Research

Comparative evaluation of marginal fit accuracy of two different designs of endocrown manufactured through CAD-CAM system: An *in vitro* study

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Abstract

Aims: To compare the accuracy of marginal fit of CAD-CAM endocrown with two different preparation forms, i.e., endocrown with ferrule and endocrown without ferrule.

Settings and Design: Various studies have opined on the impact of preparation form on the marginal fit of endocrown, but studies on the effect on the marginal fit of digitally milled endocrown with and without ferrule are sparse.

Materials and Methods: Total of 30 typodont were sectioned 3 mm above the cemento-enamel junction, and central cavity was prepared to depict a severely destructed tooth. The typodonts were divided into two groups: Group 1 contained specimens for endocrown without ferrule (WoF); Group 2 contained specimens for endocrown with ferrule (WF). The typodonts were prepared based on standard preparation. The specimens were then scanned using intraoral scanner, and the stereolithography (STL) was generated. Endocrowns were designed in the Exocad software using a digital library. The STL file format is translated into millable data file format (CNC- Computer numerical control) in the inLAB MC X5 Milling machine. The marginal fit of endocrowns was then assessed in the stereomicroscope.

Statistical Analysis: The data was analysed with a digital image analyser. The result was generated using a two-way ANOVA test. The significance level was set at $P \leq 0.05$.

Results: In the present study, the marginal fit of WoF showed a superior marginal fit than WF. A statistically significant difference was seen in the marginal fit of two endocrowns, with a higher marginal discrepancy observed in the endocrown with the ferrule. The *P* value for the difference in the means of the marginal gap without and with ferrule (-13.42) is zero. Maximum marginal gap of 96 micron is observed for with ferrule (WF) design at location B. Minimum marginal gap of 29 micron is observed for without ferrule (WoF) at location D.

Conclusions: Endocrown without a ferrule can provide a better marginal fit and can contribute to the long-term survival of restoration.

Key-words: Endocrown, marginal fit, ferrule, CAD-CAM, intraoral scanner

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INTRODUCTION

Restoration of severely damaged teeth that have undergone root canal therapy is still a challenge for a dentist to restore. Endodontically treated teeth are rehabilitated based on residual tooth structure.[1] After root canal therapy, teeth with half of the remaining crown structure are usually restored with either a full coverage crown, an endocrown, or an onlay restoration.[1] According to the meta-analysis of the clinical investigations, conventional crowns have revealed an overall 5-year survival rate slightly better than that of endocrown.[2]

The success of an endocrown depends on multiple factors, such as design (depth of intrapulpal cavity, margin) of the restoration, material used for fabrication, and the type of cementation.[3] Marginal fit accuracy of any restoration has a pivotal role in long-term survival of any restoration.[4,5] Marginal adaptation is defined as the degree of fit between a prosthesis and its supporting structures.[6] Many factors influence the true fit of the restorations, among which preparation form (ferrule or without ferrule), parameter setting (intrapulpal depth and cervical sidewalk), and cement type are primary factors.[7,8] Different authors have advocated varying designs of endocrown, citing their benefits and disadvantages.[9-13] However, the studies comparing the outcomes of these designs on marginal adaptation of digitally milled endocrown are sparse. In the present study, the marginal fit of endocrown with two different preparation designs, with and without ferrule, was evaluated. The null hypothesis was that endocrown with different preparation designs, i.e., with and without ferrule, had no difference in marginal fit.

SUBJECTS AND METHODS

A total of 30 mandibular first molar specimens were sectioned 3 mm above the cementoenamel junction (CEJ).[7] A central cavity with a flat base was prepared to mimic a grossly destructed tooth.[14] All the specimens were mounted on epoxy resin blocks for tooth preparation.[11] The specimens were grouped into two categories: the specimen of category 1 was prepared to achieve a cervical sidewalk of 2 mm (endocrown without ferrule [WoF]) denoted as Group WoF, and the specimen of category 2 was prepared to achieve a ferrule of 1 mm and a cervical sidewalk of 2 mm (endocrown with ferrule [WF]) denoted as group WF. IRB Approval number: No.IEC: ECR/15/GDC/CG/2021, date: 16/03/2021.

