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Key Consideration in the Construction of Endocrown Restorations: A Review

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ABSTRACT

As a method of tooth restoration, endocrowns have acquired popularity in recent years. Endocrown is one of the treatment options recommended after endodontic treatment. Endodontically treated teeth are more prone to crown failure compared to healthy teeth. This results from its biomechanical preparation. Recent advancements in restorative materials, such as adhesive systems, have reduced the requirement for post-core restoration in endodontically treated teeth. A monoblock ceramic crown is bonded to the remaining tooth structure to provide both functional and aesthetic benefits. This literature review intends to offer a comprehensive summary of the endocrown construction. It focuses on the advantages of endocrown restoration, including the preservation of dental structure and its aesthetic outcomes. This review also highlights the importance of tooth selection, tooth preparation, adhesive techniques, and contraindications in attaining optimal clinical outcomes and long-term restoration success. Endocrowns are a reliable alternative to conventional restorative options, provided that clinicians adhere to the prerequisites and indications outlined for this procedure.

1. INTRODUCTION

Rehabilitation of endodontically treated teeth (ETT) remains challenging due to the extensive loss of tooth structure. Multiple factors, notably periapical condition, tooth position, number of interproximal contacts, occlusal contacts, remaining tooth structure, and type of coronal restoration affect the prognosis of

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endodontically treated teeth. Generally, a direct restoration is considered when there is enough tooth structure and a small access opening. In most cases, after root canal treatment, post-placement is required to offer retention for the core of a tooth that has sustained significant loss of coronal tooth structure.

Post-placement may increase the risk of root fracture, particularly in situations involving an enlarged root canal (Schwartz & Robbins, 2004). Prefabricated posts are typically recommended for canals with a round shape and an adequate thickness of the dentin wall. On the other hand, custom cast posts are used when a significant amount of tooth structure has been lost, such as in wide or noticeably tapered canals. In preparing the tooth for a post, it was reported that 58.3% of the sound tooth structure in the incisor tooth was removed (Hussain et al., 2007). Consequently, the risk of vertical root fracture, perforation, or even cracking of the root during the preparation for post-placement could happen (Aggarwal et al., 2014). Furthermore, a post with high rigidity and a higher modulus of elasticity, such as comparing between a cast post and dentin, may exhibit an increased stress distribution across the post and root structures, promoting post-separation and root fracture (Fokkinga et al., 2006). Other treatment approaches, such as endocrown, have been proposed as an alternative.

Endocrown restoration is defined as a monoblock restoration consisting of both core structures and crown restoration (Pissis, 1995), whereby it requires only a small amount of preparation to restore endodontically treated teeth, which became one of the possible solutions that could assist in restoring severely damaged teeth (El-Damanhoury et al., 2015). Endocrown has been considered as one of the potential treatment options for endodontically treated posterior teeth, particularly molars that have suffered a substantial loss of coronal structure. With the evolution of adhesive systems, endocrown is considered an alternative to conventional post-core crowns due to its minimally invasive preparation approach (Elagra, 2019). Study by Chen et al (2022) showed that the success rate of endocrown restorations was comparable to that conventional crown restorations for endodontically treated posterior teeth. It was claimed that restoring endodontically treated teeth with endocrowns provides pleasing aesthetics, improved mechanical performance, is cost-effective and reduces working time (Fages & Bennasar, 2013; de Carvalho et al., 2018; Dogui et al., 2018). Nevertheless, the preparation design should ensure adequate restoration retention, stability, and structural durability. The objective of this study is to present a thorough review of the critical factors that must be considered in the clinical application of endocrown restorations.

1.1 Advantages

It has been demonstrated that the canal and coronal tissues can be retained and conserved by employing this endocrown preparation procedure (Dogui et al., 2018), which conforms with the current trend towards adhesive and minimally invasive dentistry. The primary benefit of endocrowns is that they do not necessitate further root dentine removal for retention, hence eliminating the possibility of recontamination during obturation (Rocca et al., 2016). Besides, if endodontic treatment is unsuccessful, re-interventions can be conducted more easily (Rocca et al., 2016).

