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Marginal Adaptation of Lithium Disilicate Endocrowns with Different Cavity Depths and Margin Designs

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ABSTRACT

Purpose: to study effect of different preparation designs on the marginal adaptation of lithium disilicate endocrowns. **Materials and methods**: Twenty human mandibular molars were selected to conduct the present study. All teeth were randomly divided into 2 groups (n=10 each) according to the preparation design of endocrown with two coronal cavity depths: Group (2D): Endodontically treated teeth with 2mm depth intra-coronal cavity preparation .Group (4D): Endodontically treated teeth with 4mm depth intra-coronal cavity preparation. Samples of each group were further subdivided into 2 subgroups (n=5 each) according to the preparation's margin configuration: Subgroup (B): preparations with butt-joint margin configuration. Subgroup (S): preparations with 90^o shoulder margin configuration. All prepared teeth were restored using IPS e.max Press endocrowns. The vertical marginal adaptation was measured after cementation using a Stereomicroscope. Measurements were made at twenty points for each crown. The recorded data were collected, tabulated and statistically analyzed. **Results**: shoulder finish line marginal preparation recorded lower vertical marginal gap values than butt joint marginal preparation. 2mm intracoronal cavity depth extension recorded lower vertical marginal gap values than 4mm intracoronal cavity depth extension. **Conclusions**: All obtained marginal adaptation values lie within the clinically accepted ranges. Increasing intra-coronal cavity depth of endocrown preparation negatively affects marginal adaptation of lithium disilicate based endocrowns. Endocrown with shoulder finish line marginal configuration has superior marginal adaptation than those with butt joint marginal configuration.

KEYWORDS

Endocrowns,
lithium disilicate,
marginal adaptation,
marginal preparations

INTRODUCTION

Rehabilitation of endodontically treated teeth is a challenge as they are very differs from vital ones; there is much dissimilarity that represented as changes in dentin composition and the evident loss of

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natural tooth structure. Many treatment modalities have been proposed for realization of endodontically treated teeth, such as traditional intracoronal post systems and directly placed adhesive restorations [(1)].

With the improvements of adhesive dentistry, treatment decisions for endodontically treated teeth are shifted toward more conservative approaches, and the need for traditional post and cores has become less demanded. Ceramic indirect inlays, onlays, and endocrowns have been presented for realization of endodontically treated molars [(2)].

The first promulgated study [(3)] on ceramic endocrown was published in 1995. It was described as the technique of ceramic monoblock fabrication for restoration of endodontically treated teeth. However, this restorative procedure was named later as "endocrown" in 1999 [(4)].

An endocrown is a single monoblock that contains the entire crown and an intra-radicular extension that adapts into the "endo-preparation" [(5)] having macromechanical retention (obtained through fitting into the pulpal walls), and microretention (by utilizing adhesive cementation) [(6)].

Molars with short, calcified, severely curved and extra thin roots are specially indicated for endocrown restorations. Endocrowns may also be used in cases with sever loss of coronal dental tissue and reduced interocclusal space as there is no enough space for the ceramo-metal restoration or ceramic substructures [(7)] .

There is no specific or defined design for endocrown preparation, Some studies recommend endocrown preparation parameters to include; occlusal reduction of 2 to 3 mm, 90° butt margins, Smooth internal line angles, Six occluso-cervical internal taper of the pulpal walls, Flattened pulpal floor and Supragingival enamel finish line when possible [(8)].

Several studies suggest a 2 mm intraradicular retentive feature to afford the sufficient retention and resistance features,[(9,10)], while other studies highlighted the effect of the depth (shallow or deep depth) of this intaradicular retentive feature on the marginal and adaptation of the endocrown restorations [(11,12)].

Long term success of fixed restorations is highly related to adequate marginal adaptation of the restoration. Exposed luting material to the oral environment with increased marginal discrepancies, may lead to cement dissolution with subsequent microleakage. Weak cement seal permits the entrance of bacteria with subsequent injury to the vital pulp. [(13)] Also, a higher plaque index is correlated with fixed restoration that has large marginal discrepancy and leads to reduced periodontal conditions [(14)].