The occlusal surface was prepared using a diamond wheel bur to achieve an axial wall height of 2 mm along with a cervical sidewalk of 2 mm [Figures 1 and 2].[12,15,16] The endodontic access cavity and coronal pulp chamber are made continuous using a cylindrical-conical diamond bur with a 7-degree taper.[16] Intracoronal retention was achieved with intracoronal extension of 4 mm height of the axial wall [Figure 3] inside the central cavity by extending the base of the preparation 2 mm below CEJ.[11,14,17] The above design form was kept same for the specimens receiving WF and WoF. Additional ferrule of 1 mm was prepared on

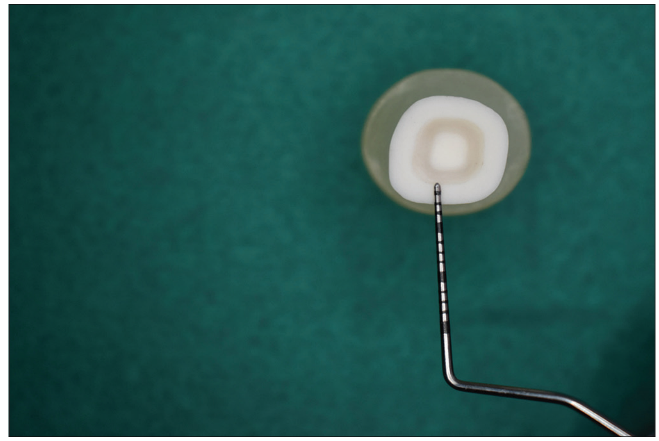


Figure 1: 2 mm cervical sidewalk in endocrown without ferrule

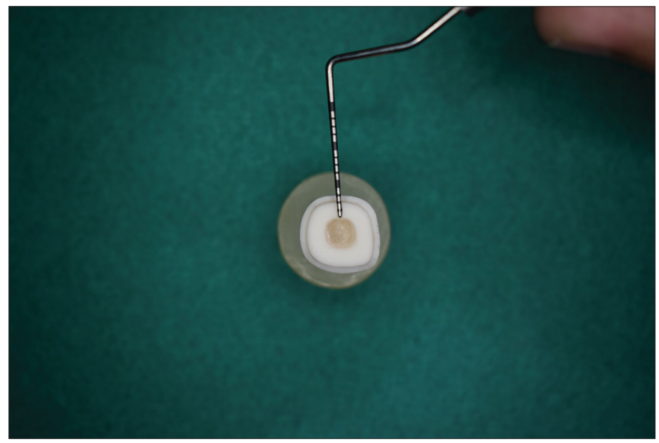


Figure 2: 2 mm cervical sidewalk in endocrown with ferrule

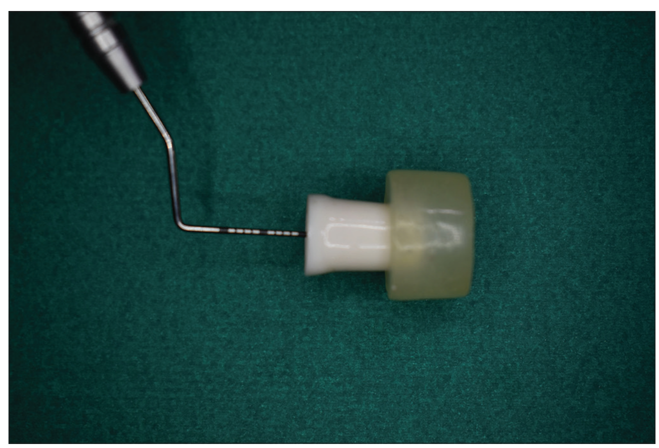


Figure 3: 4 mm intracoronal pulpal depth

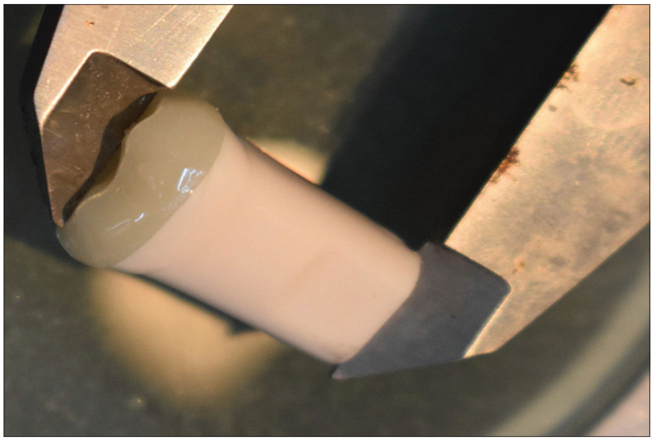


Figure 4: Evaluation of marginal discrepancy in stereomicroscope

external coronal surface apical to the endocrown occlusal table using a flat-end straight fissure bur in group WF. A tissue-protecting end-cutting bur was used to prepare a smooth margin.[13]

An intraoral scanner (IOS; Bluecam Panda) was used to scan prepared specimens following a liner movement on the occlusal–palatal surface, followed by buccal surface.[18] The scanned data were stored as stereolithography (STL) file. This STL file format is translated into millable data file format (computer numerical control). IPS Emax blocks were milled on the inLab MC X5 milling machine. The blocks were milled under 7-bar air pressure and 50 L/min air volume. After milling, the partially sintered endocrown was heat treated with an initial temperature of 403°C and raised by 90°C/min up to 840°C, where it remained for 7–10 min to get the final endocrown. After milling, no internal adjustment or postprocessing was done.

Each specimen was photographed with the help of a stereomicroscope (XTL 3400E, Wuzhou New Found Instrument Co., Ltd., China) connected with a computer [Figure 4], using a magnification of ×30. A digital image analysis system (MVIG2005 Chroma System Pvt. Ltd., India) was used to measure the distance between the endocrown margin and the prepared tooth. Five equally spaced points around the cervical circumference were marked, and the centre point was chosen to determine the marginal gaps at each of those locations. The centre point was used to determine the margins of each surface (buccal, lingual, mesial, and distal) of a tooth.

