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Endocrown restorations: A review

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Abstract

With advances in adhesive dentistry, endocrowns have emerged as a minimally invasive alternative to traditional methods for restoring endodontically treated teeth with severe tooth structure loss. Unlike traditional post applications, endocrowns are monoblock restorations anchored in the pulp chamber and the remaining coronal tooth tissue. The aim of this review is to evaluate the biomechanical properties, clinical performance, and key factors affecting the success of endocrown restorations in light of the current literature. While traditional post-core applications can weaken the tooth structure and increase the risk of root fractures, endocrowns offer advantages such as lower cost, shorter preparation time, and maximum preservation of tooth tissue. The literature reports that endocrowns exhibit excellent survival rates and adequate clinical performance in molar teeth. However, the higher non-axial (horizontal/lateral) forces and narrower bonding surfaces encountered in premolar and anterior teeth can increase the risk of restoration failure. One of the most important factors affecting clinical success is the preparation design. For optimal retention, the central retention cavity should have a minimum depth of 3 mm and a cervical margin width of at least 2 mm. Adding a ferrule, short axial walls, and a shoulder/chamfer finish line to the restoration design significantly increases fracture resistance. Furthermore, the application of immediate dentin sealing (IDS) protocols improves dentin bond strength and minimizes the risk of debonding. During fabrication, direct methods using composite resins can be used, or indirect methods using CAD/CAM technology with materials such as lithium disilicate, zirconia-reinforced ceramics, polymer-infiltrated ceramic networks (PICN), or PEEK can be preferred. Provided that appropriate cavity design, bonding surface, and material selection are ensured, endocrowns can perform similarly to, or better than, conventional treatments such as inlays/onlays, post-core restorations, or direct composite restorations. As a promising alternative for restoring heavily damaged, endodontically treated teeth, further long-term clinical studies are needed to confirm their overall suitability.

Keywords: Endocrown, endodontically treated teeth, Computer-Aided Design/Manufacturing, CAD/CAM, lithium disilicate, PEEK, dental materials

1. Introduction

The choice of technique and material for restoring endodontically treated teeth with excessive substance loss is currently a controversial issue. Biomechanical changes in teeth affect long-term prognoses (1, 2). The structural strength of a tooth depends on the amount of hard tissue in it and the integrity of its anatomical form. A conservative endodontic cavity space has been found to have minimal effect on the fracture resistance of teeth. Another issue is the deterioration of neurosensory feedback, which may reduce the protection of endodontically treated teeth during chewing as a result of pulp loss (3, 4).

Studies have shown that the main reason for decreased tooth durability is tissue loss. Some researchers have reported that dentin changes, endodontic cavities, and root canal preparation may result in loss of tooth tissue, increasing tooth fragility (5).

The most commonly used restorations for teeth with excessive tissue loss are post-core and full-crown restorations (6). The only advantage of placing a post is that it increases core retention. However, it weakens the tooth structure and increases the risk of root fractures (7). In the event of failure, the tooth is exposed to irreparable fractures, and the invasive nature of such restorations eliminates the possibility of tooth resalvage (8). With the development of adhesive techniques, minimally invasive dentistry has been adopted for the restoration of endodontically treated teeth (9).

Minimally invasive preparations with maximum tissue preservation are now considered the gold standard for restoring endodontically treated teeth (2). Following this logic, endocrowns are applied as a conservative coronal restoration option for endodontically treated incisors (10), premolars (11), and molars (12, 13) with excessive tissue loss. Endocrowns are monoblock restorations attached to the pulp chamber and the remaining coronal tooth tissue (14). Pissis first defined the concept in 1995 (15), and Bindl and Mormann used the term “endocrown” in 1999 (14).