Therefore, the effect of different endocrown's preparation on the marginal adaptation of endocrown has to be thoroughly investigated.

Two null hypothesis of the present study were that variation in coronal cavity depths and variation in margin configuration will have no effect on the marginal adaptation of endocrown restorations constructed from lithium disilicate based ceramics.

MATERIALS AND METHODS

Preparation of natural teeth:

Twenty (N=20) extracted human mandibular first molars, have no cracks, fractures or caries were selected for current study. Each molar was mounted vertically in epoxy resin block using the dental surveyor. All teeth were decapitated perpendicular to their long axis 2mm above CEJ. All decapitated teeth were endodontically treated. All endodontically treated teeth (N=20) were then divided into 2 groups (n=10 each) according to the preparation design of endocrown with two coronal cavity depths:

Grouping and subgrouping:

I. Group (2D): Endodontically treated teeth with 2mm depth coronal cavity preparation.

II. Group (4D): Endodontically treated teeth with 4mm depth coronal cavity preparation.

Samples of each group were further subdivided into 2 subgroups (n=5 each) according to the preparation's margin configuration:

a. Subgroup (B): preparations with butt-joint margin configuration.

b. Subgroup (S): preparations with 90^{o} shoulder margin configuration.

A special milling machine (Centroid milling machine) (Centroid CNC, Milling machine, USA) was used for standardized teeth preparations. The machine assembly incorporates a slow-speed hand-piece attached perpendicularly to the machine platform.

The endodontic access cavity was prepared with 8-10^{o} coronal divergence. The depth of the intraradicular retention cavity was prepared according to the assigned experimental groups; (2±0.5mm) in samples of group 2D, and (4±0.5mm) in samples of group 4D, Cavity depths were measured from decapitation level using the digital caliper.

Extracoronally, the remaining vertical portion of the crown received marginal configuration according to the assigned experimental subgroups.

Samples of subgroup (S) were prepared with 1 mm wide, 90^{o} shoulder margin with rounded internal line angles and located 1 mm above the cementoenamel junction leaving a 1mm ferrule. The external convergence angle was adjusted at 8- 10^{o}.

Samples of subgroup B received no further extracoronal preparation (i.e. butt joint margin configuration).

The remaining dentin walls' thicknesses were measured using digital caliper ensuring them to be (2±0.5 mm).

Schematic representation of prepared samples according to investigated groups and subgroups is illustrated in figure (1)

