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EFFECT OF DEEP MARGINAL ELEVATION ON MARGINAL ADAPTATION AND FRACTURE RESISTANCE IN ENDODONTICALLY TREATED TEETH RESTORED WITH ENDOCROWNS CONSTRUCTED BY TWO DIFFERENT CAD/CAM CERAMICS: AN IN-VITRO STUDY

Shams Waaz Amgad Ali* *and* Dalia Ali Ahmed Moukarab**

ABSTRACT

Aim: To evaluate the effect of deep marginal elevation on the marginal adaptation and fracture resistance in endodontically treated teeth restored with endocrowns constructed by two CAD/CAM ceramics in an in-vitro model.

Material and methods: twenty four human, intact freshly extracted mandibular first molars were endodontically treated and mounted in an upright position in a standard plastic ring filled with acrylic resin 4mm apical to the CEJ. A standard endocrowns preparation was performed with a butt- joint occlusal margin for all specimens and a proximal box preparation was done on the mesial surfaces. The specimens were then equally divided in to two groups (n=12) according to the material used in construction group (M) using IPS e.max CAD ceramic blocks and group (V) using Vita Enamic ceramic blocks; then further divided in to two subgroups (n=6) according to the application of a mesial marginal elevation or not into (ME, VE) with marginal elevation and groups (MN, VN) without marginal elevation. All endocrowns were cemented to the corresponding preparation using dual cured self- adhesive resin cement (RelyX, Unicem). All specimens were thermally aged with 10000 cycle in water bath between 5°C- 55°C. The marginal adaptation was evaluated using stereomicroscope (40 ×) at 5 predetermined points on the mesial margin for each specimen and mean gap measurement was calculated. All specimens were then subjected to fracture resistance test via universal testing machine. The collected data was recorded, tabulated and transferred for statistical analysis.

Results: Vita Enamic with deep marginal elevation (VE) recorded the lowest marginal gap measurements at (69.3 μm)which is significantly lower than all tested subgroups ($P < 0.001$), while IPS e.max CAD with deep marginal elevation (ME) subgroup showed significantly higher fracture resistance (1478.2N) than all tested subgroups ($P < 0.001$).

Conclusion: Deep marginal elevation enhances both marginal adaptation and fracture resistance of IPS e.max CAD and Vita Enamic. IPS e.max CAD has higher fracture resistance while Vita Enamic has better marginal adaptation.

KEY WORDS: Endocrown, Endodontically treated teeth, CAD/CAM technology, Deep marginal elevation, Fracture resistance, Ceramics.

* Lecturer of Fixed Prosthodontics, Department of Fixed Prosthodontics, Faculty of Dentistry, Minia University
** Lecturer of Endodontics, Department of Endodontics, Faculty of Dentistry, Minia University

INTRODUCTION

Endodontically treated teeth have always been a challenge during restoration for practitioners on a daily basis. Many factors contribute in the complexity of such cases; periodontal conditions, remaining tooth structure, root anatomy and individual habits all of which should be considered in decision making [1]**.** It is a multidisciplinary team work to provide the patient with a treatment that will not only restore function and esthetics but also provide a long term survival and preservation of the remaining tooth structure. [2]

For decayed; posts were indicated whenever there was loss of coronal tooth structure which deprives restorations from enough retentive surfaces. [3] Unfortunately this treatment modality has raised controversy; due to need of preparing a post space which will remove more of the already weak remaining tooth structure leading to increasing risk of root fracture. Especially in cases of thin roots and posterior teeth that are already considered at high risk of fracture due to the occlusal load. [4, 5] Many authors even discourage using posts due to the well documented risk of tooth fracture. [6, 7]

Fracture resistance and marginal adaptation are both crucial determinants for long term performance of a coronal restoration and the inherent limitations and drawbacks with in many restoratives justifies the ongoing search for alternatives that can provide more favorable outcome. [8]

Piassis in 1995[9, 10] introduced a less destructive alternative for post and core restoration; describing it as a mono-block porcelain technique later known as endocrowns. A core and crown in a single unit utilizing the pulp chamber axial walls for macro-retention in addition to the micro-mechanical retention provided by adhesive luting agents. It is also considered a minimally invasive technique; while providing retention for the coronal restoration it needs very little preparation moreover many practitioners accept it as a simple procedure compared to others. [11]

Dejak and Mlorkowski [12] compared endocrowns to full crown restorations in a 3 dimensional finite element analysis on molars in a mastication simulation model. Results revealed that endocrowns were significantly superior. Furthermore several studies showed endocrowns poseses better fracture resistance than did traditional full coverage restorations [13]. In other studies endocrowns showed a success rate of 94- 100 %. [14]

Rocca etal[15] studied the mode of stress distribution of endocrowns and intraradicular posts; the authors found endocrowns to transfer more homogenous occlusal forces than did posts confirming that using endocrowns don't jeopardize the remaining tooth structure which is favorable in case of posterior endodontically treated teeth.

Endocrowns while being a simple and efficient concept maintaining the philosophy of bio-integrate prosthesis and even though it has demonstrated success with in recent literature that strongly suggest it as a reliable alternative to restore endodontically treated posterior it still remains uncommon treatment modality.[16-19]

Long term success of an endocrowns may be affected with proper case selection, choosing the correct preparation, material of construction and bonding agent. [20] For an endocrown the more the surface area for bonding the better the better the adhesion and retention of the restoration, on the other hand conservation of the tooth structure is the most important factor in fracture resistance. [21] The development of an optimum balance between surface area for adhesion and preservation of tooth structure integrity is a critical determinant for success.

Ceramic restorations suffer from their brittleness; having low fracture toughness which may be due to the inherent flows with in these materials. [22] Many techniques have been developed to improve the fracture resistance of the ceramics to allow their use in posterior teeth. [23, 24]

The Recently introduced computer aided design/ computer aided manufacturing (CAD/CAM) materials have overcome volume defects and voids found in conventionally sintered porcelain which allow them to have better tensile strength. [25] Moreover, this evolving technology has opened new horizons to provide more accurate, highly esthetic and low time consumption restorations. Though proven to be a very effective modality of restoration marginal accuracy is of principle concern. [26] Due to the multiple factors involved during CAD/CAM procedure – as scanning process, designing the restoration, milling and firing- marginal accuracy is inevitably affected. [27, 28] Other studies have demonstrated that CAD/CAM restorations give comparable marginal fit to those generated via traditional impression. [31]

Many studies have recorded a wide range of marginal discrepancies both in-vitro and in-vivo studies when using different CAD/CAM systems[29,30] According to Mclean and Von Fraunhofer[32,33] mean marginal gap is clinically a ceptable- up to 120 μm- as successful restorations.

