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IMPACT OF THERMOCYCLING ON MARGINAL ADAPTATION AND FRACTURE STRENGTH OF TWO TYPES OF ALL CERAMICS ANTERIOR ENDOCROWNS

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ABSTRACT

Aim: The goal of this study is to evaluate the impact of thermocycling on fracture strength and marginal adaptation of anterior endocrowns fabricated from two different types of lithium disilicate.

Material and Method: Twenty-four freshly extracted human maxillary upper central incisors were selected from the outpatients' clinic of the surgery department, Faculty of Dentistry, Minya University. The teeth were divided into two groups: Tessera and Emax CAD. The teeth were prepared for endo-crown restoration, and the endo-crowns were fabricated using CAD/CAM technology. A thermal cycling simulation device was utilized to subject all the study samples to 5000 cycles,cold water bath immersion for 30 seconds at 5 degrees the hot water bath immersion for 30 seconds at 55 degree dewll time 10 seconds to simulate temperature fluctuations in oral cavity. Marginal gaps were measured pre- and post-cementation using a stereomicroscope at various points. Fracture resistance was evaluated by subjecting the specimens to compressive loading until failure. Statistical analysis was performed to compare the marginal gaps and fracture resistance between the two groups.

Results: Both before and after cementation, the Tessera and Emax CAD groups' total marginal gaps did not differ significantly, according to the data. However, A considerable difference in fracture resistance was found., whereas Emax CAD exhibited more resistance in contrast to Tessera. The improved mechanical characteristics, chemical makeup, and microstructure of Emax CAD are responsible for its increased resistance to fracture.

Conclusion: Both Tessera and Emax CAD materials are effective for anterior endocrown restorations in terms of marginal adaptation. However, Emax CAD is superior in fracture resistance, making it the preferred choice for applications requiring enhanced mechanical durability. These findings highlight the importance of material selection based on specific clinical needs, ensuring optimal long-term outcomes.

KEYWORDS: Thermocycling, Marginal Adaptation, Fracture strength, Endocrowns, feldspathic ceramics, lithium disilicate, restorative dental materials.

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INTRODUCTION

Dentists need to be aware of how well restorative materials can mimic dental tissue. It is now crucial to meet the growing demand for minimally invasive operations and aesthetic enhancements. In the past, endodontic therapy was necessary to restore a badly decayed tooth. This was followed by the building of a post and core for support, the preparation and placing of a crown, and finally the fabrication of a monoblock [1]

Lithium disilicate and feldspathic ceramics are common examples of indirect materials. Because of its superior aesthetics, tissue compatibility, color stability, and strong translucency, feldspathic ceramics are preferred. Both materials have a wide color spectrum, can replicate tooth fluorescence and translucency, and retain color brightness and stability. [2]

The conventional post-and-crown approach is being challenged by minimally invasive dentistry thanks to advancements in adhesive technology. Pissis's 1995 introduction of the monoblock approach served as the basis for the concept of endocrown, which Bindl and Mormann expanded upon in 1999. The term "endocrown" was used to describe a ceramic repair that was fixed within the pulp chamber and used adhesive, utilizing the walls for micromechanical retention. [3]

Three key elements determine the quality and success of a restoration: marginal adaptation, fracture resistance, and aesthetics. Inadequate marginal adaptation can result in endodontic irritation, microleakage, caries, and plaque buildup, all of which can contribute to restorative failure. The marginal gap, or the gap between the restoration's fitting surface and the preparation's end point, is used to measure marginal adaptation. Microscopy, micro-computed tomography, silicone replicas, and laser videography are some of the techniques used to assess this; of these, direct microscopic examination is the most often used because it is reproducible and non-destructive. [4]

Lithium disilicate ceramics are more aesthetically pleasing and useful than feldspathic ceramics. They also have better fracture resistance, which prolongs their clinical life. Tessera and Emax CAD are two of the varieties that are offered. [5]

Therefore, the purpose of this study is to assess and compare the fracture resistance and marginal gap of anterior endocrowns fabricated from two different types of lithium disilicate (Tessera & Emax cad).