A study investigated the fracture strength of endocrowns against glass fiber post-retained conventional crowns. It was revealed that an endocrown's fracture strength is superior to indirect conventional crowns retained by glass fiber posts with composite filling cores (Biacchi & Basting, 2012). The post was believed to potentially damage the root canal system during drilling, and that invasive preparation is no longer required (Fages & Bennasar, 2013).

Generally, post-components are constructed from materials with varying elastic modulus, such as metals or glass-reinforced fibers with resin composites for the core, followed by a ceramic crown component (Sedrez-Porto et al., 2016). The stiffness discrepancy between dentine, luting cement, and the restorative system may impact stress distribution (the greater the number of interfaces among different

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materials, the lesser the stress distribution). The monoblock concept of endocrowns would withstand further stress loading than the multi-interface nature of conventional restorations (Sedrez-Porto et al., 2016). A rigid post such as a cast alloy post and core has been routinely used. Material like nickel-chromium (Ni-Cr) with a greater modulus of elasticity (188 GPa) (Sano et al., 1994) than dentin (14.7 GPA) (Morris, 1989) may exert greater stress distribution throughout the post and root structures, resulting in post-separation as well as root fracture, given its high rigidity (Fokkinga et al., 2006).

Endocrowns offer several advantages, such as a less invasive and simple procedure, the potential for future root canal retreatment if necessary, as well as reduced chair time and costs for patients (Dogui et al., 2018; Dash et al., 2020; Badr et al., 2021). This restoration also exhibits good performance regarding occlusal forces, aesthetic recovery, and bond strength (Göhring & Peters, 2003). For optimal biomechanical behaviour of the restored tooth, it is believed that preserving intact coronal and radicular tooth structure and maintaining cervical tissue to produce a ferrule effect is essential (Dietschi D et al., 2007).

1.2 Tooth selection

Endocrown restorations obtain macromechanical retention by anchoring to the pulp chamber and cavity margins (Sevimli et al., 2015). Endocrowns are particularly recommended for molars with obliterated, short, dilacerated, or fragile roots. Endocrowns are not recommended in situations where the pulp chamber depth is less than 3 mm or the cervical margin is less than 2 mm wide, and adhesion cannot be guaranteed (Michel & Bertrand, 2013). Endocrown is regarded as the "gold standard" for the restoration of ETT due to its minimally invasive preparations and maximal tissue bio-conservation (Lander & Dietschi, 2008). A challenge in restoring the ETT is the inadequate inter-arch distance (interocclusal space) that might develop from the overeruption of the opposite tooth, leading to insufficient thickness of the ceramic layer on the metal substructures (Biacchi et al., 2013). In this scenario, an Endocrown may be suggested as it does not require an inter-arch distance (Fages & Bennasar, 2013).

It was discovered that as the pulp chamber reduces in size, the structural area of the tooth to be bonded was also reduced. Consequently, this weakens the bonding strength of adhesive system and resin cement. A systematic review and meta-analysis of endocrown restorations on permanent molar and premolar teeth published by Thomas et al., 2020 shows that between the 3- to 19-year follow-up period, the success rate of endocrown restoration on molar teeth ranges between 72.73% to 99.57%, whereas the success rate for premolar teeth ranges from 68.75% to 100%. In this study, it is interesting to note that there wasn't any significant difference in the prevalence of endocrown failure among molars and premolars (Thomas et al., 2020). On the other hand, only a few studies reported on the success rate of anterior or incisor endocrown.

