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ASSESSMENT OF VERTICAL MARGINAL GAP AND FRACTURE RESISTANCE OF TESSERA ANTERIOR ENDOCROWN WITH TWO DIFFERENT EXTENSIONS

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ABSTRACT

Aim: measure vertical marginal gap using CEREC TESSERA advanced lithium disilicate.

Materials and Methods: In this study, twenty-four natural central incisors were used to create Endocrowns, divided into two groups based on their preparation design. Group 1 involved a 1mm deep Chamfer finish line and a 2mm ferrule, extending 2mm inside the pulp from the cavosurface margin. Group 2 featured a similar Chamfer finish line depth but with a 2mm ferrule extending 4mm inside the pulp from the cavosurface margin. Each group was then subdivided into two subgroups for specific tests. Subgroup 1 aimed to measure vertical marginal gap using CEREC TESSERA advanced lithium disilicate. Subgroup 2 focused on conducting a fracture resistance test using the same material. Measurements of the vertical marginal gap were taken both before and after cementation, and all samples were subjected to thermocycling during the experimental process.

Results: There was an insignificant difference before and after cementation) in total vertical marginal gap between the two studied groups design (1) 2mm extension and design (2) 4 mm extension.There was insignificant difference in verticle Margin gap after cementation in the two studied groups design 1 (2mm extension) and design 2 (4mm extension).

Conclusion: Tessera anterior endocrowns with both 2mm and 4mm pulp chamber extensions achieve similar vertical marginal gaps before and after cementation, indicating reliable marginal integrity for both designs. The 4mm pulp chamber extension the preferable option for improving the longevity and durability of the restoration in clinical practice enhances fracture resistance.

KEYWORDS: Endocrown, Vertical marginal gap, CEREC TESSERA, Fracture resistance.

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INTRODUCTION

Several methods exist for restoring endodontically treated teeth (ETT), such as using fixed partial dentures and various restorative materials. The most common approach involves a post-retained foundation restoration and a crown, mainly to increase the retention of the core foundation. However, intracanal retention can weaken the tooth structure and raise the risk of root fractures. Additionally, the invasive nature of this method often precludes further interventions in case of failure.

The success of a dental restoration hinges on three main factors: esthetic value, fracture resistance, and marginal adaptation. Poor marginal fit can lead to cement dissolution, plaque accumulation, and an increased risk of caries and periodontal diseases. The accuracy of the final impression, master cast fabrication, and prosthesis fabrication are crucial for proper marginal adaptation. Researchers have compared the accuracy of conventional physical impressions and optical impressions to ensure a well- fitting restoration.

Beyond evaluating the material's inherent properties, it is vital to assess its structural integrity within a tooth-restoration complex, which can be done through mechanical stress tests such as monotonic and cyclic tests. In vitro testing of restorative systems often faces challenges related to the choice of dental substrate, with natural teeth being preferred but limited due to availability and variability.

Compared to stainless steel crowns, endocrown restorations require minimal tooth reduction, eliminate the need for post and core restorations, and offer high strength for cuspal overlays. They also preserve tooth structure and maintain periodontal health due to their supragingival margins.

This study aims to evaluate and compare the vertical marginal gap and fracture resistance of anterior endocrowns with two different extensions using TESSERA advanced lithium disilicate.

The null hypothesis of this study was that there will be no significant difference in the marginal gap and the fracture resistance with the different extensions. However, it was partially rejected as there was a significant difference among the fracture resistance values between the 2 groups, where it was higher in the 4mm pulp extension. However, there was an insignificant difference between the marginal gap within the 2 groups.

MATERIALS AND METHODS

The sample size for this study was determined based on a prior study by Nassar (2022). In that study, a minimum sample size of 8 per group was considered acceptable, assuming a normal distribution of responses within each group with a standard deviation of 4.15. The estimated mean difference etween groups was 6.28, with a desired statistical power of 80% and a type I error probability of 0.05. To ensure an adequate number of samples in each study group, the sample size was increased to 12 per group.

In this study, twenty-four natural central incisors were used to create Endocrowns, divided into two groups based on their preparation design: Group 1 involved a 1mm deep Chamfer finish line and a 2mm ferrule, extending 2mm inside the pulp from the cavosurface margin. Group 2 featured a similar Chamfer finish line depth but with a 2mm ferrule extending 4mm inside the pulp from the cavosurface margin. Each group was then subdivided into two subgroups for specific tests: Subgroup * aimed to measure vertical marginal gap using CEREC TESSERA advanced lithium disilicate. Subgroup 2 focused on conducting a fracture resistance test using the same material.