MATERIALS AND METHODS

Sample Size Calculation

Based on earlier research, the sample size for this study was established by Nassar (2022). This research indicated that a minimum of 8 subjects per group was necessary, assuming a normal distribution of responses within each group with a standard deviation of 4.15. The estimated mean difference was 6.28, with a power of 80% and a type I error rate of 0.05. To ensure an adequate number of samples in each study group, the sample size was increased to 12 subjects per group.

Ethical approval

The research protocol was authorized by the Minia University Faculty of Dentistry's Research Ethics Committee.

Samples preparation

We employed twenty-four recently extracted upper central incisors from humans that were devoid of coronal abnormalities, cavities, and cracks. When teeth were extracted due to periodontal issues, there was only a ±5% variation in the teeth's measurements. The blood and soft tissue clinging to the tooth structure were washed away under flowing water. An ultrasonic scaler device (Guilin Woodpecker Medical Instrument Co.Ltd. China was employed to clean the teeth of debris. The teeth were then kept until they were needed in room temperature distilled water.

Using dental scalers (woopecker, china), nylon bristle brushes, and pumice paste (PreppiesTM, USA) with a low speed hand piece to remove any remaining soft tissue materials, each tooth was carefully cleaned of calculus and soft tissues. After that, the teeth were left to be disinfected for fifteen minutes at room temperature in 5% sodium hypochlorite solution. Every tooth was cleaned using an ultrasonic cleaner (CODYSON CD-4830, MISR SINAI) and then kept at room temperature in distilled water (Caelo, Hilden, Germany) until needed.

To support the endocrown preparation and testing operations, the teeth were mounted in acrylic resin blocks using a specially designed cylindrical mold for specimen fixation. to guarantee appropriate visibility for the margin of the restoration during both construction and final testing, teeth were implanted up to 2 mm beneath the cementoenamel junction (CEJ) after filling a custom mold with self-cure acrylic resin (Acrostone, Egypt).

Endodontic Procedure

In order to evaluate the intracanal structure of the teeth, radiographic exams and measurements of their lengths were performed. Using the same technique and tools, the same operator treated all specimens with endodontic therapy. Using a large round diamond abrasive bur (endo-access, No. 856; Intensiv SA, Switzerland) with a high-speed handpiece, a minimal access cavity was created in each tooth. The pulp was removed, and endodontic instrumentation was performed. This involved using a combination of rotary Ni-Ti files (Protaper Universal 21mm, Dentsply Sirona, Switzerland) for precise cleaning and shaping of the canals with the crown-down technique until size F2. Edetate cream (MD Chelcram, Meta BioMed, Korea) was used for root canal negotiation, along with manual stainless-steel H and K-files sizes 8, 10, and 15 (Dentsply Maillefer, Ballaigues, Switzerland).

In between each instrument, there was extensive irrigation for canals with 5.25% sodium hypochlorite and recapitulation. Root canals were filled using gutta-percha (Aurum Pro, Meta Biomed, Korea) size F2 and a resin-based sealer (Ad Seal, Meta Biomed, Korea) with the cold lateral compaction technique. Excess gutta-percha was then taken out from the tooth pulp chamber up to 1 mm apical to the orifice in each canal using a round diamond bur (801,012; Intensiv SA, Switzerland). This procedure was carried out following the canals were thoroughly flushed and dried with sterile paper points.

Preparation design of Endocrown

To guarantee consistency in the procedure, the teeth were prepared using a C.N.C. (Computer Numerical Control) milling machine (Premiumimes. icore. Germany).In order to prevent cracking, The teeth's crown sections were cut horizontally. 2 mm above the CEJ using an extremely coarse diamond disc (Microdent, Monsey, New York, USA) and lots of water. The ferrule was designed to extend 2 mm from the cavosurface margin inside the pulp, and the margins were designed at the CEJ with a 1 mm deep chamfer finish line. Additionally, CNC prepared the pulp chamber as follows: The pulp chamber's internal taper was 8 degrees from the walls' divergence, and its oval shape was homogeneous, with tooth outlines at 2 mm in width mesiodistally and labiolingually. The interior line angles were rounded and smoothed with finishing stone. The same operator completed all specimen preparations, and a caliper was used to verify the vertical wall thickness of 2 mm (± 0.2 mm) and cavity depth of 2 mm (± 0.2 mm). Finally, the samples were examined using 3D CAD/CAM technology to evaluate the axial taper, wall thickness, and prescribed cavity depth. This was done with PrepCheck, (Version 4.5 software from Sirona Dental Systems GmbH, Bensheim, Germany).Every sample with a disparity greater than 0.2 mm was eliminated.

