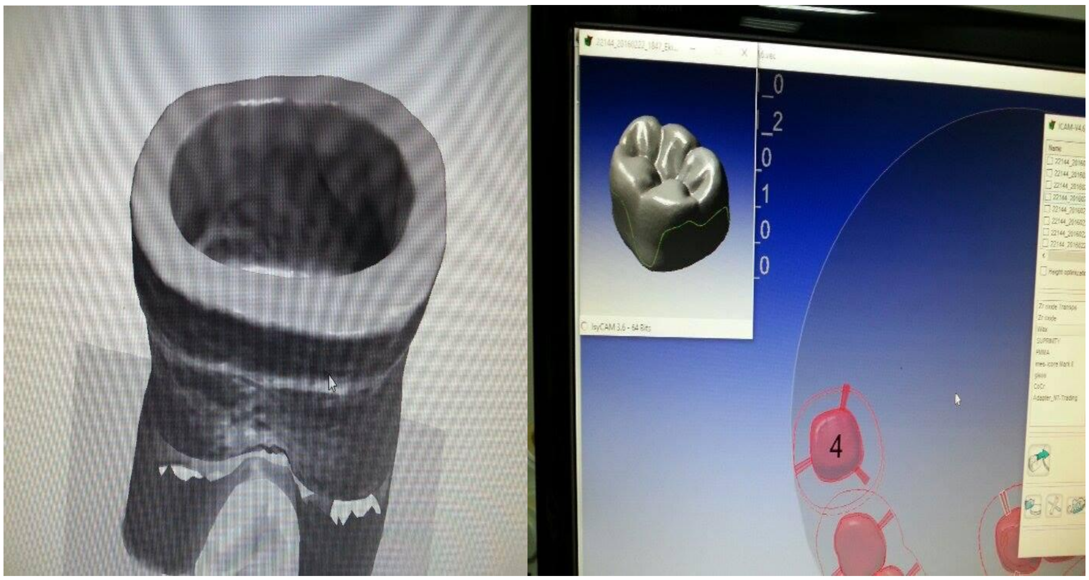

Figure 10: Making the endocrowns in wax by scanning with CAD-CAM impression

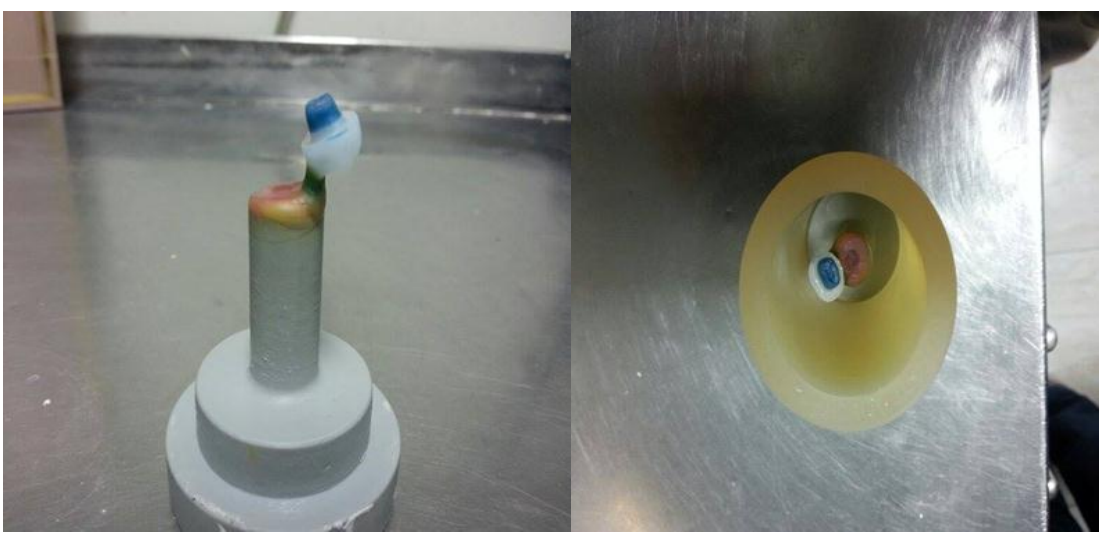

Figure 11: Wax sprues were attached to each of endocrown wax-ups before investing in investment material.