One of the recent CAD/CAM materials are lithium disilicate ceramics; a widely used ceramic among clinical practices. It's classified as a glass ceramic which supplied in blocks of a partially precrystallized structure in the blue state 40% Meta silicate (Li_2SiO_3) of moderate flexural strength 130 MPa which provides better workability during milling and lower wear of the machines [34, 35]

Maturation of mechanical properties are established after heating cycle which elevates the meta silicate crystals up to 70% and this significantly increases flexural strength and fracture toughness. The high mechanical property is attributed to the tight interlocking distribution of the elongated disilicate crystals which counteract crack propagation [36] In addition to the low hardness compared to that of conventional porcelain restoration; which provides better protection for the opposing natural dentition against excessive wear. [37]

Marginal accuracy for IPS e. max CAD is still controversial issue, many studies have investigated the gap discrepancies and internal fit; and found it to be with in the accepted clinical range.[38, 39] On the other hand due to the many variable factors involved in producing this type of restoration internal fitting and marginal quality may be negatively affected. [40]

Another bread of the CAD/CAM materials is Vita Enamic which combines the benefits of both ceramic and composite material [41]. It is a polymer infiltrated ceramic composed of 75% volume ceramic network AL_2O_3 reinforced with 25% volume polymer network of urethane di-methacrylate and tri-ethylene glycol di-methacrylate. [42, 43] This unique material possesses both properties of its components. With elastic modulus similar to dentin allowing it to absorb stress better than the conventional ceramic. [44] Many authors find it to be a reliable material during clinical performance due to its resemblance to natural tooth structure regarding the mechanical properties.[45,46] Vita Enamic unlike lithium disilicate blocks does not require crystallization firing cycle moreover it has demonstrated excellent edge stability after milling and precision marginal fit of restoration in addition to acceptable flexural strength. [47]

Butt joint preparations have demonstrated their superiority to other researched endocrowns preparations as it provides more preservation of the tooth structure than creating a finish line which increases the surface area for adhesion but on the expense of more structural loss. Most endodontically treated teeth have actually already suffered from destruction prior to treatment due to caries; especially proximal surfaces of molars which in some studies reach 77.5% of carious teeth. [48]

Proximal sub-gingival margin is a difficult location for restoration as it is challenging to adequately isolate this area for a good digital impression and to perform acceptable cementation of indirect restorations. [49] The relocation of the gingival margin of this proximal cavity using a composite resin base has long been investigated. Since first described by Dietschi and Spreafico in 1998 [50]; this procedure known as deep marginal elevation improves bonding, marginal seal and adaptation of indirect restorations. [51, 52] Moreover, it allows better optical impressions which leads to increase in marginal and internal fit of the restoration; decreasing the risk of microleakage and recurrent caries. [53] In addition many studies have shown it to decrease cusp deflection, elevate fracture resistance and improve cuspal reinforcement. [54]

So; the null hypotheses tested in the present study:

1- Deep marginal elevation does not influence marginal adaptation of endocrowns constructed from different CAD/ CAM ceramics

2- Deep marginal elevation does not influence fracture resistance of endocrowns constructed from different CAD/ CAM ceramics

The aim of the study

Evaluate the effect of deep marginal elevation on the marginal adaptation and fracture resistance in endodontically treated teeth restored with endocrowns constructed by two CAD/CAM ceramics in an in-vitro model.

MATERIAL AND METHODS

Specimen selection and preparation:

Twenty four freshly intact human mandibular molars extracted for periodontal reasons were used in this study. All teeth had complete root formation, absence of any resorpative defects or fracture lines. They were immersed in 5% sodium hypochlorite for 10 min. then thoroughly cleaned from all soft tissue debris and calculus and stored in 0.1 % thymol solution (Caelo, Hilden, Germany).

Using a digital caliper all selected teeth were measured at the CEJ for recording the buccolingual and mesiodistal dimensions and root length was also measured; all dimensions were subjected to ANOVA test to confirm the absence of any significant difference in this variable among groups. Any specimens out of the predetermined measurements were excluded and replaced [55]

Endodontic treatment

All endodontic treatments were carried out by the same operator using the same procedure and instruments for standardization purposes. Access cavity was prepared using a round carbide bur (BR-31, DIA-BURS, Mani, Japan) root canals were prepared using Protaper system (Dentsply, Maillefer: Ballaigues, Switzerland) mounted on gear reduction, torque controlled endo motor (X-smart, Dentsply, Sirona, Switzerland) canals mesiobuccal and mesiolingual up to a size F2 and distal canal up to F4 . Chlorhexidine gluconate 2 % was used in between files and as a final irrigation 5ml of saline for each specimen then dried using Protaper paper points (Dentsply, Maillefer: Ballaigues, Switzerland). Bioceramic based sealer (Total Fill, BRASSELER,USA) with a single cone technique using the corresponding size gutta percha point of the same system (Dentsply, Maillefer: Ballaigues, Switzerland) were used for obturation. Excess gutta percha removed with red hot plugger and cut 2 mm below the orifice. A thin layer of flowable composite (Tetric EVO Flow, Ivoclar, Vivadent, Germany) was bonded to seal the canal entrance and enhance bonding of the ceramic endocrowns in a later stage. Radiographic was taken for each specimen to ensure the obturation length. The specimens were stored at 37 C in distilled water for 24 hours to ensure complete setting of obturation material.

Mounting into acrylic resin and grouping of specimens

Notches were prepared in the roots of all specimens to provide retention to the mounting material, all specimens roots were shielded by a 0.2mm layer of light rubber base impression (Speedix, Ivoclar, Vivadent, Germany) for periodontal ligament simulation and then mounted in self-cured acrylic (cold cure acrylic resin, Acrostone, Egypt) in a standard cylindrical plastic ring in an upright position using a centralizing device to a level of a pre-marked point 4mm apical to the CEJ.

All specimens were equally divided into two groups (n=12) according to the type of ceramic group M were constructed with IPS e.max CAD blocks (Ivoclar, Vivadent, Liechtenstein, Germany) and group V were constructed with Vita Enamic blocks (VITA, Zahnfabrik, Sackingen, Germany) then further divided in to 2 subgroups -according to whether the deep marginal elevation was performed or not- subgroup E (with deep marginal elevation) and subgroup N (without deep marginal elevation). Fig (1)

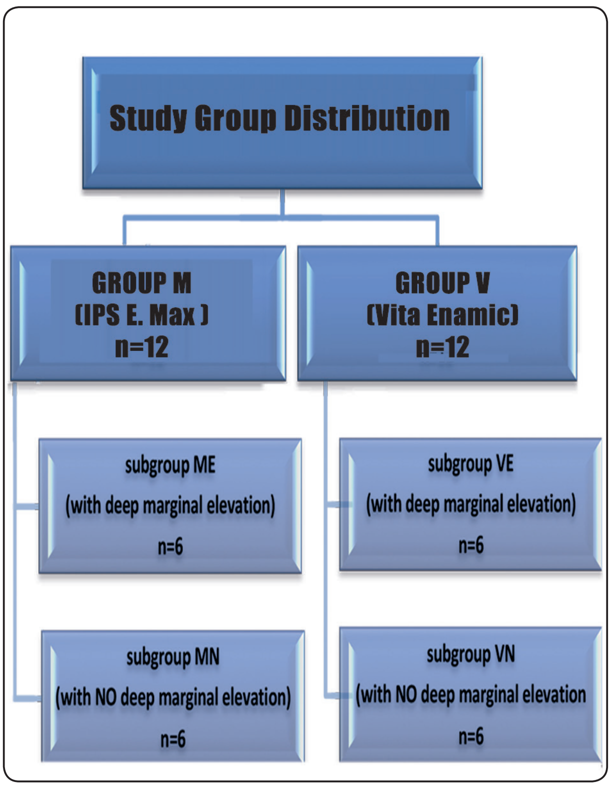

Fig. (1): Specimen distribution within different study groups

Endocrown and proximal box preparation

Teeth were decoronated with a super coarse diamond disc (Diatech, Coltene, Switzerland) under copious water. A standard endocrowns preparation was performed for all specimens; occlusal preparation was adjusted to a 90° butt margin design 3mm above the CEJ. Cavity preparation with minimum dentin removal eliminating all pulp chamber under cuts, roundation of all the internal line angles, adjusting internal axial walls to 8°. Mesial marginal cavities were made in the middle of the mesial surface 2 mm in width and extending 2mm apical to the CEJ and of 2mm in depth.