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Preparation of teeth

Twenty-four maxillary central incisors, extracted and of similar dimensions, were sourced from the Oral and Maxillofacial Surgery clinic for this study. These teeth underwent thorough inspection to confirm their condition—ensuring they were free of caries, deposits, cracks, and fractures. Extracted teeth were vertically mounted in plastic cylinder measuring 2.4 cm in height and 2 cm in diameter, filled with auto-polymerizing acrylic resin the cylinder so that they were 1.0 mm apical to the cemento- enamel junction (CEJ), with their long axis parallel to that of the cylinder. The teeth were mounted using a surveyor **1** to ensure alignment along their long axis **(Sengun et al., 2008).** Triangular access cavities were prepared using round end burs with a diameter of 1mm, employing a high-speed handpiece. Endodontic reamers were utilized to remove dead pulp tissue. A rotary Ni-Ti system was employed, and 5% sodium hypochlorite was used for irrigation between files. EDTA cream was applied to eliminate the smear layer and ensure thorough root canal cleaning. Radiographs were taken to check their length as well as the apical plug of 2mm was checked by the tug-back clinical examination. Gutta-percha points and resin sealer was used for canal obturation by single cone technique.

Endocrown preparation:

To standardize the tooth preparation, a CNC (Computer Numerical Control) milling machine (CNC Premium, imes-icore, Germany) was employed. Cavity depth was maintained at 2 mm ± 0.2 mm. Samples underwent validation using 3D CAD/CAM software (PrepCheck1*) to confirm adherence to predetermined criteria for cavity depth, wall thickness, and axial taper. Samples deviating by more than 0.2 mm were excluded from the study. Two designs were used for endocrown preparation: First design:1mm deep chamfer finish line, and 2mm ferrule with depth extension 2 mm from cavosurface margin inside pulp. Second design: 1 mm deep chamfer finish line and 2 mm ferrule with depth extension 4 mm from cavosurface margin inside pulp. **(Figure 1)**

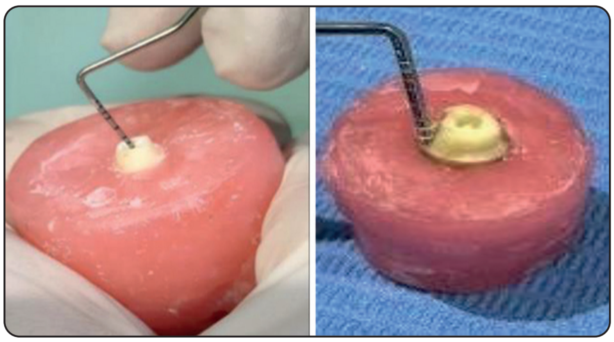

Fig. (1) Endocrown Preparation

Endocrown fabrication

Digital impressions scanning was done for the prepared teeth using inEos X5 dental lab scanner * which is based on the principle of optical triangulation with blue, structured light projection Each specimen is stabilized on the scanner's holder of inEos X5 scanner which can be rotated 360° and tilted 100° with high-precision axis control, for scanning all surfaces of the tooth surfaces. Designing of all teeth using InLab CAD/CAM software ** CAM software was carried out using a standard protocol. The internal gap was set to 50 µm, to accommodate the thickness of the luting agent, minimal radial thickness is 500 µm. Ceramic blocks were milled after completing the design phase. Cerec Tessera blocks were placed in the milling unit ***, and the design information was sent wirelessly. Finally, the

* (inEos X5; Sirona Dental Systems, Bensheim, Germany)
** inlab CAD/CAM software CAM software (inLab CAD SW 20.0; Sirona Dental Systems, Bensheim, Germany
**** Dental milling-device (inLab MC X5; Sirona Dental Systems, Bensheim, Germany

Fig. (2) Endocrown Fabrication

start milling icon was selected to begin the process. After milling all fabricated restorations were checked for accuracy and any defective restoration were discarded all endocrowns were checked and verified its seating, marginal accuracy and fitting, as shown in **Figure 2**