Endocrowns fabrication:

Next, using the CEREC CAD/CAM technology (DENTSPLY Sirona, Germany), Endocrowns are designed and fabricated after teeth were scanned. All manufactured restorations were examined for correctness after milling, and any that weren't perfect were thrown away (Figure 1).

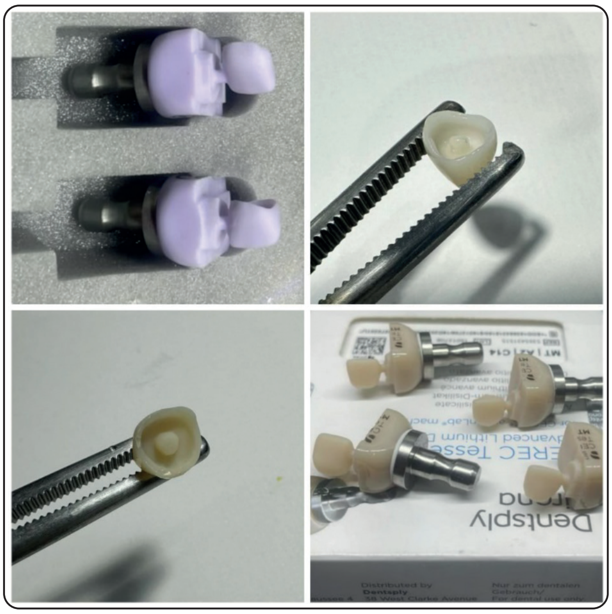

Fig. (1) Restorations were examined for correctness after milling.

Bonding of Endocrowns:

All endocrowns were submerged in diluted water in a digital ultrasonic cleaner (MCS, Egypt) for ten minutes before bonding. The prepared tooth surfaces were cleaned for 15 seconds using a low-speed handpiece polishing brush and fluoride-free pumice paste (Preppies™ , USA), then thoroughly rinsed for another 15 seconds with distilled water. The endocrown fitting surfaces were etched for 20 seconds with 9.5% hydrofluoric acid (Porcelain Etchant, Bisco, USA), dried with compressed air free of oil after being washed with distelled water. The fitting was coated with a thin layer of silane coupling agent (Porcelain Primer, Bisco, USA). for 60 seconds and allowed to air dry.

The prepared tooth surfaces were etched with 37% phosphoric acid gel (Meta Etchant, Meta BioMed, Korea) for 30 seconds, thoroughly rinsed, and air dried. They were then coated with All-Bond Universal (BISCO Inc., USA), a light-cure adhesive bonding agent, applied with a microbrush and left to sit for 30 seconds, followed by air thinning and light curing for 20 seconds with a curing light (Illed Woodpecker, China). Dual-cure adhesive resin cement (BisCem®, Bisco Inc., USA) was applied to the fitting surfaces of the endocrowns, which were then seated on the corresponding prepared teeth using static finger pressure. After five minutes, a five-kilogram axial force was applied using custom loading equipment. Initial light curing lasted for two seconds, followed by thorough removal of excess resin with a scaler and 40 seconds of full light curing on each surface. Specimens were stored in distilled water at room temperature for 24 hours before thermal aging .

Thermal aging:

A thermal cycling simulation device (SD Mechatronic Thermocycler, Germany) was used to subject all study samples to 5000 cycles. The process involved immersing the samples in a cold water bath at 5 degrees Celsius for 30 seconds, followed by immersion in a hot water bath at 55 degrees Celsius for 30 seconds, with a dwell time of 10 seconds between immersions to mimic variations in temperature in the oral cavity (Figure 2).