Many authors believe endocrowns on anterior teeth function biomechanically like short post (Waaz, 2020; Badr et al., 2021). A prefabricated post requires additional dentin removal during tooth preparation, compromising the tooth's fracture resistance and post-retention (Sorensen & Engelman, 1990). The tooth may become weaker when prepared to fit the prefabricated post, especially in cases with a short tapered root, for example, on the upper and lower lateral incisors. To avoid this problem, the restoration of endodontically treated teeth with endocrown should be able to increase their fracture resistance by having a short axial wall and shoulder finish line in their preparation design (Taha et al., 2017).

1.3 Tooth preparation design

The conservation of the remaining tooth structure is essential to ensure the longevity of endodontically treated teeth. In general, biomechanical tooth preparation involves the strength of the tooth, which is dependent on the hard tissue and anatomic form of the tooth. After coronal restoration, the preparatory

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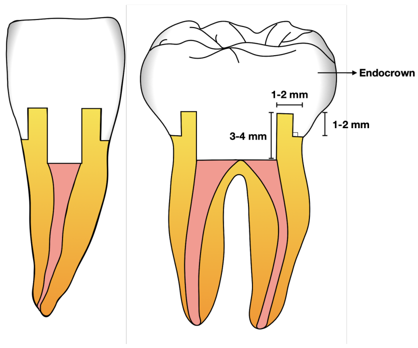
design should guarantee adequate retention, structural durability, and stability. The concept of endocrown tooth preparation is that it only invades the pulp chamber, and no other preparation is required (Elagra, 2019). It obtains stability and retention from the cavity and pulpal chamber. It has been demonstrated that both the canal tissues and the coronal tissues can be retained and conserved by employing this procedure.

Dentinal walls extending coronally from the crown margin form a ferrule, which, when encircled by a crown, provides a protective effect by significantly reducing stresses within a tooth, known as the "ferrule effect" (Juloski et al., 2012). As a result of the extension of the dentinal walls structure, the crown's resistance form is elevated (Sorensen & Engelman, 1990). Concerning the prognosis of endodontically treated teeth, the ferrule effect is generally believed to be necessary for tooth stabilization (Schwartz & Robbins, 2004).

Endocrown fracture resistance can be increased by designing their preparation with a short axial wall and shoulder finish line (Taha et al., 2017). Einhorn et al., 2017 investigated the failure strength in the absence and presence of 1 mm or 2 mm ferrule. The study focusing on extracted molar teeth indicates that higher failure load resistance was observed in ferrule-containing endocrown compared to endocrown without ferrule (Einhorn et al., 2017). An in vitro study concerning the influence of fatigue resistance on variation ferrule of endodontically treated molar teeth was conducted. They concluded that failure mode favoured the 2 mm or no build-up (endocrown) (Magne et al., 2014). On the other hand, flat overlays, which rely solely on adhesive retention and have no retentive shape, are discouraged from use due to the early debonding (Rocca et al., 2017).

The biomechanical behaviour of endodontically treated teeth using different extensions of endocrown inside the pulp chamber of extracted mandibular teeth was evaluated. They suggested increasing the pulp chamber’s length (3mm and 5 mm) to improve mechanical performance (Dartora et al., 2018). Several other studies also indicated that the cavity depth needs to be at least 3.0 mm (Fages & Bennasar, 2013; Imen, 2018). Badr et al., 2021 looked at the effect of extending the endocrown into the pulp space and the effect of the ferrule on the fracture resistance of anterior endocrowns made of nano-ceramic resin blocks. They concluded that neither long nor short extensions of the endocrowns in the pulp space made the teeth stronger against breakage. The Figure 1 below show general recommendations for endocrown preparation (Dash et al., 2020; Waaz, 2020; Badr et al., 2021):



- Butt joint margins that are 1 to 2 mm wide and 90° around the margin.
- Ferrule height of 1 to 2 mm circumferentially.
- The cervical margin must be supragingival, and region of aesthetics demand a subgingival margin.
- The cavity depth ranges from 3 to 4 mm.
- The internal transitions that are smooth and a pulp chamber floor that is reasonably flat, slot with radicular areas that have been sealed off.