A standard endocrowns preparation was performed for all specimens; occlusal preparation was adjusted to that the cervical margin 2 mm above CEJ with a 90 ^{0} butt margin design “cervical sidewalk” with the help of depth orientation grooves with a depth of 2mm by diamond wheel bur. Axial walls Preparation were performed inside the pulp chamber (3mm depth) via cylindrical-conical diamond bur to ensures that no undercuts occur. The pulpal floor is left intact. Then roundation of all the internal line angles was performed. Mesial marginal cavities were made in the middle of the mesial surface 2 mm in width and extending 2mm apical to the CEJ and of 2mm in depth.

Prior to preparation of the mesial marginal cavity - with the aid of a digital caliper the center of the mesial surface- was determined for all specimens and marked, similar marks were done on either sides of the central point 1 mm away buccal and lingual . An apical mark was also made 2mm apical to the CEJ; these marks were utilized as reference points for cutting uniform, equal cavities to standardize their dimensions. Similar mark was done on the occlusal margin 2 mm from the mesial margin to ensure the uniform depth of the cavities.

Deep marginal elevation procedure for sub-groups (ME and VE):

The deep marginal elevation was performed to elevate the cervical floor of the proximal box 2mm coronal to the CEJ level. The proximal box was cleaned by phosphoric acid etching (Meta etchant gel, Korea) for 20 second then rinsed for 20 seconds and dried; Followed by application of a thin layer of self- etch bond (all bond universal, Pisco, USA) for 15 sec. then light cured . IPS Empress direct composite restoration (Ivoclar, Vivadent, Germany) was used to elevate the mesial margin in a snow plough technique. [56] ; where flowable composite was applied to the proximal box followed by packing of regular composite on top of it then cured for 15 sec. a sub gingival sectional matrix (Matrices, stainless steel, Russia) was used to adjust the proximal contour .all surfaces and margins of the restoration was finished and polishing using (Flame, FO-21EF, DIA-BUR, Mani, Japan).

Endocrowns fabrication

All specimens were fixed on the scanning tray, scanned sequentially using a scanner (CEREC Omnicam 444, DENTSPLY, Sirona) when a final optical impression was obtained fig (2), a CAD/CAM software (Ceramil, Mind, DENTSPLY, Sirona) designed the endocrowns fig (3) and performed milling of the ceramic blocks using a computer controlled milling unit (Ceramill motion 2 (5 ×) after fixation in to the milling machine; under full automation. All endocrowns were designed with identical occlusal anatomy and height (as not to incorporate different level of action vectors in to the study design).

For IPS e.max CAD the endocrowns were further subjected to crystallization cycle in a ceramic furnace according to manufacture instructions of (Ivoclar, Vivadent) for firing of IPS e.max CAD blocks.

Cementation of endocrowns:

The fitting surface of all endocrowns were cleaned via an ultrasonic cleaner for 3 min. then thoroughly rinsed under running water and dried, the fitting surface was further etched for (90 seconds in case of IPS e.max CAD and for 60 seconds for Vita Enamic) using 9.5 % hydrofluoric acid gel (BISCO-Schaumburg, USA) followed by 20 seconds of rinsing and finally dried for another 30 seconds with compressed air. A thin layer of silane coupling agent (BISCO-Schaumburg, USA) was applied to the etched surface and left 30 seconds to dry. simultaneously all specimen prepared surfaces were etched for 15 seconds using 37% phosphoric acid (Meta Etch gel), then rinsed for 20 seconds and dried. Bonding agent (Ader single bond 3M,

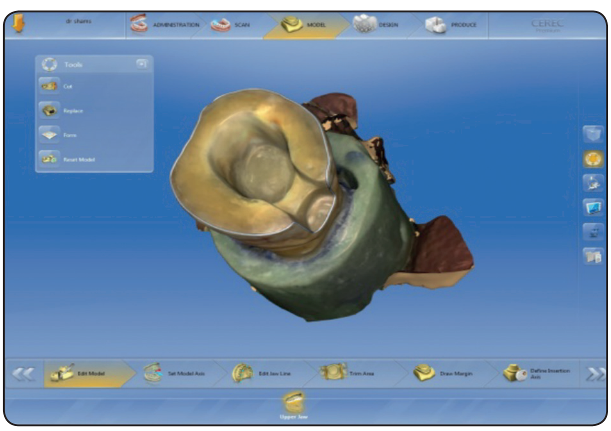

Fig. (2): On screen image of the optical impression of the endocrown preparation

Fig. (3): on screen image of the final designed endocrown restoration

ESPE, USA) was then applied and light cured for 20 seconds.

For all specimens dual cured, self-adhesive resin cement (Rely X Unicem clicker, 3M ESPE, Germany) was used as a luting agent. After mixing according to manufacturer instructions; endocrowns were cemented into placed each to the corresponding prepared specimen. An equal constant load was applied via a special loading device (1 kg for 5 min) then light cured for 2 seconds, any excess luting agent was removed using a scaler, followed by 20 more seconds light curing then stored for 24 hours in distilled water at $37C^0$ to allow bond maturation.

Thermocycling procedure:

To simulate clinical service Thermo cycling was performed for all specimens at 10000 cycle in water bath at (5- 55˚C) in a standard thermocycling machine (Thermocycler, Robota, Alexandria, Egypt) for 30 sec. / cycle and a 5 seconds transfer time between every 2 baths. The number of cycles used in this study is equivalent to 2 years clinical service according to (International Organization for Standardization- ISO/TS 11405).

Marginal Adaptation evaluation:

For marginal adaptation four stereo-microphotographs were captured via a stereomicroscope (Wild 400, Switzerland) for each specimen at magnification (40×) and transferred to computer system with image analysis software (Image Pro-plus V.6). One operator was assigned for gaps measurement. Measurement was performed at 5 equidistant predetermined points at the cervical margin of the mesial surface for each the endocrown recorded tabulated and the mean gap in μm calculated for each specimen then transferred for statistical analysis.

Fracture resistance testing:

A universal testing machine (Lloyd LRX, Lloyd Instruments, Fareham Hants, UK) was used to test fracture resistance. Each specimen was fixed into the lower compartment of the device. A 6 mm round end stainless steel rod fixed to the moving upper arm of the device applied a static, compressive load of 0.5 mm/min along the long axis of the specimen with tin foil sheet in-between to achieve homogenous stress distribution and minimization of the transmission of local force peaks. The style was applied to a point in the middle of the occlusal surface while ensuring its contact with both facial and lingual cusp inclinations. Vertical loading proceeded till fracture, and recorded in newton. Fig. (4)

Fig. (4): Universal testing machine applying load on to the endocrown

Statistical analysis:

The collected data were coded, tabulated and statistically analyzed using SPSS program (statistical package for social science) software version 25. Descriptive statistics were done for parametric quantitative data by mean standard deviation and minimum and maximum of the range. Distribution of the data was done by Shapiro Wilk test

Two way ANOVA test was done to determine the effect of different factors (material and elevation) and the interaction between them. Analyses were done for done for parametric quantitative data between the four subgroups using Independent Samples T- test. Analyses were done for parametric quantitative data between the four subgroups using One- way ANOVA test followed by post hoc analysis. The level of significance was taken at (P value <0.05)

RESULTS

Mean marginal gap values and standard deviation among all tested subgroups in micrometers (µm) are present in tab. (1), fig. (5).

