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Research Article

THE SUCCESS OF POST-ENDODONTIC RESTORATIONS USING DIFFERENT RESTORATIVE MATERIALS: A TWO-YEAR FOLLOW-UP STUDY

Sait GÜLLÜ[1], Emre ÇULHA[1*], Uğur AYDIN[1], Muazzez Naz BAŞTÜRK ÖZER[1]

[1] Department of Endodontics, Faculty of Dentistry, Gaziantep University, Gaziantep, Turkey
*Correspondence: emreculha@hotmail.com

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ABSTRACT

Objective: Coronal restoration following endodontic therapy is critical for success. Restorations after endodontic treatment should minimize fractures of residual hard tissues, and maintain dental function. The aim of this study was to evaluate the success of post-endodontic restorations using various restorative materials over a two-year period.

Materials and Methods: The study involved 60 individuals aged 18 to 40. The patients were randomly divided into three groups. Conventional composite restorations were used to restore the first group. The second group was treated with a fiber-reinforced composite covered in composite resin. The third group was reconstructed using endocrowns. The restorations were prospectively investigated for two years.

Results: In the composite restoration group, two restorations and one tooth were fractured, with two polishable surfaces found on a single restoration. In the fiber-reinforced composite restoration group, one restoration fragmented and one polishable surface was found. In the endocrown restoration group, 2 endocrowns had decementation. No significant difference was observed in periodontal examination including gingival pocket depth, plaque and bleeding indices assessment ($p > 0.05$). There were no marginal discrepancies and no caries in any of the restorations. At the last appointment, patient satisfaction was evaluated in terms of aesthetics and function using a visual analog scale.

Conclusion: All groups had a 100% survival rate over the two-year follow-up period. According to the patients, there was no functional difference between the restoration groups ($p > 0.05$); however, aesthetically, restorations with endocrowns were more successful ($p < 0.05$).

Keywords: Endocrown, Fiber-Reinforced Composite, Composite, Canal Treatment, Post-Endodontic Restoration

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INTRODUCTION

The quality of coronal restoration in endodontically treated teeth (ETT) is critical for long-term tooth prognosis. A successful coronal restoration lowers the risk of tooth loss by minimizing bacterial microleakage into the obturated root canal system. However, ETT has poorer outcomes than vital teeth, primarily associated with periodontal problems and vertical root or cusp fractures (1). 11% of the ETT was extracted owing to improper restorations (2). When restored with veneers, these teeth attain survival rates similar to vital ones because microleakage is minimized and tooth structure is preserved. However, the success rate is reduced when they are reconstructed with composite resin (CR) alone (3). Endocrown restorations, which receive support from the pulp chamber and are less intrusive than post-supported prosthetic crowns, have become increasingly popular with the advancement of minimally invasive dentistry.

Endocrowns provide the appropriate distribution of stress inside the coronal restoration and the uniform transmission of occlusal pressures (4). The manufacture of endocrowns on computer aided design-computer aided manufacturing (CAD-CAM) systems has allowed for more suitable restorations to be performed in less time. Compared to traditional procedures, the positive aspects of endocrowns are that they offer better aesthetic and functional outcomes, are less expensive, and require less time to complete (5). Glass ceramics reinforced with lithium disilicate (LD), one of the dental materials utilized for fabricating endocrowns, have enhanced crystal content to strengthen the substructure ceramics. Nevertheless, there is little information on the longer-term survival and success of endocrowns (6). As a different approach, fiber-reinforced composites (FRCs) are inserted beneath the restorations to improve the physical characteristics of ETT restored with CRs. Utilizing FRCs improves the fracture resistance of the tooth structure when applied to ETT (7).

This study was targeted to assess the clinical and radiographic survival and success rates of endocrown, FRC, and CR after root canal treatment over 2 years. In our study, follow-up was based on prosthetic, periodontal, radiographic, and patient satisfaction criteria. The null hypothesis predicted that there would be no difference in success rates among the different restoration types.

MATERIALS AND METHODS

The Scientific Studies Review and Ethics Board of Gaziantep University approved this study at its meeting on November 27, 2017, with decision number 2017/389. Participants were enrolled after receiving appropriate information and providing written consent, in accordance with the Helsinki Declaration (2013 revision). All stages of the clinical study are presented in the workflow diagram in Figure 1.