Fig. (2) A thermal cycling simulation device

Marginal Gap Measurements

After cementation, and after marking each specimen's surface equidistantly, the vertical marginal gap was measured under a stereo microscope (SEM) before and after bonding (figure 3):

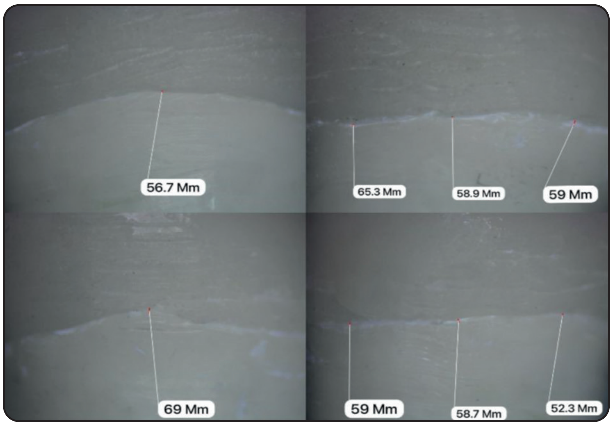

Fig. (3) Anterior endocrown marginal gap measurements.

Fracture Resistance Testing

Each sample was placed individually in the lower compartment of a computer-controlled material testing machine (Instron Model 3345, USA). A fracture test was conducted using a metallic rod in compressive mode. The load was applied occlusally with a specially designed attachment, fabricated for mounting teeth at an inclination of 130 degrees, to perform the fracture resistance test (Figure 4) .

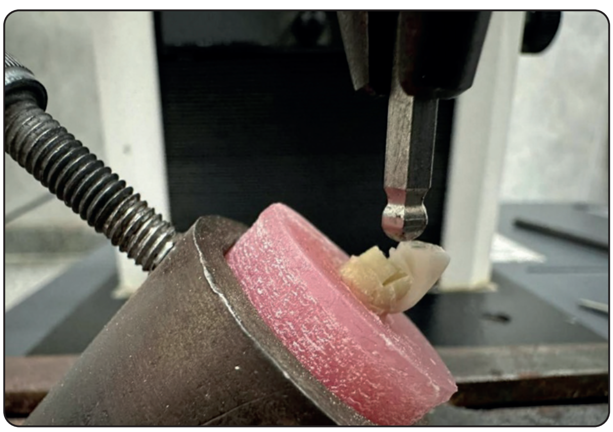

Fig. (4) A fracture test was conducted using a metallic rod in compressive mode.

Statistical analysis

Data was analyzed using IBM SPSS software version 24.0. Quantitative data were summarized using mean and standard deviation for normally distributed data. Comparisons between two independent groups were made using the independent t-test. Significance tests were reported as two-tailed probabilities, and results were considered significant at the 5% level.

RESULTS

The results indicated no significant difference in total marginal gaps between the Tessera and Emax CAD groups (0.089 N.S., 0.43 N.S.) both pre- and post-thermocycling. However, a significant difference in fracture resistance was observed (0.021 N.S.), with Emax CAD demonstrating higher resistance compared to Tessera. The enhanced fracture resistance of Emax CAD can be attributed to its superior mechanical properties, chemical composition, and microstructure.

TABLE (1) Effect of thermocycling on two studied groups regarding marginal gap before and after bonding (Figure 5).

	Group I E. max anterior Endocrowns (2mm depth)	**Group II Tessera anterior Endocrowns (2mm depth)**	**T Test P1 value**
Marginal gap before bonding			
Range	52.29-62.65	50.78-74.38	1.79
Mean	57.72	62.26	0.089
SD	4.24	8.65	N.S.
Marginal gap after bonding			
Range	63.55-76.43	59.86-82.75	0.64
Mean	71.64	70.12	0.43
SD	4.75	8.35	N.S.
T Test	2.93	1.98	
P2 value	0.003*	0.049*	

t-test = student t-test
P1 comparison between the two groups at the same period by using unpaired t-test
P2 comparison between before and after management in the same group by using paired t-test
P was significant if ≤ 0.05 N.S. Not Significant
**** Significant difference***

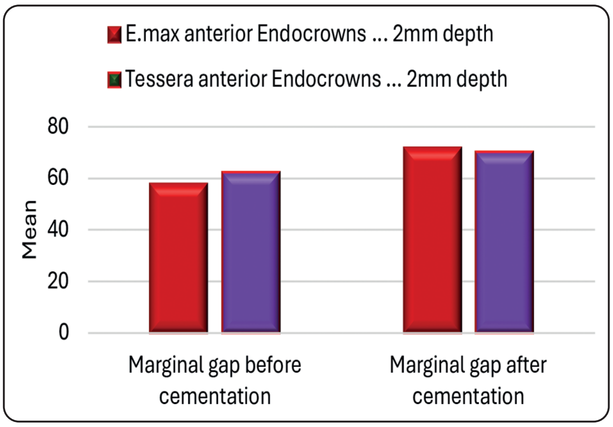

Fig. (5) Effect of thermocycling on two studied groups regarding marginal gap before and after bonding.