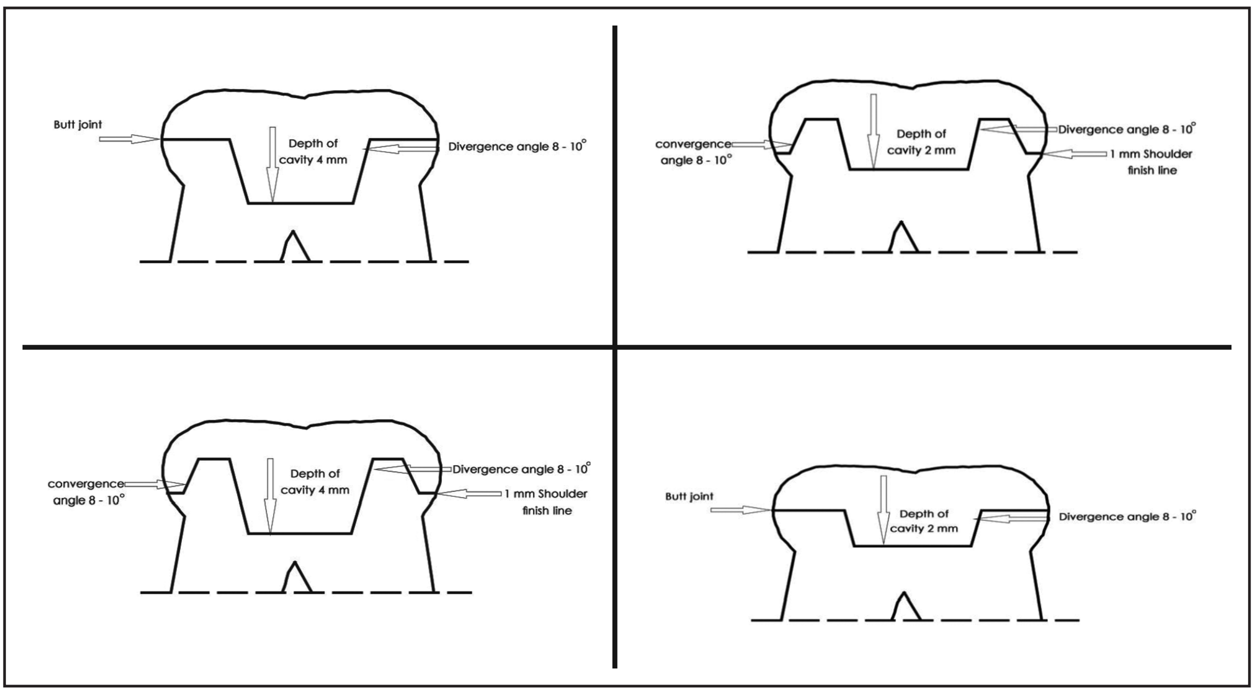

Figure (1): Schematic diagrams for endocrowm preparation designs

Construction of e.max press endocrowns

All prepared teeth samples were restored using e.max press endocrowns

Endocrowns' wax patterns were milled using CAD/CAM machine to ensure standardization.

Construction of CAD/CAM wax patterns:

In order to have a three-dimensional picture for each prepared tooth on the computer screen of the Roland system (Sirona Dental System, Bensheim, Germany); the prepared tooth was sprayed with an optical reflection powder (Telescan light reflecting powder powder, Vita Zahnfabrik, Germany), scanned using Smart optics scanner (Smart optics scan box pro, Germany), then the captured image was saved in the system's software. By using automatic margin finder the preparation's margin was detected.

The wax patterns of endocrowns were designed and fabricated using CAD/CAM Roland machine. A 3D virtual model was generated from the data gained during the acquisition phase. Restoration design parameters were standardized for all samples.

After finishing the design process, the wax disc was fixed in the milling chamber, figure, then the preview window was activated to start the milling process. DWX-50 5-axis dental milling machine started milling wax discs using SUM3D software.

Spruing: Single short axial wax sprue (diameter 3mm, length 5mm) was attached to the wax pattern in the direction of the material flow and each pattern was angled at 60.

Investing: IPS PressVest (IPS e.max Special material, Ivoclar, Schaan, Liechtenstein) investment material was used to invest the wax patterns. The investment material was poured into the investment ring till it filled the ring slightly below its rim. The ring was left to set for one hour. After setting of investment, the ring base was removed.

Preheating: The investment ring was preheated in the conventional preheating furnace but without placing the ingot, following the manufacturer's instructions. The preheating investment system started at room temperature and gradually increased with the rate of 5˚C /min. until reaching 250˚C where it was kept for 30 minutes. The temperature was increased again till it reached 1100˚C and kept for 60 min. At this stage wax was eliminated through the sprue channel forming a mold ready for pressing.

The investment ring with the ingot was placed in the center of EP600 furnace (EP600, Ivoclar Vivadent Schaan, Liechtenstein, Germany). The EP600 furnace was switched on and adjusted to the standby temperature 700 °C and kept at this temperature for at least 30 minutes. The furnace head was closed, and the program was selected and activated according to the instructions of the manufacture. The pressing process started at 1100 °C when the ceramic ingot became plasticized, it was pressed inside the investment mold at 3.5 bars. After pressing, a programmable holding period was achieved during which the plasticized ceramic material accurately reproduced the fine details of the mold and an acoustic signal indicated the end of the cycle.

The investment ring was taken away from the furnace after the program was completed, and allowed to cool at room temperature for about 60 minutes.