Subgroup VE recorded the lowest value at (69.3**µm**) while group MN recorded the highest value at (102.8**µm**). One way ANOVA test revealed statistically significant difference between all tested groups where subgroup VE (endocrowns constructed from Vita Enamic blocks with deep marginal elevation) demonstrated significantly less marginal gap formation than did VN (endocrowns constructed from Vita Enamic blocks without deep marginal elevation) p< 0.001 tab.(1)

Moreover, both subgroups constructed from Vita Enamic (VE, VN) showed statistically significant lower marginal gap formation than both subgroups constructed from IPS e.max CAD (ME, MN). P< 0.001 tab. (1)

Regarding the mean value and standard deviation of fracture resistance for all tested groups in newton (N) are present in tab (2), fig (6)

IPS e.max CAD with deep marginal elevation subgroup (ME) showed the highest mean fracture resistance at (1478.2 N), followed by (1217.2 N) for subgroup MN, then (1049N) for subgroup VE and the least was sub group VN at (928N). Tab (2)

One way ANOVA test showed statistical significant difference between all tested sub groups with (p< 0.001). Regarding the material of construction IPS e.max CAD sub groups (ME, MN) were of statistically significant higher fracture resistance than those of Vita Enamic subgroups (VE, VN) on the other hand regarding the deep marginal elevation performed or not both subgroups with elevation (ME, VE) were significantly higher than those without (MN, VN) with p value < 0.001. Tab (2)

TABLE (1): Mean marginal gap value (SD) in micrometer (µm) between different tested subgroups

	Marginal gap	P value
MN	102.8±8.2 [a]	<0.001*
ME	91.5±4.3 [b]	
VN	80.7±5.7 [c]	
VE	69.3±7.3 [d]	

Abbreviations: ME; IPS e.max CAD with elevation , MN; IPS e.max CAD without elevation, VE; Vita Enamic with elevation, VN; Vita Enamic without elevation

One-Way ANOVA test between the four groups followed by post hoc analysis between each two groups

Superscripts with different small letters indicate significant between each two groups

****: Significant level at P < 0.05***

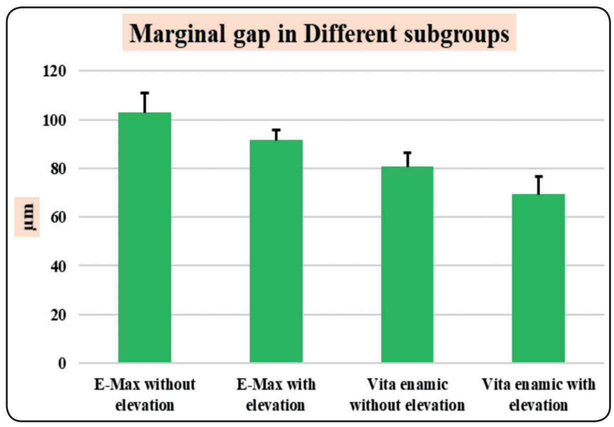

Fig. (5): Bar chart of mean marginal gap in different subgroups

TABLE (2): Mean (SD) fracture resistance between different subgroups in newton (N) .

	Fracture resistance	P value
ME	1478.2±107.5 [a]	<0.001*
MN	1217.2±76.4 [b]	
VE	1049±66.3 [c]	
VN	928. 7±69.5 [d]	

Abbreviations: ME; IPS e.max CAD with elevation , MN; IPS e.max CAD without elevation, VE; Vita Enamic with elevation, VN; Vita Enamic without elevation

One-Way ANOVA test between the four groups followed by post hoc analysis between each two groups

Superscripts with different small letters indicate significant between each two groups

**: Significant level at P < 0.05*

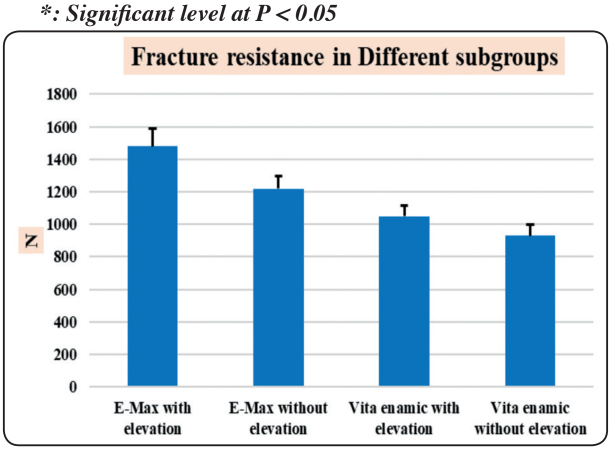

Fig. (6): Bar chart of mean fracture resistance in different subgroups

DISCUSSION

Choosing a final coronal restoration for endodontically treated teeth still comprises a major challenge in the everyday clinical practice [57,58]. The long term success of ETT depends on the quality of the coronal restoration not only in restoring the function but in its ability to protect the remaining tooth structure and maintaining a good marginal quality [59]. the constant appearance of new materials and technologies to restore the mutilated tooth structure enables the practitioner of recovery of the naturalness of the teeth.

Endocrown recently seems to be a fulfilling alternative for restoration of the ETT as it eliminates the need for additional tooth structure removal which is an inevitable procedure in post and core restoration. Being a minimally invasive technique it inherently provides protection for existing tooth structure. [11,12, 13, 14] when combined with the innovative CAD/CAM technology- that produces restorations with high mechanical properties, marginal adaptation and internal fit along with the ability to produce these restorations chair side eliminating the time factor- a new line of treatment has emerged.[22- 26]

For all the previous reasons it is logic to accept ceramic endocrown restorations as a safer, faster and stronger alternative for conventional post and core restoration. This justifies the urge to further study the best applied preparation design, material of fabrication and cementation technique.

Most proximal carious lesions in badly broken down teeth are located sub-gingival level a deep marginal elevation of this cervical margin with a suitable direct composite restoration is advisable [60]. The elevation of proximal box allows the cervical margin to be better visualized and more accessible for impression taking and for better cementation procedure; provided that the procedure respects the recommendations laid down by Magne etal [61, 62, 63]

This study is an in vitro study. This type of study allows standardization of all study procedures for all samples to better analyze the variable factor in question. This would provide important data for restoration procedures improvement. [64]

Regarding the present study human teeth were used rather than metal or plastic or bovine models; this is because human teeth simulate-the bonding properties, modulus of elasticity, thermal conductivity and strength- of clinical situation. [65] The size of all teeth selected for this study was with in comparable measurements and a statistical confirmation was done to eliminate any samples that were out of similar range of measurement. [55] Selected samples were stored in 0.1% thymol solution to prevent them from becoming brittle or drying out. [66]

A non-hypochlorite irrigation solution was used; (chlorhexidine gluconate) was selected to avoid any interference with polymerization of resins used either in the marginal elevation procedure or the cementation of the endocrown.[67,68] Obturation was done using bioceramic sealer which is also compatible with resin cement and doesn't interfere with polymerization or bond strength of resin cements. [69]

All specimens were embedded vertically in the center of a standard ring filled with epoxy resin using a special centralizing device to ensure standardization of their position. [55]