Bonding of endocrowns

To prepare for bonding restorations, for ten minutes, every endodontic repair was submerged in 99% isopropanol using a digital ultrasonic cleaner *. After 60 seconds of etching with 9.5% hydrofluoric acid, the fitting surface of the endocrowns was carefully cleaned with distilled water and dried with compressed air free of oil. Small layer of silane coupling agent ** was applied to the fitting surface for 60 seconds, and then allowed to air dry. The endocrowns were etched with 9.5% hydrofluoric acid *** for 20 seconds, then cemented using dual-cure adhesive resin cement. After applying the silane coupling agent and allowing it to dry for 60 seconds, the samples were ready for the cementation process. To prepare the teeth surfaces, 37% phosphoric acid **** etchant gel was applied for 30 seconds, followed by thorough rinsing and air-drying. A light-cure adhesive bonding agent ***** was applied with a micro-brush, left for 30 seconds, air-thinned, and then light-cured for 20 seconds using an I-led woodpecker light curing unit. Next, dual-cure adhesive resin cement ****** was applied to the fitting surface of each endocrown restoration. Using static finger pressure, the restorations were positioned on the correspondingly prepared teeth. A loading apparatus specifically made for the purpose was then used to apply axial loading of 5 kg for 5 minutes. After two seconds of initial light curing, extra resin was scraped off using a scaler. Final light curing was performed for 40 seconds on each surface. The specimens were then stored in distilled water at room temperature for 24 hours prior to thermal aging. **(Figure 3)**

Measuring vertical marginal gap after cementation

Following cementation, the vertical marginal gap will be measured under Stereo microscope ****** in 8 points (3 buccal, 3 palatal points, 1 mid-mesial and 1 mid distal), after making equidistant marks on each surface of each specimen.

* MCS,Egypt
** hydrofluoric acid (Porcelain etchant, Bisco, USA)
*** silane coupling agent (Porcelain primer, Bisco, USA)
**** phosphoric acid etchant gel (META etchant, Meta biomed, Korea)
***** bonding agent (All-Bond Universal. BISCO Inc, USA)
****** resin cement (BisCem®, Bisco Inc, USA)
******* Nikon SMZ745T Stereo microscope Nikon Japan

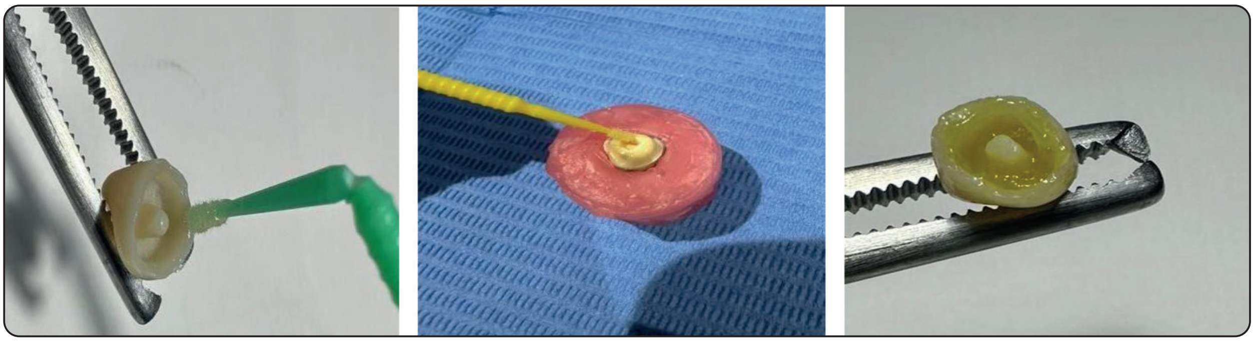

Fig. (3) Endocrown Bonding

Measuring fracture resistance

Each sample was individually placed in the lower compartment of an Instron* computer-controlled material testing machine. The fracture test was conducted in compressive mode, with the load applied palatally to the endocrowns using a metallic rod with a spherical tip (5 mm diameter) attached to the upper movable compartment of the testing machine, which moved at a crosshead speed of 1 mm/min. A tin foil sheet was placed between the rod and the sample to ensure homogeneous stress distribution and minimize the transmission of local force peaks. Data were calculated and recorded using computer software**.

Data collection, tabulation, and statistical Analysis

The obtained data was collected, tabulated, and statistically analyzed. Significance was calculated, and p-value was considered as significant.

RESULTS:

1- Statistical analysis

Data was fed to the computer using IBM *SPSS software package version 25.0*. The Shapiro–Wilk test was used to test the normality of data, the data in the study was parametric data, the Kolmogorov-Smirnov and Shapiro–Wilk had p value >0.05.

Quantitative data were described using mean and standard deviation for normally distributed data. The comparison between two independent data were done using independent t-test while for comparison between the same group at different period we used dependent t-test.

Significance test results are quoted as two-tailed probabilities. The significance of the obtained results was judged at the 5% level.

Results of vertical marginal gap

Comparison between total vertical Marginal gap before and after cementation between the two studied groups design (1) 2 mm extension and design (2) 4 mm extension. There was an insignificant difference before and after cementation) in total vertical marginal gap between the two studied groups design (1) 2mm extension and design (2) 4 mm extension.

The results showed There was insignificant difference in total vertical Margin gap before and after cementation of the two studied groups. design (1) 2 mm extension and design (2) 4 mm extension

Fracture resistance test results.