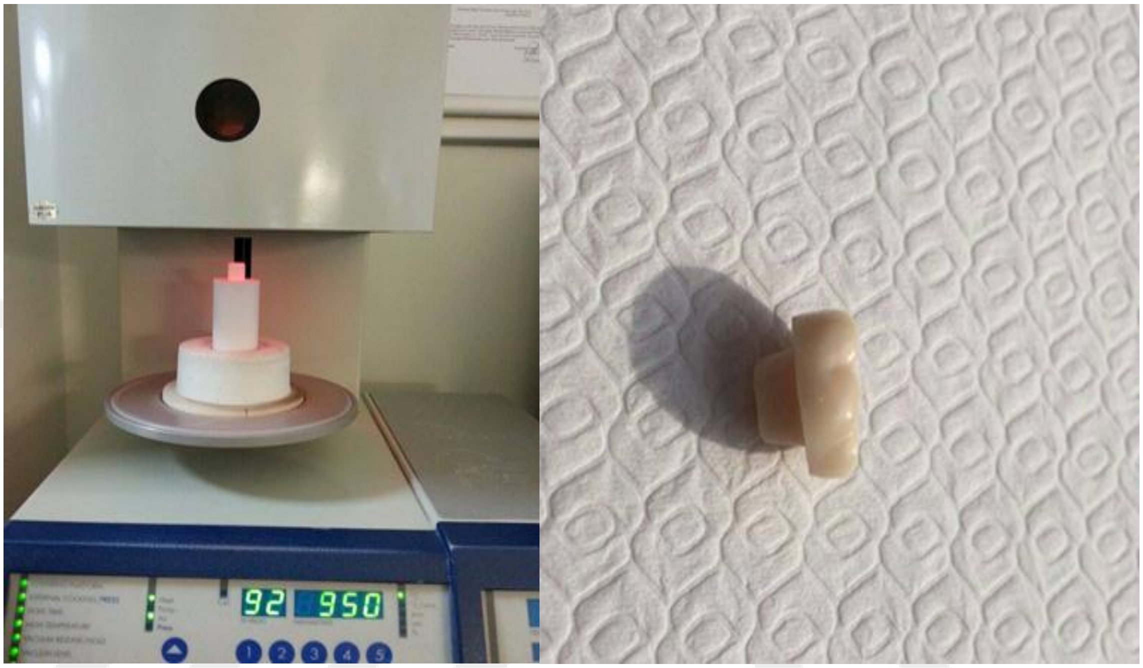

Figure 12: Placing the mold in furnace and pressing the IPS e. max press ingot (MO1)

3.5.2. Solidex and Gradia indirect composite endocrowns:

Both Solidex (Shofu inc. Japan) and Gradia (GC corporation , Japan) endocrown made by direct indirect technique, figure (13). The separating medium was applied to the cavity then composite increments were condensed into the prepared cavity, the endocrown pattern was formed with 6 mm occlusal thickness and endocrown was removed after initial curing then applying additional light polymerization, figure (14).

Figure 13: Solidex and Gradia indirect composite kits

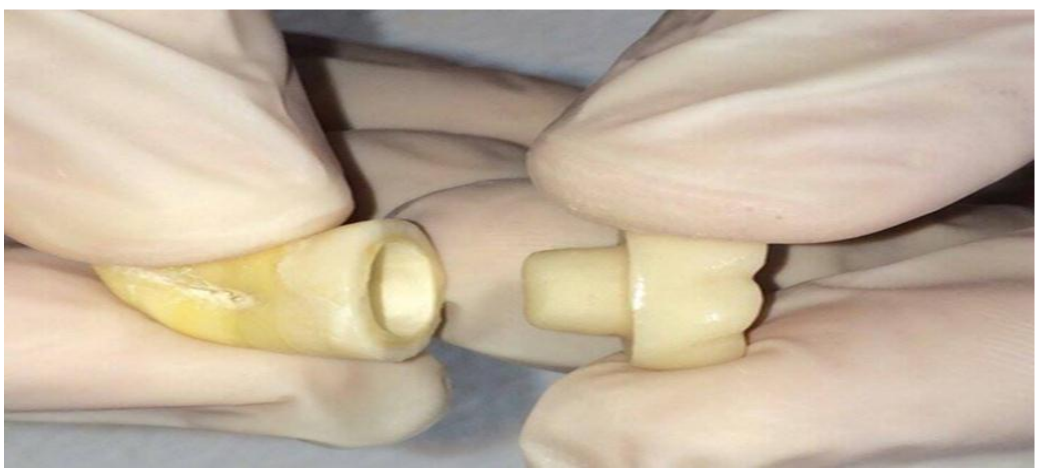

Figure 14: Removing the indirect composite endocrown after initial curing

3.6. Endocrowns cementation:

3.6.1. Intaglio surface of endocrowns treatment:

The intaglio surfaces of the lithium disilicate ceramic endocrowns were sandblast and then etched with hydrofluoric acid (Ultradent porcelain etch, 9%; Ultra dent Products, USA) for 20 seconds, figure (15). Then the surface rinsed with running water and dried with oil-free, moisture-free air, the intaglio surface of Gradia and Solidex composite sand-blasting with aluminium oxide particles for 10 sec. The universal silane coupling agent (Ultra Dent Products, USA) was applied to the intaglio surfaces of all endocrowns and allowed to dry for 60 seconds figure(16).Followed by application of a thin coat of the adhesive agent (single bond universal 3M dent, 3m Deutschlan Gmbh Germany) by a disposable applicator.