This study comprised 60 systemically healthy people aged 18 to 40. Preoperative data for each tooth were documented, including demographic information and the clinical status of each tooth. After rubber dam isolation, Specialized ultrasonic tips and a long-shaft round diamond bur were used to prepare a conservative cavity access. Root canals were explored to the apical foramen using pre-curved stainless steel #8 or #10 K-files (Maillefer, Bailague, Switzerland). Working length was determined using an electronic apex locator (Root ZX Morita, Tokyo, Japan) and confirmed with digital periapical radiography. All canals were prepared using an M-Wire alloy rotary system (ProTaper Next, Maillefer, Bailague, Switzerland) with a tip size of up to #25 and variable taper. Irrigation was carried out with 5.25% sodium hypochlorite (Imicryl, Konya, Turkey) through side-vented 30-G needles. The root canals were irrigated with 17% EDTA solution (Werax, İzmir, Turkey) for 3 minutes. The canals were dried with sterile paper points, then obturated using the lateral condensation technique with gutta-percha cones (Maillefer, Bailague, Switzerland) and AH Plus sealer (Dentsply DeTrey, Konstanz, Germany).

After root canal obturation, a different investigator evaluated the marginal integrity, surface characteristics, as well as the periodontal and radiographic findings.

Inclusion criteria were as follows:
– A molar tooth requiring root canal treatment
– Radiographic continuity of the lamina dura
– An acceptable crown-to-root ratio
– No root fractures, cracks, or periapical lesions
– Presence of a MOD cavity in the tooth
– Good oral hygiene and compliance with hygiene recommendations
– Absence of periodontal disease
Exclusion criteria included:
– Presence of any systemic health problems
– Tooth mobility greater than Grade I

After initial screening, all eligible participants were randomly assigned to one of three groups based on the type of post-endodontic restoration. Allocation was concealed using a randomization program (www.randomizer.org).

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Composite Restoration Group

Unsupported enamel that was prone to fracture on the cavity walls was removed and smoothed until a satisfactory length-to-thickness ratio was obtained. The Supermat Matrix System (Hawe Neos Dental, Switzerland) was applied to the molar tooth with the help of appropriately sized wooden interdental wedges to create proper contacts both mesially and distally. 37% phosphoric acid (Ivoclar Vivadent AG, Schaan, Liechtenstein) was applied to the cavity surface for 15 seconds, rinsed for 15 seconds, and finally dried. G-bond adhesive (GC Corporation Tokyo, Japan) was applied to the created cavity, allowed to dry for 20 seconds, and then polymerized with an LED light device (Valo Cordless, South Jordan, USA) for 40 seconds. A hybrid resin composite (Essentia Universal, GC Germany, Bad Homburg, Germany) was placed in layers of approximately 1.2 mm depth. Finally, CR was polished with a bur and composite finishing discs.

Fiber-reinforced Resin Supported Composite Restoration Group

The underlying structure (EverX Posterior, GC Corporation, Tokyo, Japan) was utilized, with short E-fibers. 37% phosphoric acid was coated over the cavity surface for 15 seconds, rinsed, and dried. G-bond adhesive (GC Corporation Tokyo, Japan) was applied to the cavity, waited 20 seconds, then dried with air and polymerized for 40 seconds with an LED light. The composite material was then used to form the mesial and distal marginal walls. Following that, the FRC material was placed in 3-4 mm increments based on the approximate cavity depth and held for 20 seconds. After that, a hybrid resin composite (Essentia Universal, GC Germany, Bad Homburg, Germany) was applied to the 1.5-2 mm thick FRC. The restoration was polymerized for 40 seconds with an LED light device prior to being polished with a polishing bur and composite finishing discs.

Endocrown Restoration Group

In this research, LD blocks (IPS e.max CAD PC/FC, Ivoclar Vivadent AG, Schaan, Liechtenstein) were chosen as endocrown restorative materials. The sealer and gutta-percha residues at the canal orifices were cleaned out using a tiny carbide diamond bur. The root canal orifices and cavity floor were covered with 1 mm of flowable CR to keep them on a level surface. The pulp chamber of the tooth obtained a central pulp cavity depth of 2-4 mm, and the undercuts of the internal surfaces in the cavity chamber were filled with CR. To create a restoration-appropriate entry way, the coronal walls were set up to extend occlusally at a 4° angle.