Sedrez-Porto et al., who conducted a meta-analysis and systematic review of endocrown restorations, reported that endocrown restorations performed better than conventional restorations in the studies they reviewed (16). Endocrowns differ from traditional methods in terms of configuration/design, thickness, and changes in the elastic modulus of the materials used. In addition, loss of intact enamel and dentin tissue around the cervical tooth structure is typically found in conventional crowns (17), and the thickness of the occlusal portion of endocrowns is 3–7 mm, while that in conventional crowns is only 1.5–2 mm (18). Considering that the greater the occlusal thickness of the restoration, the higher the fracture resistance of the system, endocrowns are more resistant to occlusal loading than conventional crowns. Furthermore, it has been suggested that intraradicular posts in endocrowns may perform similarly to, or better than, direct composite resin or inlay/onlay restorations (16).

2. Advantages of endocrowns

- Lower cost
- Short preparation time
- More conservative
- Ease of implementation
- Less number of sessions (2)
- They can be used for short teeth in the canal.
- They can be used in the presence of dilacerated roots.
- They can be used in cases with calcified canals.
- They can be used in cases where the interocclusal distance is insufficient.
- They can be used for teeth on which post-application is impossible (12).
- As supragingival restorations can be prepared, they can be listed as protecting the gums.

3. Classification of endocrowns

Endocrown restorations are classified as shown below, according to the amount of tooth tissue remaining after preparation (Figs. 1 and 2).

- **Class 1:** At least two solid walls remain in the tooth after preparation.
- **Class 2:** After preparation, at most one wall of the tooth has more than half the original height of the tooth.
- **Class 3:** After preparation, all the walls of the tooth have less than half the original height of the tooth (19).

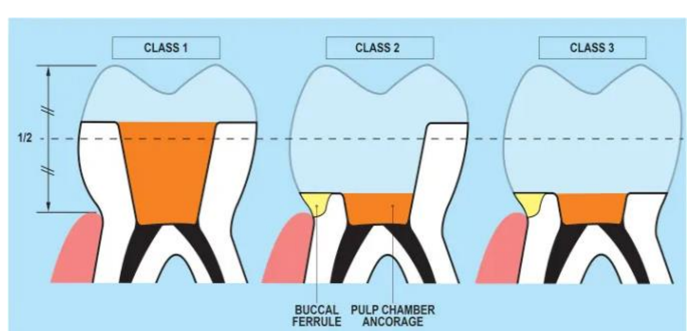

Figure 1. Classification of endocrowns (20).