Self-cured epoxy resin was selected for specimen fixation in the mold as it has modulus of elasticity (12GPa) comparable to that of human bone (18GPa) simulating the teeth with in the alveolar bone. [69]

All specimens were prepared by one operator and according to a standard pre-determined preparation criteria to ensure all preparations were of the same measurement and design. [70] The specimens were decapitated perpendicular to the long axis to create a standard butt- joint preparation 2 mm coronal to the CEJ to simulate the compromised situation of severely damaged ETT. [65,69,70] it is also an acceptable length to provide frictional retention from contact between the dentinal wall of the pulp chamber and restoration (macro- mechanical retention). [71]

Elevation of the proximal box was done using IPS Empress which is a nano composite of high physical and mechanical properties which are due to the high nano- filler particles ; this increase in the filler load dramatically improves physical properties in comparison to the regular composites. They also possess high marginal adaptation and superior bond strength. These qualities are essential factors for restoration longevity and resistance to aging. [72]

In addition to the decrease in organic monomer content which decrease the hygroscopic expansion providing long term dimensional stability cutting down the microleakage susceptibility. [73,74] All endocrowns were milled to the same occlusal anatomy and height to ensure that they were of the same dimensions. [75]

Thermocycling with water bath was used after cementation as it is a well- documented approach to simulate aging in the oral environment simulating the fluctuating humidity and thermal changes. [60]

Marginal adaptation was done via a stereomicroscope which is a non-destructive method of evaluation and provides significantly important data about marginal quality. While fracture resistance test was used in this study which is a well-documented quantifying test allowing determination of influence of restorative material, bonding procedures and preparation technique on tensile strength and longevity of the restoration. [55, 76, 77]

Fracture resistance test was performed using 6mm steel sphere which is ideal for molars because it provides contact of functional and non- functional cusps comparable to the clinical loading of the occlusion. [78- 80]

Marginal quality is a crucial concern for CAD/CAM ceramic restorations as it ensures less cement dissolution and recurrent caries. Marginal discrepancies; up to 160 µm is considered clinically acceptable[55]. Recent CAD/CAM systems are provided with highly accurate scanners, advanced soft wares and precise milling devices. [81-84]

Regarding the marginal gap measurements for all groups of the present study (VE, VN, ME, MN) recorded (69.3, 80.7, 91.5, 102.8) respectively which is within the clinically accepted range for marginal gaps. This is in accordance with previous literature[22-25]. This can be attributed to the use of CAD/CAM technology which provides an equal and uniform fitting surface and enhance the adaptation of the margins of the restoration. For these reasons the risk of incomplete seating and marginal gap formation is diminished. [26-28, 85]. However; it comes in contrast with results by Mously etal [86] that found conventional techniques to form better marginal quality than CAD/CAM ceramic technology. Similar contradicting results were demonstrated by Azar etal[87]. Recent comparative studies have demonstrated no significant difference in marginal adaptation between conventional and CAD/CAM restorations [88-90]

Regarding the material of construction Vita Enamic groups (VE,VN) recorded significantly lower gap measurements than with IPS e. max CAD groups (ME,MN) this indicates the higher marginal adaptation of vita Enamic. Results of the present study come in accordance with previous study by Bankoğlu-Güngör etal [91]

This may be attributed to adhesion between the hybrid material and the resin cement due to the chemical interaction between the polymers present in both materials. [91]

In addition; IPS e.max CAD needs an additional firing procedure to finalize crystallization of the restoration. This step inevitably causes shrinkage on the other hand vita Enamic does not need this step. [26]

Concerning the marginal adaptation of groups with deep marginal elevation (ME, VE) they showed better adaptation than did groups without elevation indicating that elevation of the cervical margin of the proximal box favorably influenced the adaptation. [59, 92]

The elevation of the proximal box allows the relocation of the cervical margin more coronally which allows a better optical impression taking, seating of the restoration in place and precise cementation procedure. This may explain the higher marginal adaptation of the restorations that had under gone proximal box elevation [60, 61]

In contrast to the results of the present study Kuper etal [58] found that composite elevation of the proximal box actually caused more microleakage and recurrent caries due to exposure of the hybrid layer which led to hydrolysis of the unprotected collagen all which negatively affects the adhesive layer and finally breaks down marginal integrity.

Fracture resistance of all groups (ME, MN, VE, VN) was with in the clinically accepted limits which may be attributed to the inherent high mechanical properties of the tested ceramic materials. Both e.max and vita Enamic have high flexural strength than the maximum biting forces which is (725 N) for a posterior single molar tooth. [93, 94]

In addition to the design of the endocrown preparation design; where occlusal forces over the endocrown is distributed as compression over the butt- joint which provides stable- parallel to the occlusal plane- surface allowing better compressive stress resistance while over the proximal box load is distributed as shear force which is counter acted by the short axial walls of the proximal box; all of which add up to high fracture resistance. [95]

In regards of the material of construction group (ME, MN) constructed of IPS e.max blocks had significantly higher fracture resistance than did groups (VE, VN) constructed of Vita Enamic blocks which is in agreement with Sagsoz and Yanikoglu [96]

In addition to the inherent mechanical properties of lithium disilicate ceramics as IPS e.max composition shows tight interlocking distribution of elongated disilicate crystals that act against crack propagation. [97]

On the other hand regarding deep marginal elevation; both materials showed that deep marginal elevation groups (ME, VE) had higher fracture resistance than those without groups (MN, VN).

This comes in accordance with previous studies that have shown deep marginal elevation had favorable influence on the fracture resistance of different restorations[98,99], and as shown by llgenstein etal[92] whom studied the influence of deep marginal elevation on fracture resistance of ETT restored with CAD/CAM ceramic inlays and found it to have favorable behavior. Especially when loads are very high or when the restoration is faced with eccentric forces.

The positive influence of deep marginal elevation has been well documented.[53, 100] As shown by Zaruba etal[61] whom also studied the marginal integrity of inlay ceramic restorations with sub-gingival box after deep marginal elevation with composite resin and found that the marginal integrity was equivalent to that of ceramic inlays placed with in dentin (without sub-gingival box), And in agreement with a study by Roggendorf etal [62] whom studied the influence of deep marginal elevation with in-direct composite inlays in an in-vitro study. The results showed no statistically significant difference between restorations with proximal box elevation and others without. This may be attributed to the resin elevation of the proximal box which acts as a stress breaker during loading of the restoration because it actually absorbs some of the stress [61]. In addition to the fact that composite resin has mechanical properties comparable to that of human dentin; this allows it to reduce the stresses generated on the residual tooth structure. [92]

Many studies have found equivalent fracture resistance in teeth restored with composite compared to intact, unrestored teeth; so, mesial marginal elevation with adhesive materials may act as an intact tooth structure under the ceramic endocrown margin which allows favorable stress distribution. [101-104]

Moreover; Zamboni etal[54] have suggested that using deep marginal elevation decrease cuspal deflection which provides cuspal reinforcement and improve fracture resistance. So the null hypotheses were rejected.

CONCLUSION

Deep marginal elevation enhances both marginal adaptation and fracture resistance of IPS e.max CAD and Vita Enamic. IPS e.max CAD has higher fracture resistance while Vita Enamic has better marginal adaptation.