For each specimen, images of the margins were obtained. After that, morphometric evaluations were performed for every image at these locations. Each mandibular first molar typodont was measured at midpoint of four surfaces, i.e., buccal surface denoted as location B, lingual surface denoted as location L, mesial denoted as location M, and distal surface denoted as location D. Each point was measured five times, and the average value was taken into consideration. The average marginal gaps of all four surfaces of each sample are tabulated in Table 1. These values were used for statistical analysis.

RESULTS

The minimum marginal gap was observed for WoF, and the maximum average marginal gap was observed for WF [Table 1 and Graph 1], assessed with two-way analysis of variance (ANOVA) followed by pairwise comparison of statistically significant factor that helped reveal the better marginal fit accuracy. The normality of the data set was checked by Anderson Darling test at 95% confidence. A general linear model was used to analyze a repeated measures design in Minitab for testing significance of the presence and absence of ferrule at 4 locations and interaction on mean marginal fit. The P value of the marginal gap was higher than significance level 0.05. The P value for the difference in the means of the marginal gap without and with ferrule (−13.42) was 0 [Table 2]. The difference was statistically significant at the 5% significance level. Tukey's simultaneous tests for differences of means were used for pairwise comparison between the four locations, with the location D [Table 3] showing the lowest mean marginal gap. The highest mean marginal gap was seen for location B [Graph 2]. The lowest mean marginal gap observed for WoF and location D was 46.53 μ. The highest mean marginal gap was observed for WF and location B. Table 4 displays the mean marginal gap for all interactions between ferrule and location. Maximum marginal gap of 96 μwas observed for with ferrule deign at location B. Minimum marginal gap of 29 μ was observed for without ferrule at location D. The design with the ferrule (WF) mostly delivered higher marginal gap. Within ferrule design (WF), location D delivered the lowest mean marginal gap, i.e., 58.87 μ. The design without ferrule (WoF) mostly delivered lower marginal gap. Within locations without ferrule designs (WoF), location D delivered the lowest mean marginal gap at 46.53 μ.