1. ***Comparison of fracture resistance test between 2 studied group design 1 (2mm extension) and design 2 (4mm extension)***

The results showed There was significant difference in fracture resistance of the group 2 (4mm pulp chamber extension)

* Testing machine (Instron model 3345 Universal testing machines, USA
** Computer software BlueHill universal Instron England.

Table (1) Range, Means and SD of total vertical Marginal gap before and after cementation between the two studied groups design (1) 2 mm extension and design (2) 4 mm extension.

Total Vertical marginal gap		Extension 2 mm Design (1)	Extension 4 mm Design (2)	P value
Vertical Marginal Gap of Tessera before cementation	Range Mean ± SD	(50.8-74.4) 62.3±8.7	(55.7-67.3) 62.1±4.2	0.488
Vertical Marginal Gap of Tessera after cementation	Range Mean ± SD	(59.9-82.8) 71.1±8.3	(65.2-78.2) 70.9±4.6	0.329
T Test P2 value		1.79 0.061 N.S.	2.11 0.06 N.S.	

P1 value: comparison between the two studied groups extension (2, 4 mm) before cementation. P2 value: comparison between the two studied groups extension (2, 4 mm) before and after cementation

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

TABLE (2) Range, Means and SD of fracture resistance test between 2 studied group design 1 (2mm extension) and design 2 (4mm extension)

		Extension 2 mm design (1)	Extension 4 mm design (2)
Fracture test	Range Mean±SD	(500.64-837.91) 623.6±114.6	(687.71-958.96) 789.3±90.7
T Test **P value**		2.96 0.010*	

P was significant if ≤ 0.05 **** Significant at level 0.05***

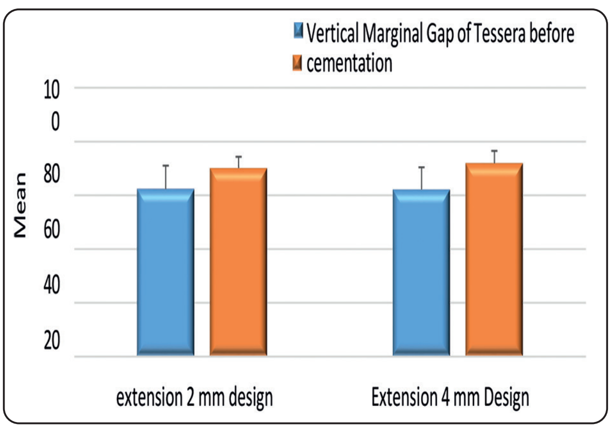

Fig. (1) Bar diagram showing Comparison between total vertical Margin gap before and after cementation in the two studied groups design (1) 2 mm extension and design (2) 4 mm extension.

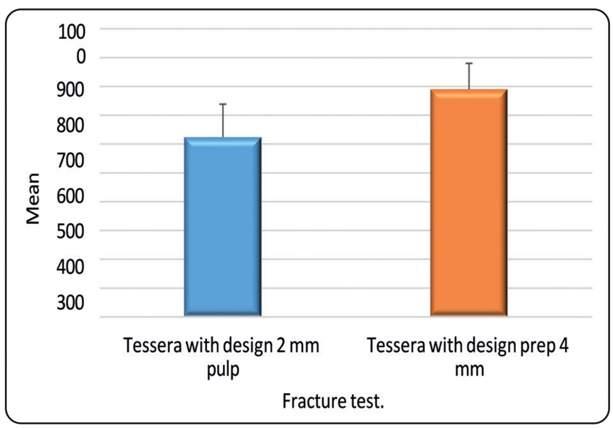

Fig. (2) Bar diagram showing comparison of fracture resistance test between 2 studied group design 1 (2mm extension) and design 2 (4mm extension)

DISCUSSION

New developments in dental materials have further enhanced the potential of endocrowns. TESSERA, an advanced lithium disilicate ceramic, offers high flexural strength, excellent aesthetics, and efficient processing, making it ideal for durable and visually appealing endocrowns. The material and restoration design play a crucial role in the effectiveness of endocrowns. Specifically, the degree of extension into the pulp chamber can impact both fracture resistance and marginal integrity. **(Mostafavi et al., 2022).**

A precise fit can only be achieved with TESSERA's high flexural strength and exceptional dimensional stability **(Lassle, 2015)**. Fit precision is further improved by its sophisticated processing capabilities, which include accurate milling with CAD/CAM systems. Not to mention, TESSERA's aesthetic properties are remarkable—it nearly resembles the color and translucency of real tooth enamel, which is crucial for anterior teeth in particular. **(Salem et al., 2024)**.