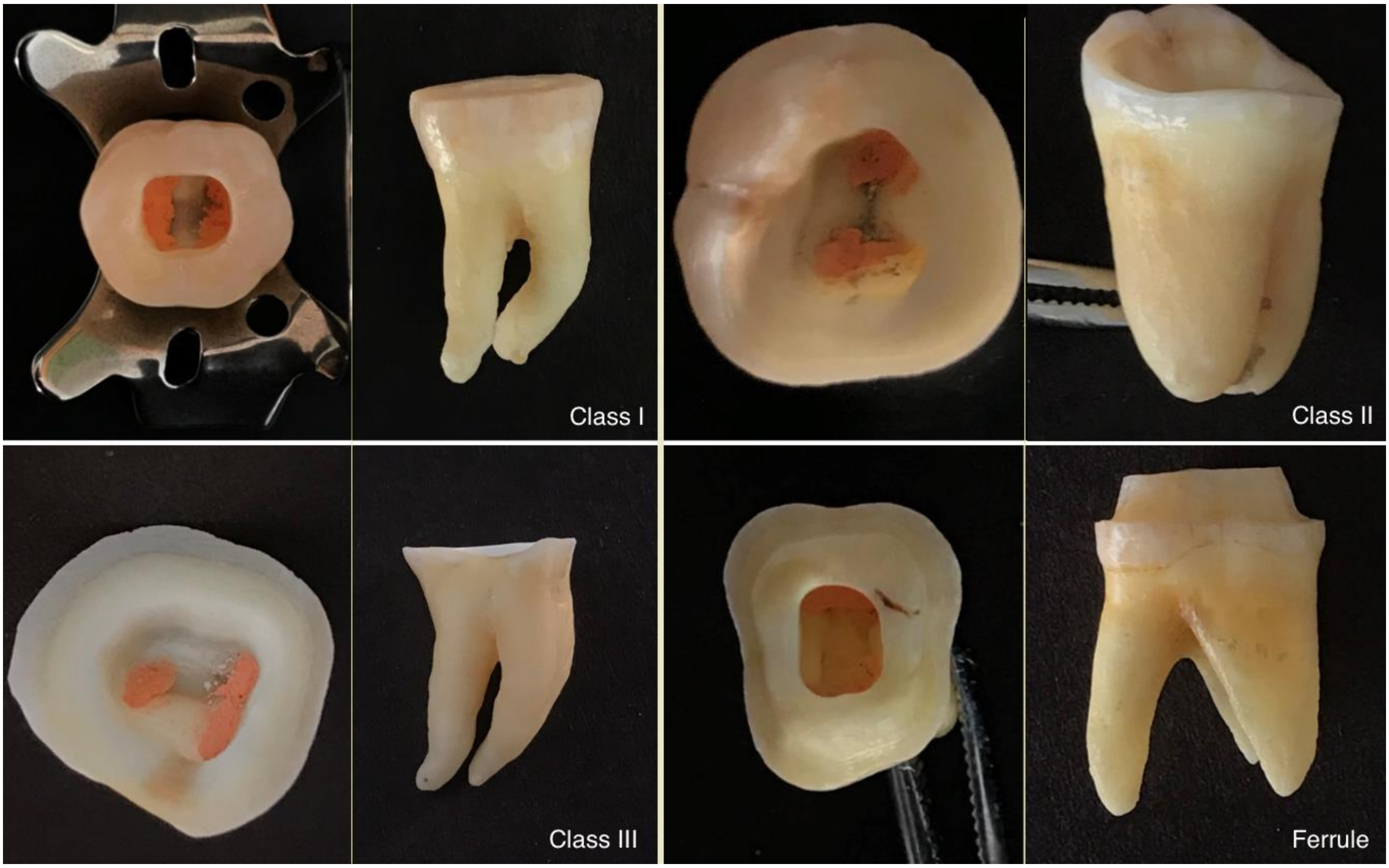

Figure 2. Classified endocrown pictures of mandibular and maxillary molars.

4. Factors affecting the success of endocrowns

4.1. Tooth with endocrown restoration

Molar teeth: The results of in vivo and in vitro studies on the restoration of root canal-treated molars with excessive material loss show that endocrowns are an excellent treatment option. It has been reported that molar teeth restored with endocrowns have excellent survival rates and adequate clinical performance in the short, medium, and long terms. In addition, fewer devastating failures were found in molar endocrowns than in crowns (with or without posts), and most of the failures found in endocrowns were due to the loss of adhesion (71%) (21). Regarding the rate of root fracture, it was 6% for endocrowns and 29% for crowns.

Premolar teeth: Clinical studies have reported a higher failure rate for premolars than for molars (21). In addition, survival rates were found to be significantly lower for molars restored with endocrowns than for premolars restored with crowns (13, 22).

Although premolar endocrowns are easier to obtain than molars, a clinical study by Bindl and Mormann revealed that endocrowns are less successful when fixed onto premolars than onto molars due to the former's smaller surface area. At the same time, premolars require a higher crown height compared to molars (14) and receive more horizontally (non-axially) oriented forces than molars, which may affect fracture resistance (17).

A clinical trial of premolars was stopped after failures occurred rapidly (22). Using maxillary premolar teeth with a central cavity depth of 5 mm in endocrowns led the authors to conclude that "[e]ndocrowns can be considered a conservative, aesthetic, and clinically viable restorative approach for endodontically treated maxillary premolars" (23). Thus, as in a clinical situation, the central retentive cavity depth of the endocrown plays an important role in survival (22). All failures in clinical trials of premolars are due to loss of adhesion and are therefore repairable. Disappointing clinical results regarding the recommendation of endocrowns in premolars contradict the results of in vitro studies (21).