DISCUSSION

The study was conducted to assess the marginal fit accuracy of endocrown with a ferrule (WF) in comparison with endocrown without a ferrule (WoF). According to the study's findings, the marginal gaps in the WF and WoF were within the acceptable range of 120 μ. A higher marginal gap was observed in WF. Therefore, the null hypothesis was rejected. The butt margin design provides a configuration without complexity and adequate thickness in the margins, which reduced the vertical marginal disparity and resulted in a proper marginal seal of endocrowns. In addition, the butt joint of endocrowns enhanced the thickness of ceramics at the butt joint/restoration contact, which improved the bonding mechanism and minimized the marginal discrepancies.[19]

The better marginal adaptation aids in long-term success of restoration. It limits the failure caused due to poor marginal fit. Improper marginal adaptation can lead to microleakage, which causes dental plaque accumulation, cement dissolution, secondary caries, periodontitis, and ultimately fracture of the restoration.[3,4] Many factors influence the true fit of the restoration; among these, preparations form (with or without ferrule), parameter setting (intrapulpal depth and cervical sidewalk), and cement type are crucial factors.[7,20] This study was conducted to analyze the effect of different preparation forms on the marginal fit of endocrown. The impact of ferrule on improving stress distribution, reducing catastrophic failure, and increasing fracture resistance is widely proven in the literature,[9,10,13] but the effect of ferrule on marginal fit was controversial due to varying opining from past studies.[11,21,22] Due to the difference in opinion of different authors on the effect of various preparation forms on the marginal fit accuracy of endocrown, there was a need for further evaluation of different designs of endocrown, i.e., with and without ferrule, on the marginal fit of CAD-CAM endocrown.

Table 1: Average and standard deviation of marginal fit

Ferrule	Location	Mean	SD	Minimum	Maximum
WF	Buccal surface	87.47	6.07	77	96
	Distal surface	58.87	4.98	50	67
	Lingual surface	75.47	4.97	69	86
	Mesial surface	72.33	4.45	64	79
WoF	Buccal surface	66.47	12.77	40	89
	Distal surface	46.53	11.15	29	73
	Lingual surface	65.27	10.48	47	90
	Mesial surface	62.20	12.33	44	89

SD: Standard deviation, WoF: Without ferrule, WF: With ferrule

Table 2: Difference of means of marginal fit accuracy without and with ferrule

Difference of ferrule levels	Difference of means	Simultaneous 95% CI	Adjusted *P* value
Without - with	−13.42	−16.69–−10.14	0***

***Highly significant at 0.05. CI: Confidence interval

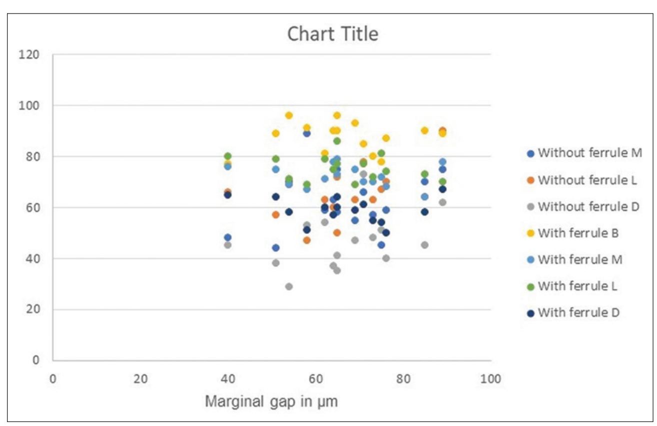
Table 3: Location D is showing the lowest mean marginal accuracy

Location	*n*	Mean
Buccal surface	30	76.97
Lingual surface	30	70.37
Mesial surface	30	67.27
Distal surface	30	52.70

Graph 1: Average and Standard deviation of marginal gap in WF and WoF group

Interpretation of the present study reveals that the maximum marginal gap was seen in ferrule design. The marginal gap was observed to be minimal in preparation designs without ferrules [Table 1]. The result of the study matched the earlier study done by Elbasty *et al*.[21] Abo-Elmagd *et al*.[22] assessed the impact of marginal design on the marginal fit and microleakage of endocrowns with butt and shoulder margins. They concluded that the shoulder margin results in poor marginal adaption and thus increases microleakage compared to butt margin.