In accordance with the conclusions of **(Ikemoto et al., 2024)**, a dual-cure adhesive resin cement was applied to the fitting surface of every endocrown restoration) for cementation. In accordance with the protocols of **(Yeslam et al., 2023 and Akila, 2019)**, the restorations were placed on the prepared teeth using static finger pressure and then subjected to axial loading with a dedicated equipment exerting 5 kg of force for 5 minutes.

Due to its influence on the seal between the restoration and the tooth structure, the vertical marginal gap is an important consideration when assessing dental restorations. A smaller gap is better since it lowers the chance of secondary caries and bacterial infiltration, extending the life of the repair. Achieving a fine marginal fit for endocrowns manufactured with TESSERA advanced lithium disilicate requires careful consideration of both the material properties and the manufacturing procedure. **(Salem et al., 2024)**.

Another important factor to consider when evaluating the efficacy of endocrowns is fracture resistance, especially for anterior teeth, which are subjected to high functional and parafunctional stresses. An endocrown's long-term endurance depends on its capacity to bear these stresses without breaking. Because TESSERA advanced lithium disilicate has intrinsic material qualities including strong flexural strength and toughness, it has a high fracture resistance. **(Balladares et al., 2024)**.

The endocrown's fracture resistance is significantly influenced by its design, particularly by the way it extends into the pulp chamber. By extending into the pulp chamber, the endocrown lessens stress concentrations that can cause fractures by more efficiently distributing occlusal pressures across the remaining tooth structure. **(Ghoul et al., 2020).**

Similar mounting methods have been used in earlier research for consistency and stability. For example, (**Souza-Zaroni et al., 2007) and Soares et al. (2008)** used acrylic resin for mounting in their studies, which helped to provide repeatable outcomes. According to (**Cavalcanti et al., 2007**), it is essential for mechanical testing to precisely replicate real functional forces by matching the tooth's long axis with the mounting cylinders.

However, because polymerization shrinkage may cause unpredictability, some research recommends alternatives. Despite its greater cost and longer setting time, epoxy resin was suggested by **(Morita et al., 2018)** due to its improved dimensional stability.

In anterior endocrown preparation, a 2mm pulp extension offers moderate structural support and retention, suitable for minimally damaged teeth with a lower risk of pulp exposure. Conversely, a 4mm pulp extension enhances retention and stability by utilizing more of the pulp chamber, beneficial for significantly compromised teeth but requiring more extensive removal of tooth structure.

The choice between the two should balance the need for retention with the risk of complications and preservation of tooth integrity.

Choosing CEREC Tessera for anterior endocrown preparation offers numerous advantages, including enhanced aesthetics due to its natural translucency, superior strength, and durability. The minimally invasive preparation preserves more natural tooth structure, while the high precision and fit achieved through CAD/CAM technology reduce the risk of complications.

According to the company, CEREC Tessera has a special microstructure in which 0.2–0.3 µm platelet- like lithium aluminosilicate crystals (Li0.5Al0.5Si2.5O6), also called virgilite, are inserted alongside

0.5 µm long lithium disilicate crystals in a glassy matrix. There are more virgilite crystals formed when the crowns are burned. These crystals, combined with the lithium disilicate, contribute to high tensile strength and help prevent crack propagation, potentially increasing the fracture strength of the endocrowns **(DJ, 2021).**

The choice of dual-cure adhesive resin cement in this study is related to the endocrown materials used, as the light used for curing cannot penetrate the ceramic to reach the deep areas for cement curing. Chemical curing completes the cement polymerization in these deep areas **(Menezes-Silva et al., 2016).**

Cerec software was used to create the endocrowns' dimensions, enabling the milling of all endocrowns with consistent size, axial, and occlusal details. This made guaranteed that every sample had the same load application point. Following milling, the last restorations were uniformly positioned on the prepared teeth, with each tooth secured on a wax block prior to scanning.

Numerous research supports the cementation protocol's efficacy. According to **(El-Damanhoury and Gaintantzopoulou's, 2018)** research, the application of silane combined with hydrofluoric acid etching significantly strengthens the binding between ceramic surfaces and resin cement, increasing the longevity of restorations. In a similar vein, **(Della Bona and Van Noort, 1995)** discovered that this treatment offers better chemical bonding and mechanical retention. **(Sultan ,2018)** emphasized that in order to improve dentin adhesion of resin cement to tooth surfaces and ensure the success of endocrown restorations, phosphoric acid etching must be applied.