Divesting: After cooling of the investment, the investment ring was separated using a separating disc

Finally, the restorations were finished and examined using magnifying lens to detect any defects like irregularities or cracks and checked for complete seating on their corresponding models.

Cementation procedure

Restorations' internal surface treatment using Ultradent silane coupling agent and hydrofluoric acid (Ultradent, Sout Jordan, Utah, USA), Tooth surface treatment using Scotchbond Universal Etchant and Single Bond Universal Adhesive(3M ESPE, St Paul, MN, USA), Bonding using RelyX Ultimate Clicker adhesive resin cement(3M ESPE, St Paul, MN, USA). Each sample was subjected to 2kg weight in a load applicator then the cement was light cured for 20 seconds for each surface.

Marginal gap distance determination

Each sample was photographed using measuring Stereomicroscope (Nikon Eclips E600, Tokyo, Japan) connected with a personal computer, using a magnification of 45X. A digital image analysis system (Image J 1.43U, National Institute of Health, USA) was used to measure and calculate the gap width. 5 equidistant landmarks along the cervical circumference for each surface of the sample (Mesial, buccal, distal, and lingual) were selected for determination of marginal gaps at those points. Shots of the margins were taken for each sample. Then morphometric measurements were done for each shot at these points. Measurement at each point was repeated five times.

STATISTICAL ANALYSIS

Values were presented as mean and standard deviation (SD) values. Data were explored for normality using Kolmogorov-Smirnov test of normality. The results of Kolmogorov-Smirnov test indicated that most of data were normally distributed (parametric data). For two groups comparison independent t test was used. While comparing more than two groups was done using One-way analysis of variance (ANOVA), and when the difference was found to be significant Tukey's post hoc test was used .The significance level was set at $p < 0.05$.

RESULTS

1. **Comparison between marginal gap-distance values (µm) among groups and subgroups:**

The highest mean value was recorded in subgroup (4DB) (26.48±6.67), followed by subgroup (4DS) (26.34±7.3), whereas the least value was recorded in subgroup (2DS) (19.29±5.7).

ANOVA test revealed that the difference between all subgroups was extremely statistically significant ($p<0.0001$).

Tukey's post hoc test revealed no significant difference between 2DB, 4DS and 4DB groups.

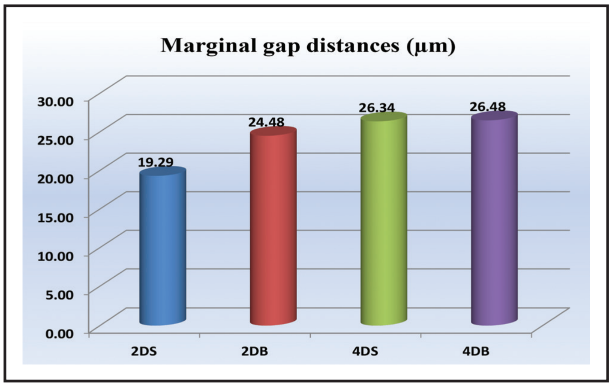

Figure (2): Column chart showing mean value of marginal gap distances in all groups

2. **Comparison between different marginal configurations within the same cavity depth:**

In two mm cavity depth, group (2D), Butt-joint margin configuration, subgroup (B) recorded higher mean value (24.48±8.18). Independent t test revealed that the difference was extremely statistically significant ($p<0.0001$).

In 4 mm cavity depth, group (4D), Butt-joint margin configuration, subgroup (B) recorded higher mean value (26.48±6.67). Independent t test revealed that the difference was statistically non-significant ($p=0.915$)