Patient data was uploaded into the software system (Dentsply Sirona Dental Systems, Bensheim, Germany) according to the manufacturer's guidelines. The intra-oral scanning was performed independently for the lower and upper jaws, and the occlusion was recorded (Figure 2). The model part was selected, the margin parts and boundaries of the tooth were determined, then the entry route was selected, the preparation analyzed, and the design created by selecting the 'design' mode (the restoration form, contact information, and closure were all organized). Following these steps, the restoration was produced on a milling device (Sirona Dental Systems, Bensheim, Germany).

During the clinical phase, the restoration was adjusted to the cavity. A diamond bur (Dentsply, Bensheim, Germany) was utilized to form the proximal contacts, followed by the margins, and the abraded areas were finished off with a polishing rubber. The restoration glazing procedure involved applying paste and liquid and firing in the porcelain oven in 'p51' mode. The interior portion of the restoration was treated with 9.5% hydrofluoric acid (Porcelain Etchant, Bisco Inc., Schaumburg, Germany) for 60 seconds, rinsed with water, and dried, then silane (Monobond N, Ivoclar Vivadent AG, Schaan, Liechtenstein) was applied for 60 seconds. The cavity was filled with resin cement (Variolink Esthetic, Ivoclar Vivadent AG, Schaan, Liechtenstein), and the restoration was immediately fitted. LED light was used briefly to clean the remaining resin, then applied for 20 seconds to each surface of the restoration to harden it properly (Figure 3). Proximal surfaces were inspected with dental floss, and the remaining resin cement was extracted. The presence of remaining cement was confirmed by a periapical film using the parallel radiography method.

Prosthodontic and periodontal records of the restorations were organized biannually for a period of two years. At the last follow-up, patient satisfaction with aesthetics and function was assessed using the Visual Analogue Scale (VAS).

Prosthetic evaluation

Margin integrity

1. Acceptable standards:

The probe revealed no fractures or grooves along the margin.

There is a slight imperfection along the margin, but no decay; repair is possible but not required.

The probe is positioned only in one direction.

2. Unacceptable conditions:

An edge that is beyond repair.

Discoloration along the pulpal margin of the restoration.
Residual cement.
Loose or broken restoration.
Decay along the entire margin.
Fractured enamel structure.
Surface characteristics
Acceptable conditions:
The surface is smooth.
The surface is moderately rough but can be polished.
Large surface imperfections that cannot be repaired.
A fractured surface.
Extensive porosity.

Periodontal Evaluation:
Gingival pocket depth, plaque index, bleeding index, and gingival index were assessed. Pocket depth was measured using a standardized probe in six tooth areas: distobuccal, distolingual, lingual, mesiobuccal, mesiolingual, and mid-buccal.

Plaque index:
0: No visible plaque.
1: No apparent plaque, but can be confirmed with a probe.
2: Moderate plaque near the gingival margin.
3: Plaque formation on the tooth surface and at the gingival margin.

Survival and Success of Restorations:
Survival was assessed based on marginal fractures, minor imperfections, and polishable roughness; broken enamel, irreparable restorations, and extensive porosity were considered failures.

Patient Satisfaction:
Patient satisfaction was assessed using the Visual Analogue Scale (VAS) at the final follow-up.
Patients were placed in an undisturbed environment and given a scale with 10 horizontal boxes numbered from 0 to 10, then asked to evaluate both the aesthetic and functional aspects of their restorations. Patients were asked to score from 1 (lowest) to 10 (highest) on various factors, including functionality, aesthetic satisfaction, discomfort, ease of oral hygiene, and bleeding.

Statistical Analysis
The data was statistically analyzed using SPSS (IBM SPSS Statistic Version 22, Chicago, Illinois, USA). The Shapiro-Wilk test determined the normality of the data distribution. Normally distributed data was evaluated with one-way ANOVA and post-hoc Tukey HSD tests. The Kruskal-Wallis test was used to assess groups that did not have a normal distribution. The statistical significance level was set at <0.05.

RESULTS

The mean age of those included in the study was 27.98±1.54 years, of which 58.3% (n=35) were female and 41.7% (n=25) were male.

Findings Related to Gingival Pocket Depth
When the pocket measurements of the groups before and 6 months, 1 year, and 2 years after the procedure were evaluated, the post-operative measurements of all groups were statistically similar to preoperative measurements (p> 0.05).