For these materials, mechanical retention alone might suffice. **(Ilkal, 2020)** questioned the necessity of dual-cure resin cements for all types of restorations, suggesting that in some cases, light-cure resins alone might be sufficient, thereby reducing complexity and potential errors during the cementation process.

The results of our study showed insignificant differences in total marginal gap between the 2 groups before and after cementation, before thermocycling and after thermocycling as well. However, significant difference was observed in the fracture resistance where 4mm pulp chamber extension teeth showed greater values than the 2mm pulp extension group.

Between the two groups, there was a negligible variation in the overall marginal gap (2, 4 mm) at the same time (before and after cementation). This may be because Tessera ceramics might possess consistent marginal adaptability and fit regardless of the extension length, Consistent and standardized tooth preparation techniques might have been employed in the study. Such uniformity can lead to negligible differences in marginal gaps between the two groups or the cementation protocols used in the study could have been optimized to ensure minimal impact on the marginal gap for both extension lengths. Fracture resistance of CAD/CAM onlays did not significantly vary with different preparation designs, including varying pulp chamber depths. This finding contrasts with the current study's results, where the 4mm extension showed superior fracture resistance.

This result agreed with **Otto, 2004 's study**. This study supports the conclusion that both 2mm and 4mm pulp chamber extensions provide similar marginal fits. Otto's findings indicate that all-ceramic restorations maintain marginal integrity with minimal differences before and after cementation, aligning with our results that show no significant difference in total marginal gaps between the two extension lengths.

Halıcı et al., 2018 was in partial agreement with our results as they found significant differences in the marginal gaps of different ceramic materials, including Tessera, with smaller gaps for GC Initial® LiSi Block compared to IPS Emax CAD and Cerec Tessera™ . This contradicts our findings that the marginal gap remains insignificantly different for different pulp chamber extensions of Tessera anterior endocrowns.

On the contrary, (**Chabouis et al., 2013 and Kojima et al., 2022**) disagreed with our results as (**Chabouis et al., 2013**) found significant differences in marginal gaps before and after cementation for certain types of ceramic restorations, suggesting that the cementation process can impact marginal integrity. In contrast, our study's results show that, for both 2mm and 4mm expansions, the marginal gap is not statistically different before and after cementation. (**Kojima et al., 2022**) found significant differences in the marginal gaps of different ceramic materials, including Tessera, with smaller gaps for GC Initial® LiSi Block compared to IPS Emax CAD and Cerec Tessera™ . This contradicts our findings that the marginal gap remains insignificantly different for different pulp chamber extensions of Tessera anterior endocrowns.

When comparing the group with the 4mm pulp chamber expansion, there was a noticeable difference in fracture resistance. According to the current study's fracture strength test results, the Cerec Tessera anterior endocrown group with a 4mm pulp extension exhibited a mean fracture strength that was higher than that of the 2mm pulp extension group. This could be attributed to the increased extension giving more strength and support to the restoration than that of the less extension. (**Fages and Bennasar, 2013**) evaluated the performance of endocrowns and found that deeper pulp chamber extensions provided greater fracture resistance.

This was in accordance with (**Bindl and Mörmann, 1999**) clinical evaluation found that adhesively placed endocrowns exhibited strong fracture resistance, particularly those with deeper pulp chamber extensions. This supports the current study's conclusion that 4mm extensions enhance fracture resistance. Shebl kassem et al., 2023, showed the mean fracture strength of each group varied significantly statistically, with group Cerec Tessera exhibiting the highest mean fracture strength, followed by groups IPS, Emax CAD, Amber Mill, and GC Initial LiSi CAD, in that order.

(Gresnigt et al., 2016; Dartora et al., 2021) were in partial agreement with our findings as they found higher mean fracture resistance values for E-max endocrowns compared to those in the present study. The differences in results could be attributed to variations in testing methods, such as crosshead speed, type of load application device, ball diameter, whether the endocrowns were bonded to natural teeth or resin dies, the type of tooth used, and the cementation technique. Additionally, it was noted that clinical masticatory forces typically range from 600 N to 800 N, and can exceed these values in bruxer patients, particularly in the molar region. In the present study, the load required to fracture any of the tested endocrowns exceeded the typical clinical masticatory forces.

On the contrary, (**Hannig et al., 2005**) found that the fracture resistance of endodontically treated teeth restored with CAD/CAM ceramic inlays was not significantly influenced by the depth of the pulp chamber extension. This contrasts with the current study's conclusion that a 4mm extension significantly enhances fracture resistance.

CONCLUSION

Whitin the limitation of this study it can be concluded to:

1- Tessera anterior endocrowns with both 2mm and 4mm pulp chamber extensions achieve similar vertical marginal gaps before and after cementation, indicating reliable marginal integrity for both designs.