TABLE (2) Effect of thermocycling on two studied groups regarding fracture resistance test (Figure 6).

Fracture resistance test	Group I E. max anterior Endocrowns (2mm depth)	Group II Tessera anterior Endocrowns (2mm depth)
Range	665.9-844.1	500.6-837.9
Mean	762.6	623.6
SD	69.6	114.6
t-test	2.41	
p value	0.021*	

P was significant if ≤ 0.05 ***N.S. Not Significant***
**** Significant difference***

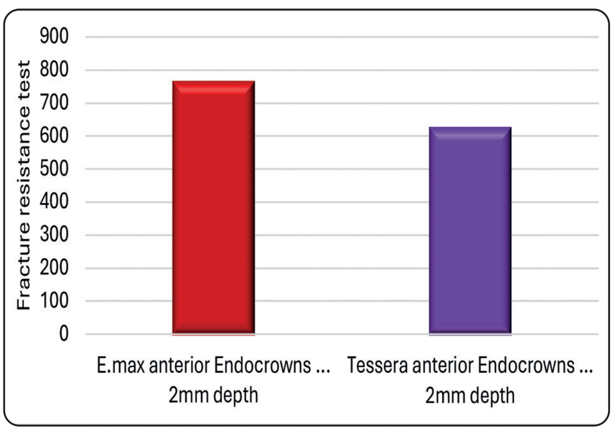

Fig. (6) Effect of thermocycling on two studied groups regarding fracture resistance test

DISCUSSION

In Restoring severely damaged teeth is a serious difficulty in dentistry. Traumatic incidents or significant deterioration might cause damage. Endodontic treatment is sometimes required in these circumstances, entailing the removal of a significant portion of the tooth structure. The mechanical characteristics and lifetime of the treated teeth may be significantly impacted by this loss in addition to microstructure alterations in the dentine, making the process of placing a prosthetic restoration difficult. [1,2].

Modern fiber-reinforced posts and metal dowels, two examples of traditional restoration techniques, have distinct disadvantages. Among these is the requirement to remove extra dental structure from the walls of the root canal, which mechanically weakens the tooth. Furthermore, different bonding surfaces may become infiltration sites, and variations in the elasticity modulus of dental materials against natural tooth structure may result in an uneven distribution of stress. [3,4,5,6].

For the conservative restoration of teeth that have received extensive endodontic therapy, endocrown has become more popular. These monolithic restorations do not extend into the pulp chamber; instead, they are fixed in it at the emergence of the root canal. Endocrowns come with a number of time-saving advantages, including less extraction of dental tissue and less clinical and technical procedures. Because of the way that endocrowns are made and how they interact with the surrounding dental structures, when they are cemented, they disperse occlusal stresses precisely like real teeth do. [8,9].

Various materials have been used for endocrowns, including lithium disilicate glass-ceramic, zirconia, zirconia-reinforced lithium silicate glass-ceramic, and resin composites [10,11 ,12]. The choice of material significantly influences the mechanical properties and performance of endocrowns(4). Lithium disilicate glass-ceramic is favored for its mechanical strength, bonding ability, and aesthetic results. Studies have shown that it has superior fracture resistance compared to other materials, especially under lateral loading [10,11,13].

The success of endocrowns depends on both the material used and the restoration's design. The depth of the endocrown within the pulp chamber can affect its marginal integrity and fracture resistance [18].

Thermocycling is planned to mimic the thermal stress to which the restorative materials and the teeth would be subject to by consuming drinks and food to get years of aging for the specimens in a short period of time

Evaluating dental restorations often focuses on the vertical marginal gap, as it impacts the integrity of the seal between the restoration and the tooth structure.. A smaller gap reduces the risk of bacterial infiltration and secondary caries, thereby extending the restoration's lifespan. For endocrowns made from advanced lithium disilicate materials, achieving an accurate marginal fit depends on both the material properties and the fabrication technique. Fracture resistance is also crucial, particularly for anterior teeth that endure significant functional and parafunctional forces [19,20].