Findings Regarding Patient Satisfaction
Patient satisfaction results showed that there was no significant difference between the groups in terms of function (p> 0.05) (Table 1). However, the endocrown provided significantly more aesthetic satisfaction than the other groups at the end of the 2-year follow-up (p<0.05).
Findings related to the plaque index and the gingival index

Table 1. Patient satisfaction values of composite, fiber-reinforced composite, and endocrown restoration groups in a two-year period

Patient Satisfaction	Composite	Fiber-reinforced composites	Endocrown
Aesthetic	5.89 ± 0.29^{a}	5.70 ± 0.28^{a}	9.10 ± 0.16^{b}
Functional	8.26 ± 0.31^{x}	8.15 ± 0.22^{x}	8.75 ± 0.20^{x}

Different superscript lowercase letters in the same row indicate statistically significant differences between groups. p<0.05; Analysis of variance, Tukey posthoc test

No significant difference was observed between the groups in the measurements regarding the plaque index and the gingival index (p> 0.05).

Findings related to the survival rate and success of the restorations
In our study, two out of 20 endocrowns experienced decementation. One decemented after 6 months, while the other decemented in the 3rd month, was recemented, and then decemented again 5 days later. In the CR group, two restorations had fractures, one tooth was fractured, and one showed slight surface roughness. In the FRC group, one restoration fractured, and one showed slight surface roughness.

DISCUSSION

There was no strong evidence to determine the optimal material or procedure for restoring the coronal part of teeth. The fact that 27% of clinical failures of ETT were connected with tooth fractures backs up the idea that ETT has a considerably higher risk of fracture than vital teeth (8). The primary reason is the reduction of hard tissue during access cavity and root canal preparation. The positioning of the tooth, whether posterior or anterior, influences the final restoration decision, as the loads on the restoration differ in these locations. Literature indicates that the fracture rate of mandibular first molars is twice that of maxillary first molars (9). Additionally, converting an occlusal cavity to a mesio-occlusal-distal (MOD) cavity in posterior teeth significantly reduces fracture resistance (10). Therefore, our study focused on ETT lower first molars with MOD cavities to better assess the strength differences among restorations.

Fracture resistance correlates directly with the remaining tooth structure. Endocrown restorations demonstrated superior fracture resistance compared to traditional restorations. This is consistent with the 5-year success rates of endocrowns, ranging from 77% to 94% (11). However, various factors, including the design, configuration, size, and elasticity of the restoration material, influence the prognosis of post-endodontic restorations. A comprehensive comparison is difficult since endocrowns and composite resin (CR) restorations have different characteristics. Therefore, this study focused on obtaining long-term follow-up data on the performance of restorations in in-vivo environments. Prospective studies with extended monitoring periods are limited due to the costs, material variations, and insufficient patient recall rates. Clinical studies on the outcomes of healed ETTs report annual failure rates ranging from 0% to 5%, but these results are based on follow-ups of only 3 to 5 years (12,13). As a result, longer-term follow-ups could differentiate between restoration options. As a result, longer-term follow-ups are necessary to distinguish between restoration options. According to Opdam et al., a more meaningful comparison of restoration prognosis can be made after 5 to 10 years of observation (14).

Two of the 20 endocrown restorations in this study experienced decementation. Improper polymerization of the cement applied to ceramic restorations can impair polymerization quality, especially when the thickness of the endocrown is excessive (15). The two decementations observed in our investigation could be related to the increased thickness of the restorations, which reduced the polymerization of the resin cement. Another explanation for decementation could be the formation of a sclerotic dentin layer, where minerals accumulate in the dentinal tubules, obstructing them. The hybrid layer in sclerotic dentin is thinner, leading to weaker bonding. Additionally, the resin-dentin interface within the endocrown cavity may degrade over time due to ongoing chemical processes. The varying shape of the cavity makes it difficult to control moisture, minimize shrinkage stresses during polymerization, and eliminate the smear layer during adhesive application. To prevent decementation, clinicians should follow the adhesion protocol and use materials with high adhesion properties, such as lithium disilicate (LD) (16). Also, the pulp chamber floor should be flattened with glass ionomer cement or flowable composite before applying the endocrown. Furthermore, preparing the axial walls of the pulp chamber with a 6° to 12° angle is recommended to minimize debonding (11).