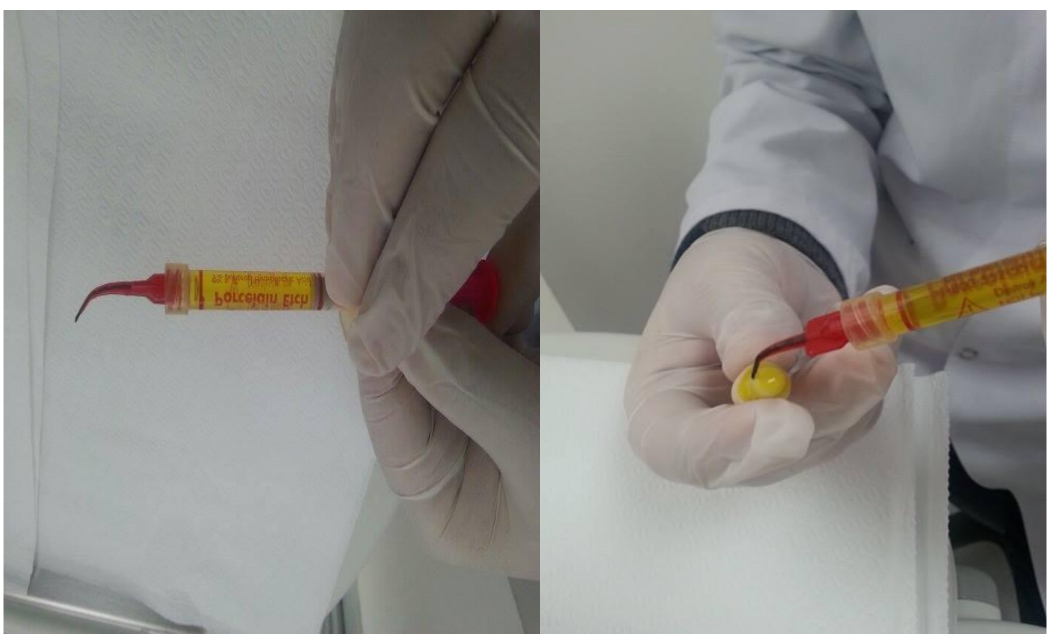

Figure 15: Etching of Intaglio surfaces of the ceramic endocrowns by hydrofluoric acid

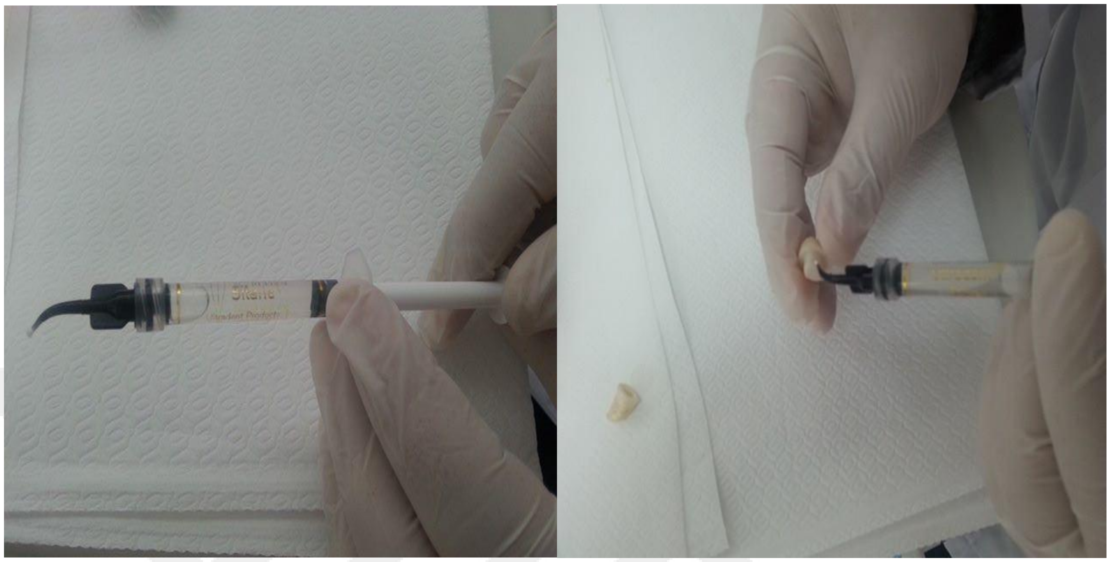

Figure 16: Silanization of intaglio surfaces of all endocrowns

3.6.2. Prepared tooth surfaces treatment and endocrowns cementation:

The prepared tooth surfaces were etched with 37% phosphoric acid gel (FINE ETCH 37, Spident Co ltd Korea) for 15 sec, then rinsed for 20 sec and dried with oil-free air for another 5 sec, figure (17). Then the adhesive resin single bond was applied to teeth followed by a light jet of air and then light cured for 20 seconds .All endocrowns were cemented with dual cure resin cement (Relyx Ultimate Clicker 3M Deutschlan Gmbh Germany) figure (18). The cement coated onto the inner surface of the endocrowns. The endocrowns were seated with light finger pressure, and excess luting cement was removed. The resin cement was light activated at each surface for 20 seconds.