The complexity and many internal angles of endocrown may make it difficult for a CAD-CAM milling unit to accurately mill it with their specific instrument geometries, which is the most likely contributing factor to the difference in marginal fit.[7,21] The increased vertical gap between the tooth margin and WF may be due to the complex pattern of the restoration and the irregular surface structure of



Graph 2: Marginal discrepancy seen in endocrown with and without ferrule

Table 4. Pairwise comparison of mean marginal fit accuracy

Difference of Ferrule*Location Levels	Difference of Means	t	Adjusted P
(With ferrule [WF] Distal surface) - (With ferrule [WF] Buccal surface)	-28.6	-8.65	0.000***
(With ferrule [WF] Mesial surface) - (With ferrule [WF] Buccal surface)	-15.13	-4.58	0.000***
(With ferrule [WF] Lingual surface) - (With ferrule [WF] Distal surface)	16.6	5.02	0.000***
(With ferrule [WF] Mesial surface) - (With ferrule [WF] Distal surface)	13.47	4.07	0.002***
(With ferrule [WF] Lingual surface) - (With ferrule [WF] Buccal surface)	-12	-3.63	0.010**
(With ferrule [WF] Mesial surface) - (With ferrule [WF] Lingual surface)	-3.13	-0.95	0.980
(Without Ferrule [WoF] Distal surface) - (Without ferrule [WoF] Buccal surface)	-19.93	-6.03	0.000***
(Without Ferrule [WoF] Lingual surface) - (Without Ferrule [WoF] Distal surface)	18.73	5.67	0.000***
(Without Ferrule [WoF] Mesial surface) - (Without Ferrule [WoF] Distal surface)	15.67	4.74	0.000***
(Without Ferrule [WoF] Mesial surface) - (Without Ferrule [WoF] Buccal surface)	-4.27	-1.29	0.900
(Without Ferrule [WoF] Mesial surface) - (Without Ferrule [WoF] Libgual surface)	-3.07	-0.93	0.983
(Without Ferrule [WoF] Lingual surface) - (Without Ferrule [WoF] Buccal surface)	-1.2	-0.36	1.000
(Without Ferrule [WoF] Buccal surface) - (With ferrule [WF] Buccal surface)	-21	-6.35	0.000***
(Without Ferrule [WoF] Distal surface) - (With ferrule [WF] Buccal surface)	-40.93	-12.38	0.000***
(Without Ferrule [WoF] Lingual surface) - (With ferrule [WF] Buccal surface)	-22.2	-6.72	0.000***
(Without Ferrule [WoF] Mesial surface) - (With ferrule [WF] Buccal surface)	-25.27	-7.64	0.000***
(Without Ferrule [WoF] Distal surface) - (With ferrule [WF] Lingual surface)	-28.93	-8.75	0.000***
(Without Ferrule [WoF] Distal surface) - (With ferrule [WF] ferrule [WF] Mesial surface)	-25.8	-7.81	0.000***
(Without Ferrule [WoF] Mesial surface) - (With ferrule [WF] Lingual surface)	-13.27	-4.01	0.003***
(Without Ferrule [WoF] Distal surface) - (With ferrule [WF] Distal surface)	-12.33	-3.73	0.007**
(Without Ferrule [WoF] Lingual surface) - (With ferrule [WF] Lingual surface)	-10.2	-3.09	0.050
(Without Ferrule [WoF] Mesial surface) - (With ferrule [WF] Mesial surface)	-10.13	-3.07	0.053
(Without Ferrule [WoF] Buccal surface) - (With ferrule [WF] Lingual surface)	-9	-2.72	0.127
(Without Ferrule [WoF] Buccal surface) - (With ferrule [WF] Distal surface)	7.6	2.3	0.303
(Without Ferrule [WoF] Lingual surface) - (With ferrule [WF] Mesial surface)	-7.07	-2.14	0.398
(Without Ferrule [WoF] Lingual surface) - (With ferrule [WF] Distal surface)	6.4	1.94	0.529
(Without Ferrule [WoF] Buccal surface) - (With ferrule [WF] Mesial surface)	-5.87	-1.77	0.638
(Without Ferrule [WoF] Mesial surface) - (With ferrule [WF] Distal surface)	3.33	1.01	0.972