REFERENCES

1. Gonzales-López S, Deharo-Gasquet F, Vilchez-Diaz M, Ceballos LM, Bravo M. Effect of restorative procedures and occlusal loading on cuspal deflection. Oper Dent. 2006; 31: 33–8.
2. Shah RJ, Lagdive S, Verma V, Shah S, Saini S. Rehabilitating endodontically treated mandibular molar having inadequate coronal length with “Endocrown”–A neoteric clinical approach. IOSR J Dent Med Sci. 2017; 16: 29–33.
3. Pissis P. Fabrication of a metal-free ceramic restoration utilizing the mono-block technique. Pract Periodontics Aesthet Dent 1995; 7: 83–94.
4. Schwartz RS, Robbins JW: Post placement and restoration of endodontically treated teeth: a literature review. J Endod 2004;30:289-301
5. Magne P, Carvalho AO, Bruzi G. Influence of no-ferrule and no-post buildup design on the fatigue resistance of endodontically treated molars restored with resin nanoceramic CAD/CAM crowns. Oper Dent 2014; 39: 595-602
6. Dietschi D, Duc O, Krejci I, Sadan A. Biomechanical considerations for the restoration of endodontically treated teeth: A systematic review of the literature, part ii (evaluation of fatigue behavior, interfaces, and in vivo studies). Quintessence Int. 2008; 39(2): 117-29.
7. Zarone F, Sorrentino R, Apicella D, Valentino B, Ferrari M, Aversa R, Apicella A. Evaluation of the biomechanical behavior of maxillary central incisors restored by means of endocrowns compared to a natural tooth: A 3d static linear finite elements analysis. Dent Mater 2006; 22(11):1035- 44.
8. Beschnidt SM & Strub JR. Evaluation of the marginal accuracy of different all-ceramic crown systems after simulation in the artificial mouth. J Oral Rehabil 1999; 26: 582-93.
9. El-Damanhoury H, Haj-Ali R, and Platt J. Fracture resistance and microleakage of endocrowns utilizing three CAD-CAM blocks. J operative Dent. 2015; 40: 201 – 10.
10. Magne P, Carvalho AO, Bruzi G, Anderson RE, Maia HP, Giannini M. Influence of no-ferrule and no-post build-

up design on the fatigue resistance of endodontically treated molars restored with resin nano-ceramic CAD/CAM crowns. Oper Dent. 2014; 39: 595–602.

11. Hood JA. Biomechanics of the intact, prepared and restored tooth: Some clinical implications. Int Dent J. 1991; 41: 25–32.
12. Dejak B & Młotkowski A. 3D-Finite element analysis of molars restored with endocrowns and posts during masticatory simulation. Dent Mater. 2013; 29: 309–17.
13. Lin CL, Chang YH, Pa CA. Estimation of the risk of failure for an endodontically treated maxillary premolar with MODP preparation and CAD/CAM ceramic restorations. J Endod. 2009; 35: 1391–5.
14. Guo J, Wang Z, Li X, Sun C, Gao E, Li H. A comparison of the fracture resistances of endodontically treated mandibular premolars restored with endocrowns and glass fiber post-core retained conventional crowns. J Adv Prosthodont. 2016; 8: 489–93.
15. Rocca GT & Krejci I. Crown and post-free adhesive restorations for endodontically treated posterior teeth: from direct composite to endocrowns. Eur J Esthet Dent. 2013; 8(2): 156-79.
16. Goto Y, Ceyhan J, Chu SJ. Restorations of endodontically treated teeth: new concepts, materials, and aesthetics. Pract Proced Aesthet Dent. 2009; 21(2): 81-9.
17. Ree M & Schwartz RS. The endo-restorative interface: current concepts. Dent Clin North Am. 2010; 54(2): 345-74.
18. Lander E, Dietschi D. Endocrowns: A clinical report. Quintessence Int. 2008; 39(2): 99-106.
19. Bernhart J, Brauning A, Altenburger MJ, Wrbas KT. Cerec 3D endocrowns-two-year clinical examination of CAD/CAM crowns for restoring endodontically treated molars. Int J Comput Dent. 2010; 13(2): 141- 54.
20. Litzenburger AP, Hickel R, Richter MJ, Mehl AC, Probst FA. Fully automatic CAD design of the occlusal morphology of partial crowns compared to dental technicians' design. Clin Oral Investig. 2013; 17: 491-6.
21. Tzimas K , Tsiafitsa M, Gerasimou P, Tsitrou E. Endocrown restorations for extensively damaged posterior teeth: clinical performance of three cases. Restor Dent Endod. 2018; 43(4): 38-47.
22. Homaei E, Farhangdoost K, Akbari M. An investigation into finding the optimum combination for dental restorations. JCARME. 2016; 6: 1-9.
23. Harrington Z, McDonald A, Knowles J. An *in vitro* study to investigate the load at fracture of Procera All Ceram crowns with various thickness of occlusal veneer porcelain. Int J Prosthodont. 2003; 16: 54-8.
24. AL-Makramani BM, Razak AA, Abu-Hassan MI. Evaluation of load at fracture of Procera All Ceram copings using different luting cements. J Prosthodont. 2008; 17: 120-4.
25. Homaei E, Farhangdoost K, Pow EH, Matinlinna JP, Akbari M, Tsoi JK. Fatigue resistance of monolithic CAD/CAM ceramic crowns on human premolars. Ceram Int 2016; 42: 1509-17.
26. Al Mansour F, Karpukhina N, Grasso S, Wilson RM, Reece MJ, Cattell MJ. The effect of spark plasma sintering on lithium disilicate glass-ceramics. Dent Mater. 2015; 31(10): 226–35.
27. Reich S,Wichmann M, Nkenke E. Clinical fit of all ceramic three-unit fixed partial dentures, generated with three different CAD/CAM systems. Eur J Oral Sci. 2005; 113: 174- 9.
28. Tinschert J, Natt G, Hassenpflug S. Status of current CAD/CAM technology in dental medicine. Int J Comput Dent. 2004; 7: 25-45.
29. Denissen H, Dozic A, Van der Zel J. Marginal fit and short-term clinical performance of porcelain-veneered CICERO, CEREC and Procera onlays. J Prosthet Dent. 2000; 84: 506-13.
30. Ellingsen LA & Fasbinder DJ: An in vitro evaluation CAD/CAM ceramic crowns. J Dent Res. 2002; 53: 24-8.
31. Anadioti E, Aquilino SA, Gratton DG. 3D and 2D marginal fit of pressed and CAD/CAM lithium disilicate crowns made from digital and conventional impressions. J Prosthodont 2014; 23: 610- 7.
32. Mclean JW, Von Frounhofer JA: The estimation of cement film thickness by an in vivo technique. Br Dent J. 1971; 131: 107-11.
33. Tinschert J, Natt G, Mautsch W, et al: Marginal fit of alumina-and zirconia-based fixed partial dentures produced by a CAD/CAM system. Oper Dent. 2001; 26: 367- 74.
34. Roscoe MG, Noritomi PY, Novais VR, Soares CJ. Influence of alveolar bone loss, post type, and ferrule presence on the biomechanical behavior of endodontically treated maxillary canines: strain measurement and stress distribution. J Prosthet Dent. 2013; 110(2): 116-26.
35. Chun KJ, Lee JY. Comparative study of mechanical properties of dental restorative materials and dental hard tissues in compressive loads. J Dent Biomech. 2014; 11: 5-11.
36. Denry I, Holloway JA. Ceramics for dental applications: A review. Materials. 2010; 3: 351-68.