Fig 1. Brief illustration on endocrown restoration design.

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1.4 Material selection

Recently, a wide selection of machinable materials have evolved and is suitable to produce an endocrown prosthesis, such as material containing lithium disilicate. Lithium disilicate, or LS_2, was produced in the 1990s with the commercial name IPS Empress 2 (Ivoclar Vivadent, Schaan, Liechtenstein). The manufacturer claimed the materials are more aesthetic, have better adhesive properties, and superior mechanical qualities (Awada & Nathanson, 2015; El-Damanhoury et al., 2015). In addition to their aesthetic features, lithium disilicate-reinforced ceramics are currently being developed to improve flexibility with a fracture strength of 400 MPa (Kanat-Ertürk et al., 2018).

Some authors favour composite resins and lithium disilicate as the material of choice, with lithium disilicate having more excellent resistance to fracture than the composite resin (Bankoğlu Güngör et al., 2017; Dejak & Młotkowski, 2018). Findings from the in vitro study shows that lithium disilicate endocrowns have a clinically permissible marginal gap (<120 μm) (Godil et al., 2021). Composite resins, on the other hand, can be repaired in the mouth, in contrast to ceramic restorations, and are less abrasive to the tooth structures they oppose (Magne et al., 2010).

Newer hybrid CAD/CAM materials can be divided into infiltrated ceramics and silicate ceramics. Polymer-infiltrated ceramic network (PICN), also known as Vita Enamic, is a hybrid infiltrated ceramic material developed by the VITA company (VITA Zahnfabrik, Bad Sackingen, Germany). This material is produced by infiltrating a porous ceramic-based structure with a monomer mixture and then curing the structure (polymerization). Compared to traditional ceramics, these hybrid materials are typically less brittle and more flexible (Awada & Nathanson, 2015). Additionally, precise margins with fewer faults and abnormalities were seen during the milling process, which improved restoration longevity when just minor tooth preparation was required (Awada & Nathanson, 2015). Because of the particular composition of resin nanoceramic, the material has a modulus of elasticity (12.8 GPa) comparable to dentine (El-Damanhoury et al., 2015). Also, concerning some CAD/CAM ceramics, resin nanoceramic restorations exhibit fewer crack propagations and offer superior fracture resistance.

1.5 Adhesive

The cementation method impacts the success of endocrown restorations. Hence, an appropriate bonding is critical to enhance the mechanical performance and durability of the endocrown restoration during oral function (Gregor et al., 2014). A clinical experimental study proved that using hydrofluoric acid etching and silanizing the glass-ceramic could improve the micromechanical interlocking and chemical bonding of the resin cement (Politano et al., 2018).

Several types of dual-cured resin cement have been suggested to lute the endocrown material, such as RelyX Ultimate (3M ESPE, St. Paul, Minn), and Panavia V5 (Kuraray Noritake) (Ghajghouj & Taşar-Faruk, 2019). Furthermore, an in vitro study was conducted to assess the microleakage in endocrowns with three distinct types of dual-cured resin cement: Panavia V5, RelyX Ultimate, and GC cement. It was found that the lowest level of microleakage was exhibited with Panavia V5 cement, and the highest with GC cement (Ghajghouj & Taşar-Faruk, 2019). It was discovered that Panavia V5 cement contains hydrophilic aliphatic dimetracrylate rather than phosphate or hydroxyl groups, as well as alkaline fillers, which explains why it achieved the lowest water absorption (Müller et al., 2017). This finding is in agreement with the study done by Ghajghouj & Taşar-Faruk. In addition, it was revealed that Panavia V5 exhibited lower microleakage over RelyX Unicem and GC cement at both enamel and dentine margins. This distinction may be associated with differences in the pH of acidic primers used by those cement monomers (Trajtenberg et al., 2008).