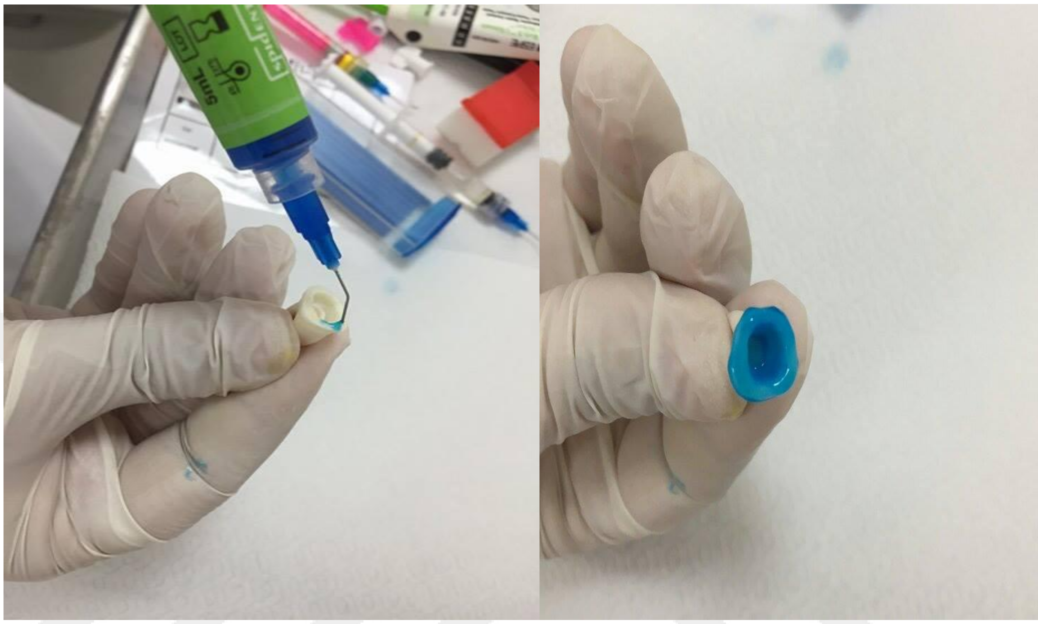

Figure 17: Etching of prepared tooth surfaces with 37% phosphoric acid

Figure18: Cementation of endocrowns by dual cure resin cement Relyx ultimate clicker 3M

3.7. Testing procedure:

Before testing, each tooth was vertically mounted in self-cured acrylic resin (True time Industrial, Tainan, Taiwan) in customized stainless steel mounting rings. The roots were embedded in resin up to 2 mm below the CEJ; figure (19). All specimens were stored in saline at room temperature for 24 hours before testing.

Figure 19: Mounting all spacemen in acrylic resin

3.8. Fracture Resistance Testing:

The fracture test was carried out in a Universal Testing Machine, the specimens were mounted in universal testing machine and stainless-steel ball (6 mm in diameter) was applied vertically perpendicular to the occlusal plane and centered on the occlusal surface of the restoration. Force was applied through a ball with a cross-head speed of 1 mm/s until facture occurred. The maximum force to produce fracture was recorded in Newton (N), figure (20). The failure modes of all samples were assessed from stereo microscope and examined by two observers. Failures above Cemento Enamel Junction

(CEJ) were considered as “Repairable” or favorable failure and failure below (CEJ) were classified as “Irreparable’ or unfavorable failures.

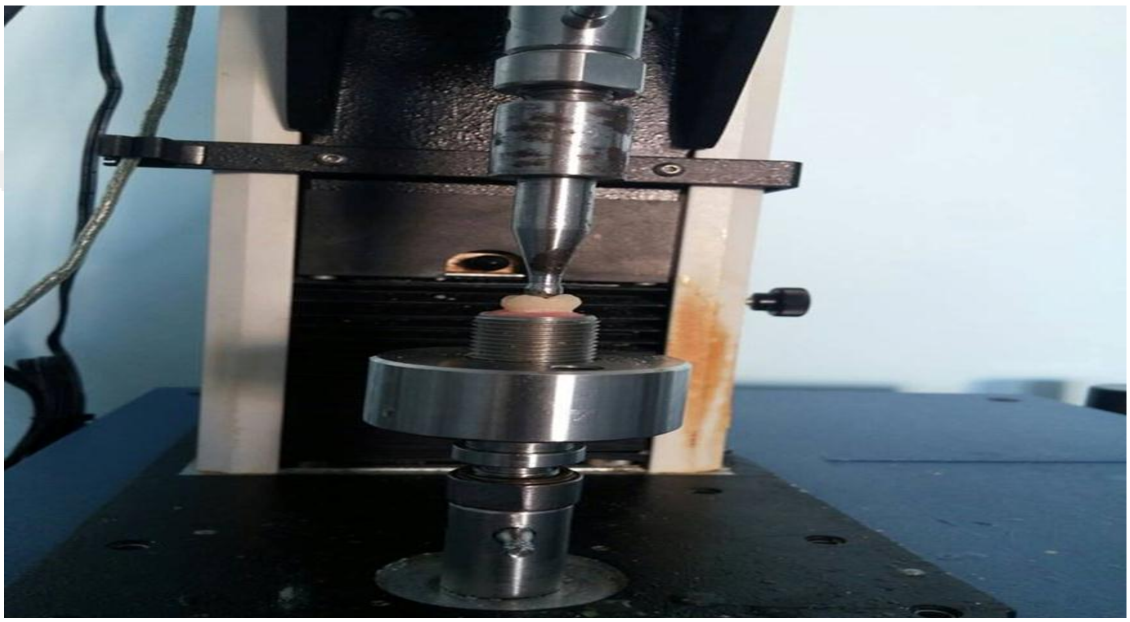

Figure 20: Testing the fracture resistance by Universal Testing Machine

3.9. Statistical method:

Statistical calculations were performed with (Number Cruncher Statistical System) 2007 Statistical Software (Utah, USA) program for Windows. Besides standard descriptive statistical calculations (mean and standard deviation), one way ANOVA was used in the comparison of groups, post Hoc Turkey multiple comparison test was utilized in the comparison of subgroups and Chi square test was performed during the evaluation qualitative data. Statistical significance level was established at p<0, 05.

4. Results

The mean fracture strength of intact teeth group (N) did not show significant difference when compared with other experimental groups. The mean fracture strength (N) of IPS e.max group had significantly higher mean fracture resistance value (3320±961) when compared with Solidex (2222 ±938) and Gradia (2366±420) indirect composite groups with (P=0.011, P=0.032 respectively). There was no significant difference between mean fracture resistance of Solidex composite and Gradia composite groups with (P=0,972), Tables (4, 5, 6) and figure21

As regard to mode of failure or fracture, the results showed that 80% of the Solidex Composite group specimens exhibited acceptable (repairable) fracture, also that 60% of Gradia Composite group exhibited acceptable (repairable) and that only 10% of IPS e.max Press group exhibited acceptable (repairable fracture), so the fracture mode of indirect composite (Solidex and Gradia) had more reparable or favorable fracture when compared with lithium disilicate ceramics IPS e.max Press, Tables(7,8) and figure(22).