2- The 4mm pulp chamber extension is the preferable option for improving the longevity and durability of the restoration in clinical practice enhances fracture resistance.

3- These insights can guide clinicians in making informed decisions about endocrown preparations to optimize both fit and functional performance.

RECOMMENDATIONS

Based on our conclusions, we recommend these findings for future research:

1. Conduct long-term clinical studies to observe the performance of Tessera anterior endocrowns with different pulp chamber extensions over time.
2. Investigate the biomechanical properties of other ceramic materials with varying pulp chamber extensions.
3. Research the influence of individual patient factors, such as occlusal forces and oral hygiene habits, on the performance of endocrowns with different pulp chamber extensions.
4. Evaluate patient satisfaction and comfort with endocrowns featuring different extensions.
5. Explore the integration of digital dentistry tools, such as CAD/CAM systems, in the design and fabrication of endocrowns.

REFERENCES

1. Amaral Colombo, L. do, Murillo-Gómez, F. and De Goes, M.F. 2019. Bond Strength of CAD/CAM Restorative Materials Treated with Different Surface Etching Protocols. Journal of Adhesive Dentistry. 21(4).
2. Baba, N.Z., White, S.N. and Bogen, G. 2017. Restoration of Endodontically Treated Teeth In: N. Chugal and L. M. Lin, eds. Endodontic Prognosis: Clinical Guide for Optimal Treatment Outcome [Online]. Cham: Springer International Publishing, pp.161–192. Available from: https://doi.org/10.1007/978-3-319-42412-5_10.
3. Balladares, A.O., Abad-Coronel, C., Ramos, J.C., Fajardo, J.I., Paltán, C.A. and Martín Biedma, B.J. 2024. Comparative Study of the Influence of Heat Treatment on Fracture Resistance of Different Ceramic Materials Used for CAD/CAM Systems. Materials. 17(6), p.1246.
4. Bindl, A. and Mörmann, W.H. 1999. Clinical evaluation of adhesively placed Cerec endo- crowns after 2 years-preliminary results. Journal of Adhesive Dentistry. 1(3).
5. Della Bona, A. and Van Noort, R. 1995. Shear vs. tensile bond strength of resin composite bonded to ceramic. Journal of dental research. 74(9), pp.1591–1596.
6. Cavalcanti, A.N., De Lima, A.F., Peris, A.R., Mitsui, F.H.O. and Marchi, G.M. 2007. Effect of surface treatments and bonding agents on the bond strength of repaired composites. Journal of Esthetic and Restorative Dentistry. 19(2), pp.90–98.
7. Chabouis, H.F., Faugeron, V.S. and Attal, J.-P. 2013. Clinical efficacy of composite versus ceramic inlays and onlays: a systematic review. Dental materials. 29(12), pp.1209–1218.
8. Dartora, N.R., Moris, I.C.M., Poole, S.F., Bacchi, A., Sousa-Neto, M.D., Silva-Sousa, Y.T. and Gomes,
9. E.A. 2021. Mechanical behavior of endocrowns fabricated with different CAD-CAM ceramic systems. The Journal of Prosthetic Dentistry. 125(1), pp.117–125.
10. DJ, F. 2021. CEREC Tessera Restorative Whitepaper. 2021.
11. El-Damanhoury, H.M. and Gaintantzopoulou, M.D. 2018. Self-etching ceramic primer versus hydrofluoric acid etching: Etching efficacy and bonding performance. Journal of prosthodontic research. 62(1), pp.75–83
12. Fages, M. and Bennasar, B. 2013. The endocrown: a different type of all-ceramic reconstruction for molars. J Can Dent Assoc. 79, p.d140.
13. Ghoul, W. El, Özcan, M., Tribst, J.P.M. and Salameh, Z. 2020. Fracture resistance, failure mode and stress

concentration in a modified endocrown design. Biomaterial investigations in dentistry. 7(1), pp.110–119.