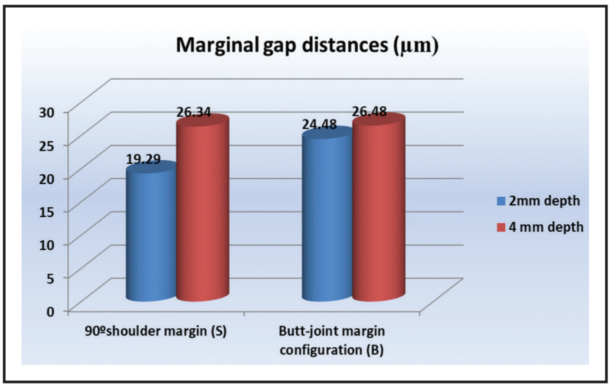

Figure: (3): Column chart showing mean values of marginal gap distances in different marginal configurations within the same cavity depth

3. Comparison between different cavity depths within the same marginal configuration:

Using 90^{O} shoulder margin, subgroup (S), 4mm cavity depth, group (4D), recorded higher mean value (24.48±8.18). Independent t test revealed that the difference was extremely statistically significant ($p<0.0001$) than 2mm cavity depth, group (2D).

Using Butt-joint margin configuration (subgroup (B)), 4mm cavity depth, group (4D), recorded higher mean value (26.48±6.67). Independent t test revealed that the difference was statistically non-significant ($p=0.145$) than 2mm cavity depth, group (2D).

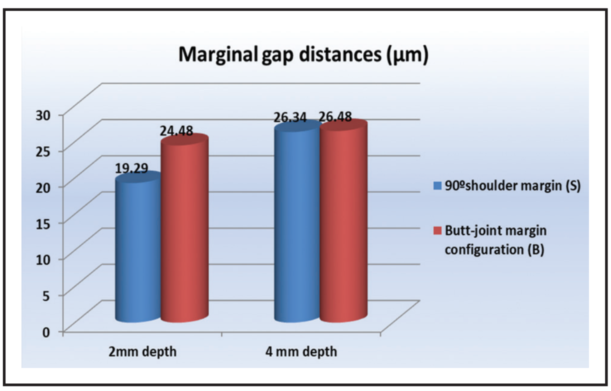

Figure (4): Column chart showing mean value of marginal gap distances in different cavity depths within each margin configuration

DISCUSSION

During the last decade, evolution of adhesive systems has changed the treatment decisions of mutilated teeth toward more conservative modalities as Adhesion ensures sufficient material retention without the need of aggressive macro-retentive techniques, thus more tooth structure can be conserved [(15)]. Conservative preparation with minimal tissue destruction is now the gold parameter for restoring mutilated teeth [(16)]. Owing to this rationale, endocrowns were introduced as a prosthetic technique in rehabilitation of endodontically treated incisors, [(17)] premolars [(18)] and molars [(19,20)]. The intra radicular extension that fits into the pulpal walls improves the bonding surface of restorations inside the root and provides macro-mechanical retention for the restoration[(21, 22)].

As the prognosis of fixed restorations is directly related to their marginal adaptation; the current study was designed to investigate the marginal adaptation of e.max press endocrown restorations with various margin configurations and intracoronal cavity depths after being cemented with adhesive resin cement.

The preparation of teeth was designed with two different intra pulpal cavity depths (2mm and 4mm) and two different marginal preparation (butt joint and 90^{o} shoulder). For standardization of teeth preparations, a special milling machine (Centroid milling machine), was used for all endocrowns' preparations.

Lithium disilicate based ceramic (e.max press) was selected for fabricating the endocrown restorations since it is a glass ceramic that can be etched and silanated for adhesive bonding using resin cement. Strong and durable resin bonds can be achieved by etching of the ceramic bonding surface with hydrofluoric (HF) acid- etching thus improving micro-retention, then for chemical bonding a silane coupling agent can be applied [(23,24)]. Moreover, lithium disilicate glass provides excellent fit, form and function combined with high strength value of 500 MPa [25]. In a study that retrospectively evaluated documented cases of ceramic and composite posterior endocrowns; it was reported that lithium-disilicate glass-ceramic is a reliable material for endocrown realization [26].

For standardization of e. max press restorations, the wax patterns of endocrowns were designed and fabricated using CAD/CAM Roland machine. For occlusal anatomy similarity between all endocrowns the biogeneric reference design option was used which ensured that all restorations have the same exact design [12].