Table3: Fracture strength results (mean± standard deviation) (Newton) of experimental groups

Fracture strengt (Newton)	N	Mean	SD	Minimum	Maximum
Intact Teeth Group	10	2596,19	459,96	2164,75	3724,19
IPS e.max Press Group	10	3320,35	961,21	1898,49	4915,54
Solidex Composite Group	10	2222,14	938,50	1102,52	4126,31
Gradia Composite Group	10	2366,50	420,86	1802,60	3312,21

Table4: One-Way ANOVA Test was used in the comparison fracture strength results (mean± standard deviation) (Newton)

	N	Fracture strength (Newton)
Intact Teeth Group	10	2596,19±459,96
IPS e.max Press Group	10	3320,35±961,21
Solidex Composite Group	10	2222,14±938,5
Gradia Composite Group	10	2366,5±420,86
P		**0,01**

Table5: Turkey multiple comparison test was utilized in the comparison of subgroups significant difference between groups with (P>0,05)	**p**
Intact Teeth Group / IPS e.max Press Group	0,146
Intact Teeth Group / Solidex Composite Group	0,674
Intact Teeth Group / Gradia Composite Group	0,899
IPS e.max Press Group / Solidex Composite Group	**0,011**
IPS e.max Press Group / Gradia Composite Group	**0,032**
Solidex Composite Group / Gradia Composite Group	0,972

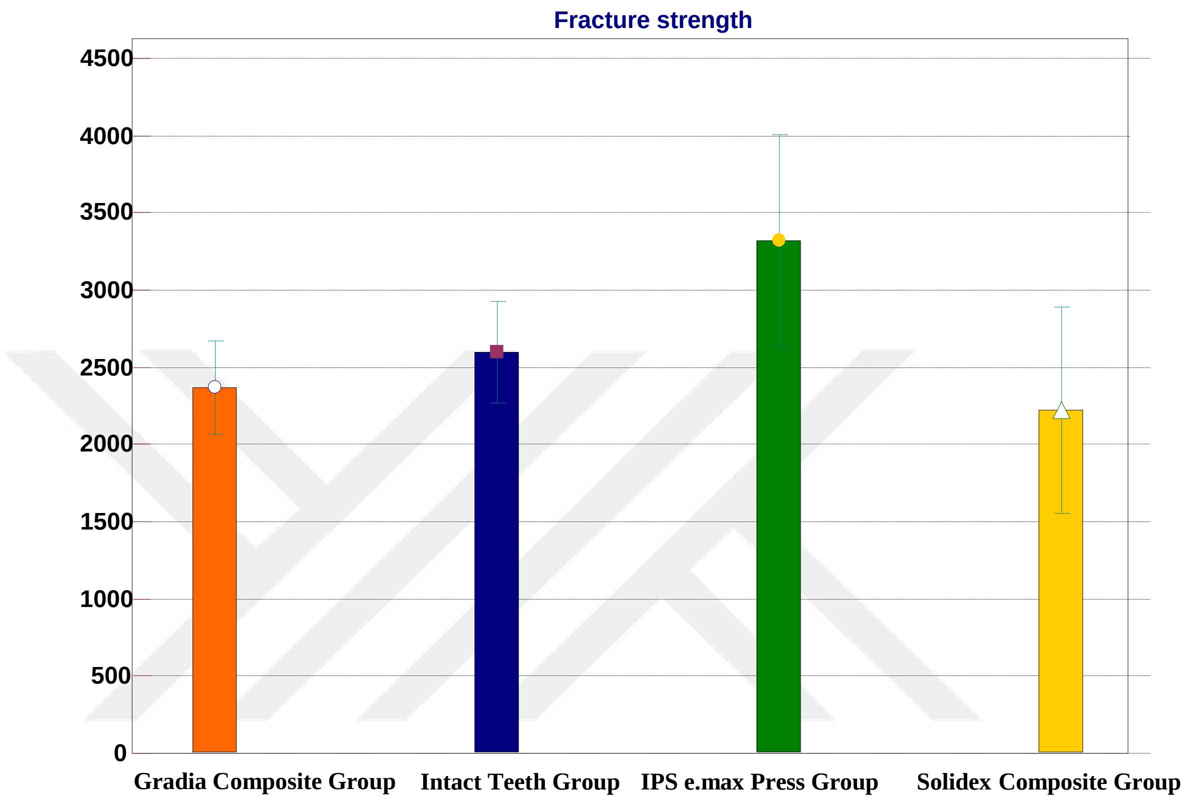

Figure 21: Bar-chart for mean fracture resistance of all groups (Newton).

Table6: Failure modes showing number and percentage of repairable and irrepairable failure.