Therefore, this study evaluated the marginal gap and fracture resistance of anterior endocrowns after thermocycling crafted from two types of lithium disilicate materials: Tessera and Emax CAD. Recently extracted human teeth were utilized to replicate clinical conditions, including enamel and dentin bonding, strength, pulp chamber contours, and the elastic modulus of hard dental tissues. Teeth with caries, cracks, or prior restorations were excluded from the study.

The current study utilized recently extracted human teeth to mimic the clinical conditions related to enamel and dentin bonding, strength, pulp chamber contours, and the elastic modulus of hard dental tissue in order to replicate the distribution of forces on the root part of the tooth structure. Any teeth with caries, cracks, or prior restorations were excluded. This came in accordance with the study of **Elsharkawy A. 2021**[21].

To fix the specimens, a custom cylindrical mold filled with self-cure acrylic resin was used to embed the teeth in acrylic resin blocks. This method supported the endocrown preparation and testing processes, in line with techniques described in earlier research[6].

After endodontic treatment, crowns were prepared using a CNC machine to ensure standardized axial wall thickness and cavity depth. CAD/CAM technology was employed to standardize the restoration thickness and geometry and to determine the area of load application during testing [22,23].

All specimens underwent the endodontic procedure then, Crowns were prepared using a CNC machine to ensure a standardized axial wall thickness of 2 mm (± 0.2 mm) and a cavity depth of 2 mm (± 0.2 mm) following the recommendation of **Hayes et al.** [22] ,The authors noted that endocrowns with deep pulpal extensions were more prone to irreparable fractures.

The study opted for CAD/CAM technology to standardize the restoration thickness, geometry, in order to determine the area of load application during testing. This was following the study of **El-Damanhoury HM et al., 2015**[23] .

To achieve optimal adhesion and longevity, endocrowns were soaked in distilled water using a digital ultrasonic cleaner. The teeth were cleaned using pumice paste, followed by rinsing, and drying. The endocrown fitting surfaces were etched with hydrofluoric acid, a silane coupling agent was applied, and teeth surfaces were treated with phosphoric acid. Dual-cure adhesive resin cement was used for cementation, with initial light curing to remove excess resin and final light curing to ensure complete polymerization, this was done following **Albelasy, E. et al., 2021** adhesive cementation procedures in their study and in accordance to **Makaronidis'** systematic review [24,25]

Regarding the cementation, we used dual-cure adhesive resin cement on the fitting surface of each endocrowns restoration this came in accordance with **Ikemoto, S. et al., 2024** [26]. The restoration was placed on the prepared tooth with static finger pressure, then subjected to axial loading with a specialized device that applied 5 kg of force for 5 minutes as **Yeslam, H. E., et al., 2023** and **Akila, V. 2019** studies [27,28] . An initial light curing of 2 seconds was done to aid in the removal of excess resin, which was essential in preventing marginal discrepancies. Final light curing was then performed on each surface for 30 seconds to ensure complete polymerization as **Patel, A. A. 2020** study [29].

The null hypothesis of our study posited that there would be no significant difference in marginal gap and fracture resistance after thermocycling between Tessera and Emax CAD endocrowns. This hypothesis was partially rejected, as a significant difference in fracture resistance was observed between the two groups, while no significant difference was found in the marginal gap values.

This study evaluated the changes caused by thermocycling ,the study revealed no significant differences in total marginal gap between the two groups pre- and post-cementation (p =0.089 and 0.43 respectively) table (2,3) The marginal discrepancy values were found within clinically accepted borders in each group as it was significant in the Emax endocrowns group before and after cementation where (p=0.003) (table 2,3) and also significant in the Tessera endocrowns group before and after cementation where (p=0.049) (table 5,6). Nonetheless, a notable contrast was noted in fracture resistance between the two groups, where the Emax cad endocrowns group revealed statistically higher fracture resistance than Tessera endocrowns group (p =0.021). The variance in mechanical properties, chemical composition, and microstructure between the two materials could account for this outcome. The E max CAD material boasts impressive mechanical characteristics, such as a high flexural strength of 360MPa and a high fracture toughness of 2.25MPa m1/2. This could also be attributed to the excellent adhesive properties and strong resistance to dislodgment, which can be further explained by its acid-etching process [30].