However, Thomas et al., in a systematic review and meta-analysis of the results from individual studies and combined estimates, found no statistically significant difference in the failure rate between molar and premolar endocrown restorations. The available evidence in the study indicates that premolar and molar endocrowns have similar longevity rates and that premolars could potentially be considered candidates for endocrowns (24).

Anterior teeth: The limited number of studies available and conflicting results have made it difficult to draw any conclusion regarding the use of endocrowns as an alternative treatment for incisors. Overall, the number of clinical studies focusing on anterior endocrowns remains low. Long-term prospective studies are needed to confirm the findings (21).

Despite the lack of prior work comparing the performance of anterior and posterior endocrowns, Sedrez-Porto et al. found that endocrowns have a higher likelihood of failure when placed on anterior teeth than on posterior teeth (16). Incisors and/or canines, similar to premolars, are subject to higher non-axial (lateral) forces during function compared to the axial forces encountered by posterior teeth (25). As a result, anterior teeth are subjected to greater stress than posterior teeth, increasing the likelihood of restoration failure. This fact may explain the lack of clinical and in vitro studies on anterior teeth and highlight the need for well-designed studies on this subject (16).

In the systematic review and meta-analysis published by Al-Dabbagh (2020), endocrowns perform better when placed on posterior teeth due to the fact that premolar and molar teeth have larger pulp chambers and receive more axial loads during function (26).

4.2. Preparation of the endocrown cavity

The restoration success of endocrowns is affected by the adhesion surface and the amount of remaining tooth tissue (27). The distribution of the enamel layer in the cervical line, which determines the adhesion surface and the amount of remaining tooth tissue, varies according to the preparation of different marginal forms of endocrowns (28). Endocrowns can be prepared with a butt joint or in steps (Figure 3) (29). While a butt joint endocrown has more tooth tissue and provides less attachment area, a stepped endocrown with a 90-degree shoulder results in a larger attachment area but less dental tissue (28). The presence of enamel remaining in the preparation margins is beneficial for adhesion and is believed to impact load failure in premolar teeth (30).

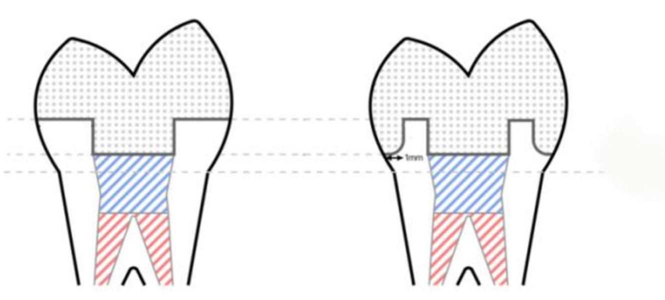

Figure 3. Schematic view of a butt joint and endocrowns prepared with a 1 mm step (29).

In an in vitro study published by Taha et al., it was shown that molar endocrowns with a 1 mm shoulder finish line exhibit a higher mean fracture resistance than those with a butt joint design. The difference was found to be statistically significant. Butt joint designs are prepared parallel to the occlusal plane, providing a stable surface that can withstand compressive stresses. In terms of biomechanics, a restoration allows for stresses and adaptation to the bonded surface. The same forces can be distributed on the cervical step (compression) and axial walls (shear force) (31). Therefore, the addition of short axial walls with a shoulder finish line may have resulted in resisting shear stresses along the walls and better load distribution along the edge, thereby relieving the load on the pulpal floor (32).

In the study by Botto et al., both the butt joint margin and the chamfer finish line were used. The study suggesting a 3 mm occlusal reduction stated that when the buccal and palatal/lingual wall thicknesses are more than 2 mm, the addition of a 1.2 mm chamfer finish line may have a ferrule that can improve the fracture resistance of the teeth and the retention of the restoration (33).

Attempts to add a ferrule to endocrown restorations should not damage the enamel on teeth with margins close to the cemento-enamel junction. In the absence of a ferrule, a concave slope on the peripheral enamel can increase the bonding surface area of the enamel and thus improve the biomechanical behavior of endocrowns (34).