	Failure Modes					
	Irrepairable		**Repairable**		**Total**	
GROUPS	**n**	**Row %**	**n**	**Row %**	**n**	**Row %**
Intact teeth	8	80,00%	2	20,00%	10	100%
IPS e.max Press	9	90,00%	1	10,00%	10	100%
Solidex Composite	2	20,00%	8	80,00%	10	100%
Gradia Composite	4	40,00%	6	60,00%	10	100%

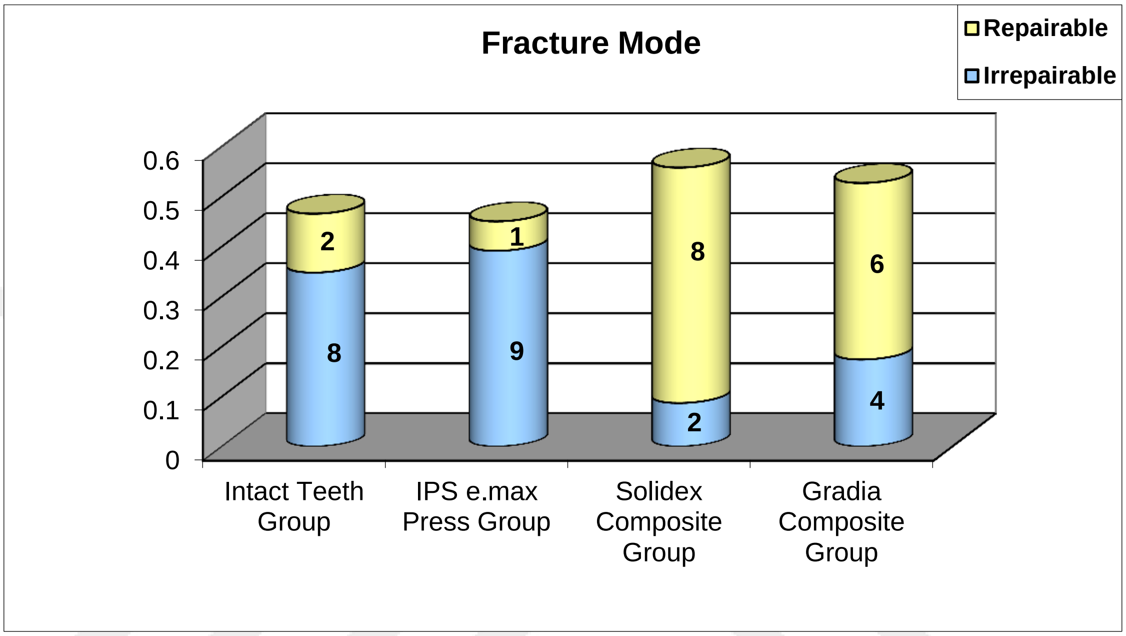

Figure 22: Bar-chart for modes of failure or fracture, frequencies of repairable (above CEJ) and irrepairable (below CEJ) fractures

5. Discussion

Posterior teeth with inadequate remaining tooth structure have been classically restored by post, core and crown. The post, core procedures associated with many complications that include the risk of root perforation and weaken the tooth associated with widening the root canal to facilitate entering of the post (61). Compared to conventional crowns with post and core the endocrowns are easier to apply and require a shorter clinical and chair time, lower cost, ease of application, also supra gingival margins preparation of endocrown provide more aesthetic and help plaque control, clinical examination and facilitate visibility during procedures and taking the impression, the endocrown preparation design is more conservative and preserve sound root canal structures without weakening of teeth when compared with the traditional crown with post, moreover the endocrown, appear to be a solution for teeth with a short clinical crown and calcified, curved or short root canals that make it difficult to use posts. Also endocrowns have another advantage over conventional crowns like reduced number of bound interfaces in the restorative system (dentin/enamel/ceramic) group when compared with the dentin/ enamel/post/resin/ceramic group, so the stress concentration is less because of the reduction in the non-homogenous material present (62). Biacchi and Basting in 2012 observed greater fracture strength of lithium disilicate endocrowns restoration when compared with lithium disilicate conventional crowns supported on posts (22). Chang et al. in 2009 compared the fracture resistance and failure modes of Cerec endocrowns with traditional Cerec crowns supported on post and core, they reported that the Cerec endocrowns exhibit higher fracture resistance than traditional crowns (1). Dejaka et al in 2013, 3D Finite Element Analysis of molars restored with endocrowns and conventional crown supported by posts during masticatory simulation, they showed the teeth restored by leucit ceramic endocrowns exhibit more failure resistant under static loads than teeth restored with conventional crown with reinforced posts (63). The probability factors that make the fracture strength of endocrown better than fracture strength of conventional crown are the endocrowns are prepared without ferrule, but the ferrule preparation present in conventional crowns that cause the loss of sound enamel and dentin tooth structure that would be important for cementation of the restoration. Also the occlusal thickness of endocrowns varies from 3 to 7 mm greater than occlusal thickness of conventional crown that varies from 1.5 to 2 mm, the greater the occlusal thickness of the restoration the higher the fracture resistance. Hamdy compared the fracture resistance of endodontically treated molars restored by lithium disilicate IPS e max press restoration: endocrown, conventional crown, onlay and inlays. He reported that, endocrowns and conventional crowns showed the highest fracture resistance with no significant difference. Onlays and inlays showed the least fracture resistance, so the endocrowns were more resistant to fracture than onlay and inlay restoration (64). Bindl and Mörmann evaluated that the survival rate and the clinical quality of 19 endocrowns (4 premolars and 15 molars) in 13 patients after approximately 2 years, they reported that the general clinical quality and success rate of the Cerec endo-crowns was very good (5).

Endocrowns appear to be the best choice for restoring endodontically treated posterior teeth with inadequate remaining coronal structure especially molars. The clinical success of molar endocrowns was better than premoelar endocrown, because of the endocrown Lake of adhesion on premolar teeth. Bindl and Mörmann evaluated the survival rate of Cerec endo-crowns for premolars and molars after approximately 55 month, they showed that the molar endocrown less failure than premolars endocrowns, It is believed that the pulp chamber of premolar is smaller than molar, so the surface of adhesive bonding is smaller than molars and the anatomical shape of premolar crowns in which the crown height is greater than the width may create a high leverage arm and more subject to horizontal force than molars increasing the risk of endocrowns cementation break and displacement(65).