In order to substantiate and authenticate the outcomes of this investigation, it is crucial to cite prior research that has produced similar findings and conclusions pertaining to the marginal gap and fracture resistance of anterior endocrowns. Additionally, to provide an unbiased viewpoint, it is equally important to consider studies that have yielded contradictory results and conclusions.

Our findings came in accordance Salem et al., 2024 conducted a comparison of marginal adaptation between lithium disilicate (Emax) and hybrid nano-ceramic (Grandio) CAD/CAM endocrowns [19]. The results indicated that in terms of marginal adaptation, retention, and fracture, all restorations in both groups received Alpha scores at baseline, as well as after 12, 24, and 36 months.

Additionally, **Sağlam et al., 2020** assessed the marginal fit and fracture strength of feldspathic and Polymer-Infiltrated Ceramic Network (PICN) CAD/CAM endocrowns for maxillary premolars. They found that while both types of CAD/CAM-fabricated endocrowns exhibited adequate marginal adaptation, the PICN endocrowns showed greater fracture resistance compared to the feldspathic ceramic endocrowns [31]. Moreover, **ElHamid et al., 2023** who Assess the fracture resistance and marginal adaptation of endocrowns using two distinct heat-press ceramic materials. It was found that for marginal adaptation assessment, both materials showed no significant difference, and their values fell within the clinically acceptable range [32].

Fracture strength test results of the present study showed that Emax cad anterior endocrowns had a higher mean fracture strength than Tessera endocrowns group. This came in agreement with **Sherif and El-Dwakhly, 2012** who assessed fatigue resistance of three unit CAD/CAM restorations. Teeth reinforced with restorations possessing an elastic modulus like dentin, such as Empress-CAD, showed improved stress distribution throughout the restorative complex, resulting in a more restorable mode of failure [(33)].

Furthermore, Ali and Moukarab, 2020 investigated how deep marginal elevation affects the marginal adaptation and fracture resistance of endodontically treated teeth restored with endocrowns made from two different CAD/CAM ceramics in an in-vitro setting. Their findings revealed that IPS Emax CAD demonstrated better fracture resistance than Vita Enamic [(34)].

Additionally, **Dejak & Młotkowski, A.2018** evaluated the durability of anterior teeth repaired with ceramic endocrowns in contrast to individually crafted post and core. Endocrowns made from lithium disilicate ceramic demonstrated high resistance to fracture[(35).]

On the contrary, **al-Fadhli et al.**, **2021** reported to significant difference between IPS Emax press and Celtra Press anterior endocrown [(36).] Additionally, **Abd El HALIEM et al., 2021** compared the endocrowns that were fabricated using IPS Emax press and CERASMART hybrid ceramics. Findings revealed that CERASMART anterior endocrowns demonstrated a promising treatment option when compared to IPS Emax press anterior endocrowns [(37).]

CONCLUSION

In conclusion, this study demonstrates the changes caused by thermocycling on both Tessera and Emax CAD lithium disilicate materials which are viable options for anterior endocrowns in terms of marginal adaptation. However, Emax CAD significantly outperforms Tessera in terms of fracture resistance, making it a preferable choice in scenarios where mechanical durability is critical. The lack of significant differences after thermocycling in marginal gaps post-cementation suggests that both materials can achieve similar levels of fit and finish. The impact of thermocycling lead to enhanced fracture resistance of Emax CAD can be attributed to its superior mechanical properties and microstructure, which are critical considerations for long-term clinical success.

RECOMMENDATIONS

Based on the findings of this study, the following recommendations are proposed:

- For anterior endocrowns where mechanical strength and durability are paramount, Emax CAD should be preferred over Tessera due to its superior fracture resistance.
- Dental practitioners should consider the specific mechanical and chemical properties of restorative materials when planning treatments involving endocrowns, particularly in load-bearing areas.
- Additional studies should be conducted to explore the long-term clinical performance of these materials in a larger population and across different clinical settings.

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