The two-year follow-up of this study revealed no negative impacts on the surface characteristics or margin integrity of the endocrown restorations. Additionally, the survival rate was 100%, consistent with previous studies with follow-up periods of 6, 15, and 36 months (17,18). This success may be attributed to specific characteristics of endocrowns. First, their modulus of elasticity is similar to dentin, allowing for better occlusal stress distribution across the bonded area. In contrast, conventional restorations consist of multiple subunits, such as metal or glass fiber-reinforced supports, ceramic or composite cores, and crowns. This complexity can make load distribution less efficient compared to endocrowns, which, due to their monoblock structure, can better withstand stress (19).

In our study, one tooth and two restoration fractures occurred when assessing the marginal integrity of composite resin (CR) restorations. Additionally, two teeth with CR showed a polishable surface. In the short term, there was no significant difference in the likelihood of tooth loss between ETT restored with CR or an indirect restoration (20). CRs are effective for posterior teeth due to vertical chewing forces and the mechanical anchorage of the pulp chamber. They can also be quickly restored in the mouth and are less abrasive to antagonistic tooth structures compared to ceramic restorations. However, CRs can degrade over time due to hydrolysis, mechanical stress, and leaking of the filler-matrix interfaces, which weaken their mechanical properties. Inadequate polymerization can also compromise the integrity of large CRs. Our study found no significant difference in surface texture between CR and indirect restorations. The surface quality of CRs depends on factors such as the degree of conversion, finishing, polishing, and the composition of the filling material (21). Clinical failure of CRs may result from inadequate fracture resistance or weak resistance to crack progression under functional and para-functional stresses. In our study, CRs fractured more frequently than FRCs. However, the study's null hypothesis was supported because the failure rate of CRs did not differ significantly from that of FRCs. FRCs, especially those with fibers like polyethylene and glass fibers, improve the marginal integrity and fracture resistance of CRs by providing reinforcement beneath the restoration (22). This improvement may be due to the isotropic reinforcement provided by EverX Posterior, which uses irregularly organized short glass fibers to strengthen the tooth in multiple directions. Short fiber fillers, as noted by Garoushi et al., can limit crack development and increase fracture resistance (23). Furthermore, the less rigid E-glass fibers in EverX Posterior offer better adaptability to dentin and CR, while the thixotropic viscosity of FRC ensures it stays in place when inserted into maxillary molars. Consequently, the FRC substructure helps transmit forces from the polymer matrix to the E-glass fibers, enhancing the restoration's durability.,

In the 6-month periodontal evaluation of this study, no statistically significant differences were observed in pocket depth, plaque index, or gingival index. This can be attributed to the fact that the participants were periodontally healthy and maintained good oral hygiene. Additionally, the LD ceramics used for the endocrowns may contribute to a reduced plaque retention rate (24). Furthermore, endocrowns have supragingival margins, which make it easier to control plaque and assess the restoration margins compared to CRs and FRCs (25).

Similar to many studies, the present research showed that endocrowns offer better aesthetics than conventional restorations after two years, based on patient preferences (16,19). This can be attributed to the fact that the morphological features of the endocrowns were designed in a computer environment using thousands of tooth shapes stored in the program's database. Moreover, the LD crystal content and the monoblock structure of endocrowns likely contributed to superior light transmission compared to FRC and CR, enhancing patients' aesthetic satisfaction.

CONCLUSION

Although there was no statistical difference in our study, the use of FRCs under the CRs prevents restoration fractures. All restoration groups had a 100% survival rate over the two-year follow-up period. Endocrowns have become the materials preferred by patients in terms of both aesthetics and durability.

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Authorship contributions
SG and UA created the idea/concept and the design of the study. SG, EÇ and UA undertook the control and supervision of the study. SG and MNBÖ carried out the data collection and processing. SG, UA and MNBÖ performed the analysis and interpretation of the results. EÇ carried out literature review. EÇ and MNBÖ wrote the article. EÇ and UA carried out the critical review. EÇ provided the references. SG collected the materials of the study.

Data availibity statement
The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declaration of competing interest
The authors deny any conflict of interest related to this study. We affirm that we have no financial affiliation, or involvement with any commercial organization with a direct financial interest in the subject or materials discussed in this manuscript, nor have any such arrangements existed in the past three years.

Ethics
Ethical approval for this study was obtained from The Scientific Studies Review and Ethics Board of Gaziantep University (27/10/ 2017, decision number 2017/389).

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