The central retention cavity should have a minimum depth of 3 mm and a cervical margin width of at least 2 mm, which are necessary for both macro- and micro-mechanical retention (24, 32). In their study, Otto and Mormann attributed the insufficient stabilization of endocrowns to minimal pulp chamber extension, which was less than 2 mm (22). Endocrowns are contraindicated in teeth with minimal tooth structure or a short pulp chamber space (35).

Regarding the finish line configuration, endocrowns were placed on non-ferrule prepared teeth in many studies. However, the presence of a ferrule provides greater fracture resistance to teeth restored with endocrowns (31, 36) and those restored with conventional crowns (37, 38). Ferrule insertion attempts should not damage the enamel on teeth with margins close to the cemento-enamel junction. In the absence of a ferrule, a concave slope on peripheral enamel can increase the enamel bonding surface area and thus improve the biomechanical behavior of endocrowns (34). The placement of the supra-gingival margins also remains an important parameter. Isolating the prepared tooth is necessary to ensure optimal adhesion protocols can be applied under a rubber dam (21).

Immediate dentin sealing (IDS) improves dentin bond strength in indirect restorations and may contribute to clinical performance, particularly when located in outline dentin (20, 39). In a 10-year clinical study, only two of 99 (2%) endocrowns cemented with IDS were separated (20). In endocrowns, any intermediate in the pulp chamber can be blocked during the IDS procedure using composite resin, thus preserving the dental tissue (40). When IDS was not used, 14 of 87 (16%) endocrowns were separated in a 7.5-year clinical study. In this study, a direct composite resin cement was used to bond all indirect restorations. A six-minute curing time was used to ensure adequate polymerization.

The authors stated that these adhesive deteriorations occur between the composite and dentin, and the cured composite remains on the surface of the endocrowns (13).

4.3. Preparation of endocrown restorations by direct or indirect method

Endocrowns can be prepared directly using conventional or bulk-fill resin composites or indirectly using computer-aided inspection/computer-aided design/computer-aided manufacturing (CAI/CAD/CAM) technology, such as lithium disilicate, feldspathic ceramic, leucite-reinforced ceramic, zirconium-reinforced lithium silicate, resin composite ceramics, and polymer-infiltrated ceramic network (21).

For endodontically treated teeth without extensive coronal damage, direct composite restorations are primarily indicated for teeth with minimal or moderate tooth structure loss (41). Some evidence suggested that direct and indirect methods show similar results, and they stated that direct restorations should be preferred over indirect restorations because they are more effective and less costly (42, 43, 44). However, the accuracy and skill of the practitioners can significantly influence the decision to repair or replace the direct restoration (45). For example, direct restorations are susceptible to this technique, with greater polymerization shrinkage, marginal discrepancies, microleakage, undesirable close contacts, and a risk of secondary caries (46, 47). On the other hand, indirect restorations (inlay/onlay/endocrown) have a reduced volume of composite shrinkage confined to the resin-adhesion layer, thus increasing the marginal adaptation of restorations (48, 49).

The application technique and the choice of materials used vary. Direct composite restorations are preferred by clinicians for the restoration of root canal-treated teeth due to their good esthetic properties, relatively low cost, ease of use, time savings, and preservation of tooth structures (46, 47). Some in vitro studies have shown no significant difference in the load required to fracture endodontically treated teeth prepared using direct or indirect restorations (47, 50). Later, it was reported that indirect ceramic restorations may pose a higher risk of irreversible tooth fracture (47).

According to the study of Fennis et al., although the initial and 5-year clinical evaluations of both techniques did not show a statistically significant difference, the direct technique was found to be more appropriate, mostly because of the shorter treatment time and lower cost (51).

In the study published by Dartora et al. (2019), the fracture strengths of lithium disilicate (LD), polymer-infiltrated ceramic network (PICN), and direct composite resin endocrown restorations were compared. In the study, it was determined that all groups exhibited similar biomechanical behavior in terms of fracture load and average survival probability. In the same study, the use of indirect restorations (especially for lithium disilicate glass ceramics) resulted in the highest structural reliability (52).