In our study we aimed to evaluate and compare the fracture resistance and failure mode of endocrowns for lower molars made of either by lithium disilicate reinforced glass ceramic or micro-hybrid indirect resin composite materials with natural teeth under axial direction of forces. In this study by using human teeth as abutment material instead of artificial teeth we have increased the variability of the fracture strength; in addition the use of human teeth as the abutment material more closely approximates a clinical situation with respect to tooth architecture and morphology. Furthermore the natural teeth have dentin and enamel surface for bonding, also depth and contour of pulp chamber and the ratio between the crown and root are more accurate than on an artificial resin tooth. Also the selection of teeth of similar sizes and shapes was performed before testing to decrease possible variations and errors.

The extracted teeth should be stored on storage media until further processing; the storage medium maintenances the chemical, physical and mechanical properties of extracted teeth also avoid dehydration of tooth. Dehydration of tooth dentine does not appear to weaken strength and toughness of dentine, it tends to decrease flexibility and increase stiffness of dentine and affected on the outcomes of the results (66). The revision of the papers from many dental researches, during the period from 1999 to 2002, on the storage media of natural human teeth showed that formaldehyde, ethanol, chloramine, freezing, water, distilled water, saline solution and thymol have been the major storage media utilized (67). In our study the storage media for extracted teeth was distilled water, which considered as one of the best storage medium capable of reassuring adequate results concerning to the enamel and dentine characteristics. Silva et al. compared the effect of the storage time, type of storage on bond strength of extracted tooth. They showed that extracted teeth stored in distilled water provided the less variation in bond strength values (68).

The preparation of endocrown requires cavity space inside the pulp chamber to increase the stability and retention of the endocrown restoration. Bindl et al had reported that the intra coronal extensions should be varying from 2 to 4 mm, corresponding to variances in pulp chamber depth (5). The minimal intra coronal extension should be 2 mm that allowed for testing endocrown/ tooth system with ability of the remaining tooth structure to retain the restoration and the ability of the adhesive restoration to reinforce the remaining weakened tooth structure (4). In our study, the intra coronal extension of endocrown inside pulp chamber was prepared 4 mm, because the deeper of the pulp cavity and greater extension of endocrown inside pulp chambers have been a chance for increasing the surface area that can be utilized for adhesive retention and transmission of masticatory forces.

In the present study the materials that were chosen for endocrown was lithium disilicate glass ceramic IPS e max press and micro-hybrid indirect resin composite materials (Solidex and Gradia). Both materials are widely used as restorative materials in modern dentistry. The lithium disilicate IPS e max press provides adequate mechanical strength and esthetics and adhesive property which is sensitive to etching by hydrofluoric acid, so it is now considered as the one of the best restorative materials available today for single unit indirect restorations. The micro-hybrid indirect composite restoration have lower cost than ceramics and stress-absorbing properties of these materials are better and their practical benefits like the possibility to modify and repair the surface easily than ceramic and ease of handling.

All samples of endocrown was cemented by Relyx ultimate clicker 3M because dual cure cement with ultimate bond strength, also this cement ease to use which have only two component (Relyx ultimate clicker cement single bond universal adhesive) that decrease number of cementation procedural steps furthermore the Relyx ultimate clicker has high marginal integrity, were resistance, natural fluorescence, less waste and controlled dosage of material due to clicker delivery.

An important method used to measure the ultimate strength of posterior restoration is the compressive fracture resistance test by universal testing machine, there is many factors that influence on the fracture resistance, such as the crosshead speed and type of load application device, Several studies have used a universal testing machine to produce a compressive load to the specimen by means of several metallic load types such as steel sphere (69,70,71), steel cylinder (72,73), wedge shape device with a straight (74) and cast metal antagonist tooth (75,76). The type of load application device affected on the fracture resistance failure mode result values of experimental teeth. The variation of type of load application influences directly the obtained results. In our study the type of test load was stainless-steel sphere (6 mm in diameter), the sphere 6 mm provide adequate results, Silva et al in 2012 reported the teeth loaded with stainless-steel sphere (6 mm in diameter) had lower fracture resistance values and the failure or fracture modes more repairable compared with other test load (77).

Axial loading that we do in our study may represent occlusal forces where the intrinsic strength of each component of the system (tooth, adhesive system, luting cement layer, and restoration), elasticity modulus (the ratios of elastic moduli between the restoration material, and dentin) and thickness of the restoration may be decisive for survival of a restoration under axial occlusal force. An Tsai et al study reported that the fracture resistance of crowns increases with increasing occlusal thickness of crown (78). Mörmann, et al, showed that the fracture resistance of endocrowns with an occlusal thickness of 5.5 mm was 2 times greater than that of ceramic crowns with occlusal thickness of 1.5 mm (79). The thickness of the occlusal portion of endocrowns is usually about 3 mm to7 mm. In our study the oclusal thickness or height of all endocrwns was 6 mm.

Before performing mechanical tests, specimens have to be embedded in self polymerizing acrylic resin; stainless steel cylinder can be used as mould for resin. The teeth have been embedded in acrylic resin blocks to simulate cortical bone, the CEJ of teeth should be situated approximately 2 mm above the level acrylic resin to simulate bone crest, In our study, the lack of a simulated periodontal ligament the previously study reported the fracture strength results of restored teeth without artificial ligament were greater than those with simulated ligaments and showed that periodontal ligament simulation could alter the fracture strength and failure modes results in a positive way in that the ligament could acts as a shock absorber (80,81).