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Recently, composite resin has gained popularity as luting cements to increase bond strength with the tooth surface (Giannini et al., 2015; Nikaido et al., 2018). The combination of a two-step self-etching technique with a low-viscosity composite resin such as Clearfil Flow FX (Kuraray Medical Inc., Tokyo, Japan) produces optimal adhesion (Udo et al., 2007). The wear resistance and physicomechanical properties of composite resin are superior to those of a standard dual-cured resin cement with a lower filler percentage (Politano et al., 2018). Several studies have found that the micro-tensile bond strength of composite resin used in conjunction with such a two-step self-etch adhesive are significantly higher than that of the standard dual-cured resin cement (Sarr et al., 2010; Kameyama et al., 2015).

1.6 Contraindication

Application of endocrown might not be appropriate in cases where severe dental tissue reduction has occurred, for example the finish line margin of the endocrown is below the cementoenamel junction. A higher risk of tooth fracture may occur, as well as a reduction in retention form of the restoration.

Therefore, restoring the endodontically treated teeth through conventional methods would be more suitable (Zhu et al., 2017). In cases where there is evidence of significant functional and lateral stresses, such as steep occlusal anatomy, parafunctional habit, or wear facets, the treatment of choice is a conventional full-coverage crown, either with or without a post (Atash et al., 2017).

Normally, premolars, incisors and canines are subjected to greater non-axial forces during function compared to more axially directed forces that posterior teeth perceive (Sedrez-Porto et al., 2016). As a result, the former would be subjected to higher stresses than the latter, resulting in an increased likelihood of failure. Hence, proper patient and tooth selection is essential in achieving a favourable clinical outcome with endocrowns.

2. DISCUSSION

Several issues concerning the outcome measures for conventional crowns have been questioned in modern dentistry. Material interfaces with various modulus of elasticity constitute the critical vulnerability of restorative systems because the mismatch between toughness and stiffness affects stress distribution (Sedrez-Porto et al., 2016). Endocrown restorations provide the benefit of reducing the number of interfaces that the restorative system needs to handle, as they are made from a single solid material block. The elimination of the post and core has resulted in a significant reduction in the total number of interfaces. Also, when compared with the conventional crown in a badly broken-down tooth that needs additional support, endocrowns are much simpler to fabricate and require fewer expenditure and time in a clinical setting.

Endocrowns conserve root tissue and prevent excessive pulp chamber preparation following their anatomical shape. However, the biomechanics of molars and incisors are different. The incisor teeth have a 10.5 mm crown height and 7.0 mm width relative to the molar, which measures 7.5 mm in height and 10.0 mm in buccolingual diameter in the cervical area (Nelson & Ash Jr, 2010). The bending moments exerted on the incisors' restorations are greater than those exerted on the molars due to the equilibrium of a lever. The definition of bending moment is a calculation of the applied force multiplied by the distance of the load application and the fulcrum line (Marchionatti et al., 2017). Additionally, the bonding area of endocrown for anterior teeth is typically 30 mm^2, which is significantly less than the bonding surface in molars (60 mm^2) and may negatively impact the retention of such restorations (Nelson & Ash Jr, 2010).

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The primary function of ferrule is to increase tooth structure integrity, which allows for higher force dissipation and load distribution. Additionally, the ferrule may provide a more stable base for the endocrowns, resulting in increased resistance to rotation with decreased necking of the restoration (Badr et al., 2021). An in vitro study reported that endodontically treated teeth with post/core restored maxillary central incisors had a more extensive variety of failure loads when part of a ferrule is lost (such as missing facial or palatal portions). The strength may be decreased to a below clinically acceptable load-bearing level. This might be due to the reduced number of ferrule reinforcing the body of the teeth. However, ferrule preparation may lead to the destruction of sound enamel and dentin tissues, which are necessary for successful bonding (Skupien et al., 2016).