The marginal accuracy of the ceramic material replacing lost dental structure is highly related to the long term success of the prosthesis which has a great value for the scientific evidence of clinical situations. [27, 28] In this study the marginal adaptation was the main parameter tested. It had been extensively studied in the literature, since it is very critical for the quality and success of the prostheses.

In this study e.max lithium disilicate endocrowns were constructed by Press technique. Based on a study that compared vertical marginal gap of e.max lithium disilicate-based restoration constructed using either Press or CAD/CAM techniques; it was concluded that e.max lithium disilicate restorations constructed by Press technique have relatively smaller marginal gaps when compared with those constructed by CAD techniques [29]. A discrepancy of the size of the cutting tools, with respect to tooth preparation geometry may cause maladaptation with subsequent inferior marginal fit of the computer milled ceramic restoration [30, 31].

Results of marginal gap obtained in the present study revealed that 4mm cavity depth (group 4D) recorded significantly higher mean gap values than 2mm cavity depth (group 2D) regardless the marginal preparation design (butt joint or shoulder finish line), Therefore, the first null hypothesis that there would be no difference in marginal adaptation with variation in cavity depth was rejected. Intra-coronal cavity depth affected the marginal adaptation significantly.

These results agree with a study [11] that reported that an endocrown with a 4-mm inraradicular cavity depth has a larger marginal gap than an endocrown with a 2-mm inraradicular cavity depth.

In addition to another study [12] that stated that increasing the intraradicular extension of endocrown restorations increases the marginal and internal gap of endocrown restorations.

Due to technical limitations associated with optical impressions, previous study[32] stated that CAD-CAM constructed endocrowns with deep cavities are associated with larger marginal gaps between the restoration and the cavity compared with endocrowns with shallower endo-cores. The same assumption can be applied to CAD/CAM fabricated wax patterns which could have been subjected to the same limitation, yielding larger gaps with deeper preparations.

In addition, minimal marginal gaps associated with shallow depth can be attributed to the proper seating of the endocrown compared to deeper cavities thus minimizing the vertical marginal gaps[33].

Moreover, results also revealed that for the marginal gaps within the same cavity depth (groups 2D and 4D); butt joint configuration recorded higher mean marginal gap values than shoulder finish line. The difference between the two subgroups was extremely statistically significant within group (2D), and statistically insignificant within group (4D). The second null hypothesis assuming that the margin configuration would has no effect on the marginal adaptation of endocrowns was therefore rejected. The margin configuration affected the marginal adaptation significantly.

This may be secondary to a limitation of the technique used in fabrication of the endocrown by press technique. Pressing e.max press recorded the rounded surface of the shoulder finish line better than the butt margins according to a study [13] that used the same fabrication technique (press) comparing the marginal adaptation of lithium disilicate crowns and endocrowns and reported that mesial and distal surfaces in endocrown group have shown the lowest mean marginal gap (22.08µm ± 4.43, 21.54µm ± 3.16, respectively) and attributed that to the rounded shoulder finish line in the proximal surfaces in the endocrown group which resulted in less marginal gaps.

These findings can also be related to the greater surface area available for bonding in endocrowns with 1 mm shoulder finish line as it promotes the presence of four axial walls instead of two in the butt joint preparations improving the marginal adaptation [34].

However, these findings were opposed by another study [35] which stated that by using the adhesive technique; preparing a shoulder finish line might cause loss of so much tooth structure and results in decreased bonding quality, because bonding to enamel is favorable than bonding to dentin. This opposing finding might be related to the difference in the methodology between the two studies, where the used samples on this study were premolar teeth rather than molars used in present study.

CONCLUSIONS

Within the limitations of this study, the following conclusions can be drawn:

1. All obtained marginal adaptation values lie within the clinically accepted ranges.
2. Increasing intra-coronal cavity depth of endocrown preparation negatively affects marginal adaptation of lithium disilicate based endocrowns.
3. Endocrown with shoulder finish line marginal configuration has superior marginal adaptation than those with butt joint marginal configuration.

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