In our study, there was no significant difference in fracture strengths of the all samples of endocrown compared to control group (intact teeth), the probability for explaining the endocrowns made from either Lithium disilicate IPS e max press or

Solidex or Gradia indirect composite had been capacity to withstand a considerable amount of compressive loads similar to the unrestored control group. Also the mean fracture strengths for all the samples groups were above the possible mean fracture strengths of human masticatory bit force in the molar regions which reportedly arranging from about 600 to 900 N for females and males respectively (82,83,84). It may be suspected that such restorations may be capable of clinical success in similarly ideal condition, and any complications or failures related to fracture strength would likely be due to factors well above normal maximum biting loading like (cyclic fatigue, trauma, etc.).

Gresnigta et al in 2016 compared fracture resistance and failure mode type of lithium disilicate and multiphase resin composite (Lava Ultimate) endocrowns under axial and lateral loads they reported under axial loading did not show significant difference in fracture strengths of the all samples of endocrown that made by lithium disilicate and multiphase resin composite when compared with control group (intact teeth) also, did not show any significant difference between lithium disilicate and multiphase resin composite (Lava Ultimate) when used as endocrown (85) The probability reasons may be lava ultimate has adequate mechanical properties such as high fracture toughness, flexural strength and resiliency, and excellent durability.

Hatem et al. compared fracture resistance and marginal leakage of 3 different CAD/CAM fabricated endocrowns from feldspathic porcelain, lithium disilicate and multiphase resin composite (lava Ultimate) preformed on maxillary molars showed that multiphase resin composite (lava Ultimate) endocrowns have significantly higher fracture resistance than lithium disilicate and feldspathic porcelain (2). These results were in disagreement with our study that showed a significantly higher mean fracture resistance value for lithium disilicate IPS e max press when compared with solidex and Gradia composite. The probable reasons for our results may be due to IPS e max press had adequate mechanical properties and higher- strength with a flexural strength in the region of (350–450MPa) when compare to Gradia and solidex composite with the flexural strength (120 MPa and 70 MPa respectivly). Furthermore the adhesive property of lithium disilicate–based ceramics which can be infiltration of the resin cement into the micropores created by the acid is the key factor in the bonding between the ceramic and the luting agent. The internal voids in the indirect composite endocrown introduced by the layering process of indirect composite able to decrease strength of endocrown composite restoration. The other probable reasons for difference to the other studies, the other studies were used the different type of material ,multiphase resin composite (lava ultimate) these material has adequate mechanical properties like high fracture toughness, flexural strength and resiliency, and excellent durability, also the other study may use different crosshead speed, different type of load application device and another type of cement was used for cementation.

In our study, the patterns of fracture mode recorded on Solidex and Gradia composite endocrowns was more reparable, which the fracture mode above the CEJ and intact root theoretically allows the repeated restoration of the tooth, while the patterns of fracture mode recorded on lithium disilicated glass ceramic endocrowns was more irreparable fracture, the fracture involves the root leaves the tooth un restorable and tooth requiring extraction, these result was agreement with Hatem et al. They compared fracture resistance and marginal leakage of 3 different CAD/CAM fabricated endocrowns (feldspathic porcelain, lithium disilicate and multiphase resin composite (lava ultimate) preformed on maxillary molars showed that multiphase resin endocrown endocrowns group had more repairable fracture mode than lithium disilicate and feldspathic porcelain (2). The possible reasons may be due to the modulus of elasticity influences the susceptibility to fracture of a cemented restoration. The composite material have a modulus of elasticity approximately compatible to that of dentin so the composite materials tend to bend under load and distribute stresses more evenly, also indirect composite is resilient and have stress-absorbing properties, while the lithium dislocate is a rigid materials with different elastic moduli than dentine, that produce stress concentrations at critical areas that might cause catastrophic failures.

Gresnigta et al in 2016 compared fracture strength and failure type characteristics of lithium disilicate and multiphase resin composite (lava ultimate) endocrowns under axial and lateral forces. They reported that both groups of lithium disilicate and multiphase resin composite endocrown had more repairable fracture (85). The possible reason of these result may be due to different crosshead speed, different type of load application device and different type of luting cement was used for cementation and different occlusal thickness of endocrown restoration, also may be the weak extracted teeth due to trauma during extraction or dehydration of extracted teeth due to improper storage in storage media was used in study.

The test used in the present study does not simulate the reality of the clinical situation, because study was carried out in vitro conditions without chemical, physical, thermal and static (dynamic) stress, so the endocrown restoration in vivo subjected to these fatigue stresses over a longer period, in vivo may adversely affect the results, therefore further studies should also focus on performance of the tested materials for endocrowns under fatigue procedures.

6. Conclusions

1- The mean fracture resistance (N) of all endocrown experimental groups did not show significant difference when compared with intact teeth group (control group).

2- There was no significant difference between mean fracture resistance (N) of indirect composite groups (Solidex composite and Gradia composite).

3- The lithium disilicate ceramic endocrowns exhibit higher fracture resistance when compared to indirect composite groups (Solidex composite and Gradia composite).

4- Indirect composite endocrowns (Solidex composite and Gradia composite) exhibited more repairable or favorable failure or fracture mode when compared to lithium disilicate ceramics endocrowns.

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