37. Brondani LP, Pereira-Cenci T, Wandsher VF, Pereira GK, Valandro LF, Bergoli CD. Longevity of metal-ceramic crowns cemented with self-adhesive resin cement: a prospective clinical study. Braz Oral Res. 2017; 31: 22-8.
38. Memari Y, Mohajerfar M, Armin A, Kamalian F, Rezayani V, Beyabanaki E. Marginal adaptation of CAD/CAM all-ceramic crowns made by different impression methods: a literature review. J Prosthodont. 2019; 28(2): 536–44.
39. Alfaro DP, Ruse ND, Carvalho RM, Wyatt CC. Assessment of the internal fit of lithium disilicate crowns using micro-CT. J Prosthodont. 2015; 24: 381–6.
40. Schaefer O, Decker M, Wittstock F, Kuepper H, Guentsch A. Impact of digital impression techniques on the adaption of ceramic partial crowns in vitro. J Dent. 2014; 42(6): 677–83.
41. Ramirez-Sebastia A, Bortolotto T, Cattani-Lorente M, Roig M, Krejci I. Adhesive restoration of anterior endodontically treated teeth: influence of post length on fracture strength. Clin Oral Investig. 2014; 18: 545-54.
42. Lauvahutanon S, Takahashi H, Shiozawa M, Iwasaki N, Asakawa Y, Oki M. Mechanical properties of composite resin blocks for CAD/CAM. Dent Mater J. 2014; 33: 705–10.
43. Coldea A, Swain MV, Thiel N. Mechanical properties of polymer-infiltrated ceramic- network materials. Dent Mater. 2013; 29: 419–26.
44. Taha D, Spintzyka S, Schille C, Sabetb A, Wahsh M, Salah T. Fracture resistance and failure modes of polymer infiltrated ceramic endocrown restorations with variations in margin design and occlusal thickness. J Prosthodont Res. 2018; 62: 293- 7.
45. Dirxen C, Blunck U, Preissner S. Clinical performance of a new biomimetic double network material. Open Dent J. 2013; 7: 118- 40.
46. He LH, Swain M. A novel polymer infiltrated ceramic dental material. Dent Mater J. 2011; 27: 527–61.
47. Azarbal A, Azarbal M, Engelmeier RL, Kunkel TC. Marginal Fit Comparison of CAD/CAM Crowns Milled from Two Different Materials. J of Prosthodon .2018; 27:421-8.
48. Demirci M, Tuncer S, Yuceokur AA. Pevalence of caries on individual tooth surfaces and its distribution by age and gender in university clinic patients. Eur J Dent. 2014; 4:270-9.
49. Veneziani M. Adhesive restorations in the posterior area with subgingival cervical margins: New classification and differentiated treatment approach. Eur J Esthet Dent. 2010; 5: 50–76.
50. Dietschi D& Spreafico R. Current clinical concepts for adhesive cementation of tooth-colored posterior restorations. Prac Periodont Aesthet Dent. 1998; 10(1): 47- 54.
51. Nikaido T, Takada T, Burrow MF, Satoh M, Hosoda H. Early bond strengths of dual cured resin cements to enamel and dentin. J Jpn Soc Dent Mater Dev. 1992; 11: 910– 15.
52. Magne P, So WS, Cascione D. Immediate dentin sealing supports delayed restoration placement. J Prosthet Dent. 2007; 98: 166– 74
53. Zaruba M, Kasper R, Kazama R. Marginal adaptation of ceramic and composite inlays in minimally invasive MOD cavities. Clin Oral Investig. 2014; 18: 579– 87.
54. Zamboni SC, Nogueira L, Bottino MA, Sobrinho LC, Valandro LF. The effect of mechanical loading on the cusp defection of premolars restored with direct and indirect techniques. J Contemp Dent Pract. 2014; 15: 75–81.
55. Yildiz C, Vanlıoglu BA, Evren B, Uludamar A, Kulak-Ozkan Y. Fracture Resistance of Manually and CAD/CAM Manufactured Ceramic Onlays. Journal of Prosthodontics. 2013; 22: 537–42.
56. Frese C, Wolff D, Staehle HJ. Proximal box elevation with resin composite and the dogma of biological width: clinical R2-technique and critical review. Oper Dent. 2014; 39: 22–31.
57. Dietrich T, Kraemer M, Losche GM, Roulet J. Marginal integrity of large compomer Class II restorations with cervical margins in dentine. Journal of Dentistry. 2000; 28(6):399-405.
58. Kuper NK, Opdam NJ, Bronkhorst EM, Huysmans MC. The influence of a proximal restoration extension on the development of secondary caries Journal of Dentistry. 2012; 40(3): 241-7.
59. Cavalcanti AN, Mitsui FH, Ambrosano GM, Marchi GM. Influence of adhesive systems and flowable composite lining on bond strength of Class II restorations submitted to thermal and mechanical stresses Journal of Biomedical Materials Research. Part B, Applied biomaterials. 2007; 80(1): 52- 8.
60. Rocca GT, Rizcalla N, Krejci I, Dietschi D. Evidence-based concepts and procedures for bonded inlays and onlays. Part II. Guidelines for cavity preparation and restoration fabrication. The international journal of esthetic dentistry. 2015; 10(3): 392-413.
61. Zaruba M, Gohring TN, Wegehaupt FJ, Attin T. Influence of a proximal margin elevation technique on marginal adaptation of ceramic inlays. Acta odontologica Scandinavica. 2013; 71(2): 317-24.

62. Roggendorf MJ, Kramer N, Dippold C, Vosen VE, Naumann M, Jablonski-Momeni A. Effect of proximal box elevation with resin composite on marginal quality of resin composite inlays in vitro. Journal of dentistry. 2012; 40(12): 1068-73.

63. Magne P & Spreafico RC. Deep Margin Elevation: A Paradigm Shift. American Journal of Esthetic Dentistry. 2012; 2(2):86-96.

64. Molin MK & Karlsson SL. A randomized 5- year clinical evaluation of 3 ceramic inlay systems. Int J Prosthodont. 2000; 13: 194-200.

65. Alamin AM, Sakrana AA, Al-Zordk W A. Impact of Marginal Preparation Design on the Fracture Resistance of Endo-Crown All-Ceramic. JDMS. 2019; 18(4): 11-17.

66. Giannetopoulos S, Noort R, Tsitrou E: Evaluation of the marginal integrity of ceramic copings with different marginal angles using two different CAD/CAM systems. J Dent. 2010; 38: 980- 6.

67. Souza SFC, Bombana AC, Francci C, Gonçalves F, Castellan C, Braga RR. Polymerization stress, flow and dentine bond strength of two resin-based root canal sealers. Int Endod J. 2009; 42: 867- 73.

68. Rocha AW, de Andrade CD, Leitune VCB, Collares FM, Samuel SMW, Grecca FS, de Figueiredo JAP and dos Santos RB. Influence of Endodontic Irrigants on Resin Sealer Bond Strength to Radicular Dentin. Bull Tokyo Dent Coll. 2012; 53(1): 1–7.

69. Reyhani MF, Ghasemi N, Rahimi S, Milani AS, Omrani E. Effect of Different Endodontic Sealers on the Push-out Bond Strength of Fiber Posts. Iran Endod J. 2016; 11(2):119

70. Hamdy A. Effect of Full Coverage, Endocrowns, Onlays, Inlays Restorations on Fracture Resistance of Endodontically Treated Molars (2015) 1: 1-5.