4.4. Materials used in endocrown restoration

Ideally, an endocrown should be manufactured from a material with a low modulus of elasticity (similar to a tooth structure), high mechanical strength, and adequate bond strength to the underlying tooth structure. A modulus of elasticity comparable to dentin helps distribute occlusal forces across the bonded surface and increases fracture resistance, while high mechanical strength helps to withstand occlusal load and resist material breakage (53).

Several studies have compared the different materials available for endocrown restoration (54, 55). Kanat-Ertürk et al. described the potential advantage of using machinable composite resin to produce endocrowns since their elastic modulus is similar to dentin (56). El-Damanhoury et al. reported that teeth restored using nanoceramic resin (Lava Ultimate, 3M ESPE, St. Paul, MN, USA) showed better fracture resistance than teeth restored using lithium disilicate (IPS e.max, Ivoclar, Schaan, Liechtenstein) and feldspathic porcelain (VITA Mark II, VITA Zahnfabrik, Bad Säckingen, Germany) (54). However, in another study comparing nanoceramic resin and lithium disilicate ceramics, no significant difference was found in the fracture resistance of endocrowns restored with these materials and subjected to axial force; better results were obtained with lithium disilicate ceramics when subjected to lateral force (55). Aktaş et al. found no difference in the fracture resistance of endocrowns prepared with feldspathic ceramic (VITA Mark II, VITA Zahnfabrik, Bad Säckingen, Germany), polymer-infiltrated ceramic network (PICN) (VITA Enamic, VITA Zahnfabrik, Bad Säckingen, Germany), and zirconia-reinforced lithium silicate glass ceramic (VITA SUPRINITY PC, VITA Zahnfabrik, Bad Säckingen, Germany) (57). The main difference between these materials is that the rate of irreversible breakage increases as the modulus of elasticity increases. Therefore, an increase in the rate of critical failures occurring in fracture modes can be observed (21). Thus, the nanocomposite resin (Lava Ultimate, 3M ESPE, St. Paul, MN, USA) has the lowest failure rate compared to lithium disilicate-reinforced glass ceramic (IPS e.max, Ivoclar, Schaan, Liechtenstein) (54, 55). Zirconia-reinforced lithium silicate glass ceramics (VITA SUPRINITY PC, VITA Zahnfabrik, Bad Säckingen, Germany) and zirconia (inCoris TZI, Dentsply Sirona, Charlotte, NC, USA) have the highest irreversible fracture rates (56, 57).

El-Damanhoury et al. revealed a higher degree of marginal leakage for nanoceramic resin restorations (Lava Ultimate, 3M ESPE, St. Paul, MN, USA) (54). This can be explained by the thermal expansion coefficient of resins, which is higher than ceramic and dentin due to their composition (80% nano-ceramic particles and 20% resin matrix) (21).

Ghajghouj et al. compared the effects of different restoration designs (2 mm, 3 mm) and different CAD/CAM materials (i.e., lithium disilicate [(IPS e.max CAD, Ivoclar, Schaan, Liechtenstein], zirconia-reinforced glass-ceramic [VITA SUPRINITY PC, VITA Zahnfabrik, Bad Säckingen, Germany], and poly-ether-ether-ketone [PEEK]) in endocrowns on fracture resistance. PEEK endocrowns were found to have higher fracture resistance compared to lithium disilicate- and zirconia-reinforced glass ceramics. Different intracoronal cavity depths (2 mm and 3 mm) had no effect on fracture resistance (58).

When Godil et al. compared the marginal and internal fit of lithium disilicate and PEEK endocrowns, the marginal and internal fit of lithium disilicate endocrowns were found to be superior to PEEK endocrowns. The clinically acceptable marginal space is less than 120 µm. The marginal void values recorded in this study were found to be within the acceptable range for both materials (59).