In reality, it is difficult to achieve ideal bonding protocols within the root canal, and it is unavoidable that the resin-dentin contact would deteriorate with time. The unique anatomy and physiology of the root canal system raised some other problems throughout the adhesive application procedure. These concerns include proper control of the moisture level and the smear layer (Mjör et al., 2001). Furthermore, the anatomical structure of the root canal system creates a surface geometry that is particularly unfavourable for releasing such shrinkage stresses that occur during the polymerization of the resin cement. When restoring the tooth with an endocrown, most of the interface occurs on the dentin surface, and dentin adhesion is deemed weaker than enamel adhesion (De Munck et al., 2012).

In modern dentistry, CAD/CAM milling enables the fabrication of one-piece endocrown with precise replication of the root canal compared to prefabricated glass fiber post, whose shapes cannot be altered and may be unsatisfactory, especially for severely broken teeth with large root canals. In addition, CAD/CAM milling lowered the thickness of the cement layer. Hence, it does not necessitate the usage of composite resin cement, including customized fiber posts and cores with three or four interfaces, which contribute to higher failure rates and lower survival rates (Sedrez-Porto et al., 2016). Additionally, the restorations can be made and delivered in a single appointment which is time-saving compared with the post and core construction (Tay & Pashley, 2007).

It has been demonstrated that endocrowns are more susceptible to debonding than they are to fracture (Rocca et al., 2017). Selecting materials with the highest adhesion values, such as lithium disilicate, is the most prudent course of action. Therefore, ceramics with a high modulus of elasticity, such as zirconium or aluminium oxide, should not be practised (Zarone et al., 2006). It will generate a maximum high-stress concentration at the interface between the restoration cement and the dentin. In addition, these materials don't bond well with dentin as effectively as enamel. In conclusion, it is recommended to use ceramics made of lithium disilicate for endocrown because they possess the necessary level of strength and can adhere to enamel dental tissues.

The review focuses on the applicability of endocrowns. Most of the recent studies explored the usage of endocrowns to restore endodontically treated posterior teeth such as molars and premolars. They found that endocrowns performed similar, if not exhibiting better fracture strength than conventional treatment with intraradicular posts, direct composite resin, or inlay/onlay restorations (Sedrez-Porto et al., 2016). On the other hand, there was extremely limited information concerning the anterior endocrown. Future studies should emphasize either clinical assessment or in vitro investigations of anterior endocrown.

3. CONCLUSION

In conclusion, endocrowns offer a viable restoration option for endodontically treated teeth, provided that factors influencing tooth fracture such as load-bearing capacity are considered, as these are the main failure mechanisms. Both in vitro and in vivo studies confirm that endocrowns are a practical and effective restorative treatment. They present a significant alternative to conventional post-core crown systems by

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preserving natural tooth structure while offering aesthetic and mechanical benefits. Endocrowns made from lithium disilicate ceramic are more resilient to physiological stresses and are generally more repairable. Moreover, lithium disilicate endocrowns have shown superior fracture resistance compared to fiber-reinforced post-and-core crowns. Hybrid materials also emerge as an excellent choice for endocrowns, owing to their balance of mechanical strength and aesthetic appeal.

CLINICAL SIGNIFICANCE

Using a standard post and core retained crown system is regarded as the most common practice in the clinic in treating teeth with a significant loss of coronal tooth structure. However, during its preparation, a substantial amount of the sound tooth structure is removed. The endocrown system provides an excellent alternative to restore teeth with severe loss of coronal tissue by utilizing minimally invasive preparation. Thus, allowing a maximum tissue bio-conservation.

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CONFLICT OF INTEREST STATEMENT

The authors declare they have no conflicts of interest

AUTHORS' CONTRIBUTIONS

Nazrin Rosli carried out the research, wrote and revised the article. **Nik Zarina** conceptualised the central research idea and provided the theoretical framework. **Abu Razali** providing the concept of digital and latest advancement in dentistry. **Nik Zarina** and **Nik Rahayyu** designed the research, supervised research progress; **Nik Zarina** anchored the review, revisions and approved the article submission.

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