71. Bassir MM, Labibzadeh A, Mollaverdi F. The effect of amount of lost tooth structure and restorative technique on fracture resistance of endodontically treated premolars. J Conserv Dent. 2013; 16: 413- 9.

72. Rocca G.T, Daher R, Saratti C.M, Sedlacek R, Suchy T, Feilzer A.J, &Krejci I. Restoration of severely damaged endodontically treated premolars: The influence of the endo-core length on marginal integrity and fatigue resistance of lithium disilicate CAD-CAM ceramic endocrowns. Dent J. 2018; 76: 139- 47.

73. Abuelenain DA, Abau Neel EA, Al-Dharrab A. surface and mechanical properties of different dental composites. Aust J Dent. 2015; 2(2): 1019-25.

74. Verma KG, Verma P, Trivedi A. evaluation of microleakage of various restorative materials: an in-vitro study. J Life Scie. 2011; 3(1): 29-33.

75. Nidarch MH. Comparative analysis of bond strength and microleakage of nanocomposite to enamel and dentin. IJSR. 2015; 4(11): 347-9.

76. Carvalho AO, Bruzi G, Anderson RE, Maia HP, Giannini M, Magne P. Influence of adhesive core buildup designs on the resistance of endodontically treated molars restored with lithium disilicate CAD/CAM crowns. Oper Dent. 2016; 41: 76-82.

77. Kokubo Y, Nagayama Y, Tsumita M, Ohkubo C, Fukushima S, Vult von Steyern P. Clinical marginal and internal gaps of in-ceram crowns fabricated using the GN-I system. J Oral Rehabil. 2005; 32: 753– 8.

78. Coli P & Karlsson S. Fit of a new pressure-sintered zirconium dioxide coping. Int J Prosthodont. 2004; 17: 59–64.

79. Burke FJ& Watts DC: Fracture resistance of teeth restored with dentin-bonded crowns. Quintessence Int. 1994; 25: 335-40.

80. Burke FJ: The effects of variations in bonding procedure on fracture resistance of dentin bonded all-ceramic crowns. Quintessence Int. 1995; 26: 293-300.

81. Hikita K, Van Meerbeek B, De Munck J. Bonding effectiveness of adhesive luting agents to enamel and dentin. Dent Mater. 2007; 23: 71-80

82. Beuer F, Schweiger J, Edelhoff D. Digital dentistry: an overview of recent developments for CAD/CAM generated restorations. Br Dent J. 2008; 204: 505-11.

83. Souza RO, Ozcan M, Pavanelli CA, Buso L, Lombardo GH, Michida SM . Marginal and internal discrepancies related to margin design of ceramic crowns fabricated by a CAD/CAM system. J Prosthodont. 2012; 21: 94-100.

84. Nedelcu RG & Persson AS. Scanning accuracy and precision in 4 intraoral scanners: an *in vitro* comparison based on 3-dimensional analysis. J Prosthet Dent. 2014; 112: 1461-71.

85. Patzelt SB, Emmanouilidi A, Stampf S, Strub JR, Att W. Accuracy of full-arch scans using intraoral scanners. Clin Oral Investig. 2014; 18: 1687-94.

86. Mously HA, Finkelman M, Zandparsa R, Hirayama H. Marginal and internal adaptation of ceramic crown restorations fabricated with CAD/CAM technology and the heat-press technique. J Prosthet Dent. 2014; 112: 249-56.

87. Azar B, Eckert S, Kunkela J, Ingr T, Mounajjed R. The marginal fit of lithium disilicate crowns: Press vs. CAD/CAM. Braz Oral Res. 2018; 32: 1- 6.

88. Dolev E, Bitterman Y, Meirowitz A. Comparison of marginal fit between CAD-CAM and hot press lithium disilicate crowns. J Prosthet Dent. 2019; 121: 124–8.

89. Azarbal A, Azarbal M, Engelmeier RL, Kunkel TC. Marginal fit comparison of CAD/CAM crowns milled from two different materials. J Prosthodont. 2018; 27: 421–8.

90. Al Hamad KQ, Al Rashdan BA, Al Omari WM, Baba NZ. Comparison of the fit of lithium disilicate crowns made from conventional, digital, or conventional/Digital techniques. J Prosthodont. 2019; 28(2): 580-6.

91. Bankoğlu-Güngör M, Doğan A, Turhan Bal B, Karakoca Nemli S. Evaluation of marginal and internal adaptations of posterior all-ceramic crowns fabricated with chair-side CAD/CAM system: an *in vitro* study. Acta Odontol Turc. 2018; 35(1): 1-8.

92. llgenstein I, Zitzmann N, Bühler J, Wegehaupt F, Attin T, Weiger R. Influence of proximal box elevation on the marginal quality and fracture behavior of root-filled molars restored with CAD/CAM ceramic or composite onlays. Clinical oral investigations. 2015; 19(5): 1021-8.

93. Al-Akhali M, Chaar MS, Elsayed A, Samran A, Kern, M. Fracture resistance of ceramic and polymer-based occlusal veneer restorations. J Mech Behav Biomed Mater. 2017; 74: 245–50.

94. Ghajghouj O & Tasar-Faruk S. Evaluation of Fracture Resistance and Microleakage of Endocrowns with Different Intracoronal Depths and Restorative Materials Luted with Various Resin Cements. Materials. 2019; 12: 2528- 34.

95. Adel S, Abo-Madina MM, Abo-Elfarag SA. Fracture resistance of hybrid ceramic endocrown restoration with different preparation depths and designs. JDMS. 2019; 18(5): 17-23.

96. Sagsoz NP, Yanikoglu N. Evaluation of the fracture resistance of computer aided/ computer aided manufacturing monolithic crowns prepared in different cement thickness. Niger J Clin Pract. 2018; 21: 417-22.

97. Zarone F, Di-Mauro MI, Ausiello P, Ruggiero G, Sorrentino R. Current status on lithium disilicate and zirconia: an arrative review. BMC oral health. 2019; 19: 134-48.

98. Andersson-Wenckert IE, van Dijken JW, Kieri C. Durability of extensive Class II open-sandwich restorations with resin-modified glass ionomer cement after 6 years. Am J Dent. 2004; 17: 43- 50.

99. Bitter K, Paris S, Hartwig C, Neumann K, Kielbassa AM. Shear bond strengths of different substrates bonded to lithium disilicate ceramics. Dent Mater J. 2006; 25: 493–502.

100. Marchesi G, Spreafico R, Frassetto A. Cervical margin-relocation of CAD/CAM lithium disilicate ceramic crown using resin-composite. Dent Mater. 2014; 30: 14- 19

101. Shafiei F, Memarpou M, Karimi F. Fracture resistance of cuspal coverage of endodontically treated maxillary premolars with combined composite-amalgam compared to other techniques. Operative Dentist. 2011; 36(4): 439-47.

102. Burke FJ, Wilson NH, Watts DC The effect of cuspal coverage on the fracture resistance of teeth restored with indirect composite resin restorations. Quintessence International. 1993; 24(12): 875-80.

103. Brunton PA, Cattell P, Burke FJ & Wilson NH. Fracture resistance of teeth restored with onlays of three contemporary tooth colored resin-bonded restorative materials. J Prosth Dent. 1999; 82(2) 167-71.

104. Mondelli RF, Ishikiriama SK, de Oliveira Fillo O, Mondelli J. Fracture resistance of weakened teeth restored with condensable resin with and without cusp coverage. Journal of Applied Oral Science. 2009; 17(3): 161- 5.