Regarding the choice of materials used, nanofil composite resins have some interesting properties for endocrown fabrication, thanks to their modulus of elasticity, which is similar to dentin and thus limits irreparable fractures while maintaining high fracture strength. However, a decrease in the elastic modulus increases stress at the interface and reduces stress on dentin, leading to a risk of debonding and separation of the prosthesis (53). Materials with large adhesion values, such as lithium disilicate, may be considered the best choice, as the risk of bonding has been shown to be greater than the risk of fracture. The aesthetic properties of this material are unrivaled with composite resin, which may be an advantage for some patients. Ceramics also age better and have lower plaque retention than composite resins (60).

In another study, maxillary premolar teeth were prepared in different configurations with a butt joint and a 2 mm ferrule + 1 mm chamfer step, and the fracture strengths of the determined groups as glass fiber reinforced (everStickNET, GC Europe N.V., Leuven, Belgium), polyethylene fiber reinforced (Ribbond Ultra THM, Ribbond, Inc., Seattle, WA, USA), and fiberless groups were compared. Maxillary premolar endocrowns were prepared using bulk-fill composite resin (Bioinfinity Esthetic Restorative Composite, Avrupa Implant [Umg Uysal], Istanbul, Türkiye) by direct technique. This study concluded that fiber reinforcement of endodontically treated maxillary premolar teeth restored with direct bulk-fill composite resin endocrowns contributed to fracture strength. Although the glass fiber-reinforced groups were statistically significant compared to the control group, the polyethylene fiber-reinforced groups were not statistically significant (29). However, the very low rates of irreversible fractures in teeth reinforced with polyethylene fiber suggest that polyethylene fibers should be preferred for the reinforcement of direct composite endocrowns in terms of long-term survival (29).

Endocrowns cemented with Variolink (Variolink Esthetic, Ivoclar, Schaan, Liechtenstein) showed similar fracture strength to the control groups (cemented at the same time and with the same cement material), while endocrowns cemented with All-Bond 1 and C&B (Bisco Inc., Schaumburg, IL, USA) or RelyX ARC (3M ESPE, St. Paul, MN, USA) resulted in higher fractures (16).

In the study by Gregor et al. (2014), molar endocrowns (Paradigm MZ 100 composite resin block (Paradigm MZ100; 3M ESPE, St. Paul, MN, USA) and feldspathic ceramic block (Vita Mark II; Vita)) with a thickness of 7.5 mm were cemented using dual polymerizable resin cement (Variolink II, Ivoclar, Schaan, Liechtenstein) and light polymerizable resin cement (Tetric, Ivoclar, Schaan, Liechtenstein). An in vitro study concluded that both materials can polymerize sufficiently when used to cement thick indirect restorations, based on Vickers microhardness (VMH) values of the two resin cements. According to the data obtained in the same study, it has been shown that VMH values are not affected by the restoration material when the opacity degrees and sizes of different materials are prepared to be comparable (62).

Ghajghouj et al. compared the marginal leakage of endocrowns with different restoration designs (2 mm and 3 mm) and cement types (Panavia V5, Relyx Ultimate, and GC cement). Panavia V5 cement had the lowest degree of microleakage, while GC resin cement had the highest degree of microleakage. Different intracoronal cavity depths (2 mm and 3 mm) had no effect on microleakage (58).

5. Conclusion

Endocrowns can perform similarly to or better than conventional treatments (e.g., inlays/onlays, post-core restorations, and direct composite resin restorations). The axial wall and shoulder/chamfer finish line added to the restoration design can increase fracture resistance. Endocrown restorations can be prepared with composite resins using the direct technique, as well as with feldspathic ceramics, lithium disilicate ceramics, zirconia-reinforced lithium disilicate ceramics, leucite-reinforced ceramics, resin composite ceramics, PICN, zirconia, and PEEK using CAD/CAM in the indirect technique. Endocrowns appear to be a promising alternative for restoring heavily damaged and endodontically treated teeth, but further studies are needed to confirm their suitability.

Disclosures

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D.G.; Literature Review – D.G., E.A.; Writer – D.G.; Critical Review – E.A.

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