***Highly significant at 0.05, **Significant at 0.05

the prepared tooth.[21] Incorporation of the ferrule resulted in a decreased thickness of the dentine wall between the endocrown cervical extension and ferrule feature. Due to overmilling of the complex intaglio surface, the entire endocrown and ferrule structure complex would be weakened.[11] The marginal fit of a CAD/CAM crown depends on how perfectly the tooth is scanned and how precisely the milling machine grinds the block.[4] In a pairwise comparison of the different surfaces of WF and WoF, the distal surface of endocrown (location D) shows the lowest mean marginal gap. The highest mean marginal gap is seen for location B, i.e., the buccal surface of the endocrown, irrespective of the presence or absence of ferrules. The possible cause of this might be the absence of a circumferential flat surface. This result is in accordance with a study conducted by Hmaidoucha *et al.*[8] Fages and Bennasar[16] stated the importance of the butt joint margin of the restoration; it provides wide, uniform flat surface that withstands the compressive loads that are most common on posterior teeth. The prepared surface is parallel to the occlusal plane, which helps in better stress distribution along the long axis of the tooth leading to improved resistance.

Carbajal Mejía *et al.*[23] demonstrated in their study the effect of prepared tooth design on the accuracy of a digital scanner based on the total occlusal convergence angle of prepared teeth. The working principle of all IOSs is that the software stitches together the scan of following images based on the original reference image, using the scan of the first image as a point of reference.[24] According to Carbajal Mejía *et al.*'s comparison of the IOS and conventional impression, the IOS correctly scans the abutment tooth regardless of geometry.[23]

In the current research, an endocrown was fabricated using IPS Emax CAD blocks. Lithium disilicate is preferred for the endocrown restoration due to the inherent properties of lithium disilicate, such as increased flexural strength, better fracture toughness, and good thermal expansion.[8] Lithium disilicate crystals minimize the propagation of microcrystal cracks and have better aesthetic and adhesive qualities.[8] Lithium disilicate provides a higher bonding capacity, leading to increase fracture resistance in dentin, enamel, and ceramic groups.[10] In conclusion, Taha *et al.*[19] found in their study that polymer-infiltrated ceramics and lithium disilicate demonstrated the highest values of fracture resistance, recommending their usage for endocrown restorations. In a study by El Ghoul *et al.*,[25] endocrowns fabricated of CAD/CAM materials that have been exposed to thermomechanical cycle loads are evaluated for fracture resistance and failure modes. According to their findings, the highest fracture resistance was recorded by lithium disilicate glass-ceramic under axial and lateral loading.

Advanced IOSs, CAD-CAM milling equipment, and advancements in adhesive materials have all made it possible to use endocrown in clinical settings. In our study, we evaluated the impact of preparation form on marginal fit accuracy, keeping the other factors constant, which can affect the result of the present study.

Limitations in the present study are as follows: in the present study, the marginal discrepancy of endocrown designs was evaluated, but the effect of ferrules on internal adaptation is yet to be seen. Endocrown is far more complex than the geometry of the crown, which may affect the efficiency of grinding the CAD-CAM block. As the study was an *in vitro* study, a clinical scenario might affect the scanning processing, resulting in a less precise digital image because of the presence of saliva. The accessibility of the oral cavity will also affect the scanning. All the discrepancies were measured without cementation of the endocrown to the tooth. It has been revealed that the cementation affects the marginal adaptation. Further studies are recommended to evaluate the effect of preparation forms of CAD-CAM endocrowns in clinical studies.

CONCLUSION

Marginal fit of the restoration plays an important role in survival of restoration. Endocrown without ferrule shows better marginal fit than with ferrule, which shows higher marginal discrepancy. This indicates that endocrown without ferrule can provide higher survival. The present in-vitro study has the limitation such as the result might get affected in *in-vivo* study due the factors such as variation in anatomic form, uneven remaining axial wall, intraoral environment, difference in scanning intra orally, which is a future scope of study.

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Conflicts of interest
There are no conflicts of interest.

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