14. Gresnigt, M.M.M., Özcan, M., van den Houten, M.L.A., Schipper, L. and Cune, M.S. 2016. Fracture strength, failure type and Weibull characteristics of lithium disilicate and multiphase resin composite endocrowns under axial and lateral forces. Dental materials. 32(5), pp.607–61
15. Halıcı, S.E., Hekimoğlu, C. and Ersoy, O. 2018. Marginal Fit of All-Ceramic Crowns Before and After Cementation: An In Vitro Study. The International journal of periodontics & restorative dentistry. 38(3), pp.e41–e48.
16. Hannig, C., Westphal, C., Becker, K. and Attin, T. 2005. Fracture resistance of endodontically treated maxillary premolars restored with CAD/CAM ceramic inlays. The Journal of prosthetic dentistry. 94(4), pp.342–349.
17. Ilkal, M.S. 2020. Comparative Evaluation of Flexural Strength of Three Dual Cure Resin Luting Cements in Self Curing and Dual-Curing Modes: An In-Vitro Study.
18. Kojima, K., Nagaoka, K., Murata, Y., Yamamoto, K., Akiyama, S., Hokii, Y. and Fusejima, F. 2022. Marginal adaptation of CAD/CAM milled lithium disilicate glass ceramic crowns. Journal of Osseointegration. 14(4), pp.201–204.
19. de Kuijper, M.C.F.M., Cune, M.S., Tromp, Y. and Gresnigt, M.M.M. 2020. Cyclic loading and load to failure of lithium disilicate endocrowns: Influence of the restoration extension in the pulp chamber and the enamel outline. journal of the mechanical behavior of biomedical materials. 105, p.103670.
20. Lassle, M.J. 2015. CAD/CAM lithium disilicate crown performance cemented extraorally and delivered as a screw-retained implant restoration.
21. Mahesh, B., Vandana, G., Sanjay, P., Jaykumar, G., Deepika, C. and Aatif, N. 2015. Endocrown: conservative treatment modality for restoration of endodontically treated teeth–a case report. Endodontology. 27(2), pp.188–191.
22. Menezes-Silva, R., Espinoza, C.A.V., Atta, M.T., de Lima Navarro, M.F., Ishikiriama, S.K. and Mondelli, R.F.L. 2016. Endocrown: a conservative approach. Brazilian Dental Science. 19(2), pp.121–131.
23. Morita, K., Tsuka, H., Kato, K. and Tsuga, K. 2018. Effect of polymerization temperature on the properties of autopolymerizing resin. The Journal of prosthetic dentistry. 119(5), pp.840– 844.
24. Mostafavi, A.S., Allahyari, S., Niakan, S. and Atri, F. 2022. Effect of Preparation Design on Marginal Integrity and Fracture Resistance of Endocrowns: A Systematic Review. Frontiers in dentistry. 19, p.37.
25. Otto, T. 2004. Computer-aided direct all-ceramic crowns: preliminary 1-year results of a prospective clinical study. International Journal of Periodontics and Restorative Dentistry. 24, pp.446–455.
26. Özcan, M. and Vallittu, P.K. 2003. Effect of surface conditioning methods on the bond strength of luting cement to ceramics. Dental Materials. 19(8), pp.725–731.
27. Salem, M.A., Ibrahim, S.H. and Abou-steit, S.S. 2024. Three Years Clinical Evaluation of Lithium Disilicate and Hybrid Nano-ceramic CAD/CAM Endocrowns (Randomized Clinical Trial). Egyptian Dental Journal. 70(1), pp.551–561.
28. Sedrez-Porto, J.A., da Rosa, W.L. de O., da Silva, A.F., Münchow, E.A. and Pereira-Cenci, T. 2016. Endocrown restorations: A systematic review and meta-analysis. Journal of dentistry. 52, pp.8–14.
29. Sengun, Abdulkadir, Funda Kont Cobankara, and Hasan Orucoglu. “Effect of a new restoration technique on fracture resistance of endodontically treated teeth.” Dental Traumatology 24.2 (2008): 214-219.
30. Shebl kassem, A., Mohammad, M. and abd elhamid, tarek 2023. Fracture Resistance of Four Different Types of Cad/Cam Lithium Disilicate Endocrowns. Egyptian Dental Journal. 69(2), pp.1493– 1500.
31. Soares, P.V., Santos-Filho, P.C.F., Queiroz, E.C., Araújo, T.C., Campos, R.E., Araújo, C.A. and Soares,
32. C.J. 2008. Fracture resistance and stress distribution in endodontically treated maxillary premolars restored with composite resin. Journal of Prosthodontics. 17(2), pp.114–119.
33. Souza-Zaroni, W.C., Seixas, L.C., Ciccone-Nogueira, J.C., Chimello, D.T. and Palma-Dibb, R.G. 2007. Tensile bond strength of different adhesive systems to enamel and dentin. Brazilian Dental Journal. 18, pp.124–128.
34. Sultan, S.E.K. 2018. The Effect of Cementation Techniques and Surface Treatments on the Retention of Hybrid Ceramic Endocrowns.
35. Veríssimo, A.H., Moura, D.M.D., Tribst, J.P.M., Araújo, A.M.M. de and Leite, F.P.P. 2019. Effect of hydrofluoric acid concentration and etching time on resin-bond strength to different glass ceramics. Brazilian oral research. 33, p.e041.