REVIEW ARTICLE

A Thorough Analysis of the Endocrown Restoration: A Literature Review

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Abstract

Aim: The aim of this literature review is to determine whether endocrowns are a reliable alternative for endodontically treated teeth with extensive loss of tooth structure, the indications and contraindications of this restorative choice, the principles that should be followed for tooth preparation and which material is most appropriate for endocrown fabrication.

Background: Rehabilitation of endodontically treated teeth with severe coronal destruction has always been a challenge for the dental clinician. Until recently, the fabrication of a metal-ceramic or all-ceramic full-coverage crown along with a metal or glass fiber post has been the "gold standard" proving its efficacy via numerous clinical studies. With the development of CAD/CAM technology and the evolution of dental materials, new minimally invasive techniques have been introduced with less need for adjustments and less incorporation of structural defects. One of them, the "monoblock technique," proposed by Pissis in 1995, was the forerunner of endocrown restoration, a term used by Bindl and Mörmann to describe an all-ceramic crown anchored to the internal portion of the pulp chamber and on the cavity margins, thus obtaining macromechanical retention provided by the axial opposing pulpal walls and microretention attained with the use of adhesive cementation.

Review results: Endocrowns require a decay-oriented preparation taking advantage of both the adhesion and the retention from the pulp-chamber walls, they are strongly indicated in endodontically treated molars in cases where minimal interocclusal space and curved or narrow root canals are present and they should be manufactured from materials that can be bonded to the tooth structure.

Conclusion: Endocrowns are a reliable alternative to traditional restorative choices, given that the clinicians respect the requirements and indications describing this technique.

Clinical significance: Traditional restorative techniques demanding tooth substance removal and minimizing the opportunity for reinterventions should be reconsidered.

Keywords: Endocrowns, Endodontically treated teeth, Literature review, Restorative dentistry.

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Background

Loss of dental substance, not only due to carious disease but also as a result of the access cavity for endodontic treatment, weakens an endodontically treated tooth. According to a study by Reeh et al.,[1] loss of the marginal ridges reduces dental resistance by 63% on account of the rupture in the continuity of the peripheral circle of the tooth, which may result in flexion and thus in microfractures or microinfiltration creating gaps in the edges of the restoration.

Following removal of the pulp tissue, a deterioration of the tooth's neurosensory feedback system is observed, something that seems to reduce its protection against masticatory forces.[2]

Water loss concerns only free water and not the water bound to the collagen. According to Papa et al.,[3] it accounts for 9% or less of total water, so the loss is not significant. Furthermore, Sedgley and Messer[4] have shown no change in the elastic modulus or hardness of dentin after endodontic treatment and according to Huang et al.,[5] there is no significant loss in resistance to traction and compression after a tooth has been endodontically treated. The classical approach for the preparation of an endodontically treated molar with a post and core involves widening of the anatomically complex system of canals, which in these teeth are narrow, sometimes curved with variable angulation.[6] Such a restoration results in a 58.3% loss of tooth structure,[7] not to mention the fact that it involves a risk of accidental root perforation.[8] Studies have confirmed that endodontically treated teeth restored without posts have similar fracture resistance and failure modes compared with those with posts, which suggests that posts are not necessarily required.[9] It has also been shown that anchorage of the crown only within the pulp chamber provides satisfactory clinical retention.[10]

This along with the fact that restorative dentistry stands against the wastage of tooth tissue, makes endocrowns an appealing alternative. Pissis[7] was the forerunner of endocrown restoration, a term used by Bindl and Mörmann[10] to describe an all-ceramic crown anchored to the internal portion of the pulp chamber and on the cavity margins, thus obtaining macromechanical retention provided by the axial opposing pulpal walls and microretention attained with the use of adhesive cementation.[11] However, even if literature suggests that endocrowns may perform similarly or better

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than the conventional treatments using intraradicular posts, direct composite resin, inlay/onlay restorations[12] and in comparison with the abovementioned they constitute a simple and quick procedure, when it comes to practical application, few professionals feel confident to proceed to this technique.[13]

Review Results

Preparation

In general, endocrowns have a decay-oriented design concept.[14] General guidelines for endocrown preparation include the following[7,15,16]

- A 2- to 3-mm cuspal reduction –90° circumferential butt joint margins with a width of 1 to 2 mm.
- All cervical margins placedas supragingivally as possible.
- An occlusal divergence of 5 to 7° in order for the coronal pulp chamber and the endodontic access cavity to be continuous.
- Gutta-percha removal to a depth not exceeding 2 mm, thus taking advantage of the saddle-like anatomy of the cavity floor.
- Smooth internal transitions and a relatively flat pulp chamber floor with sealed radicular spaces.

It is supported that the overall reduction in the height of the occlusal surface depends on the restorative material. More precisely Rocca and Krejci[17] recommended an overall reduction of 1 to 1.5 mm from the occlusal plane when resin composite is used, taking advantage of the material's elastic modulus and stress absorbing properties similar to those of dentine. On the other hand, Fages et al. suggested at least 2 mm of reduction in the axial direction, when a monoblock ceramic material is used.[16]

The addition of a uniform or no uniform ferrule to preparation increases the dentine surface available for bonding,[18] but it has its drawbacks. Namely, according to Einhorn et al.,[19] the addition of ferrule would enact sufficient dentine removal of the endocrown preparation, so that the entire complex would be weakened. Furthermore, areas of reduced dentine wall thickness may result in overmilling of the intaglio features of that area due to the limitations of the milling bur diameter.

There are no definitive guidelines concerning the pulp chamber extension depth required for adequate retention and resistance form. One report suggests that a 2-mm extension into the pulp chamber is sufficient.[20] Ghajghouj and Tasar-Faruk[21] evaluated the biomechanical behavior of endodontically treated teeth restored using different extensions of endocrowns inside the pulp chambers and concluded that the greater extension provided better mechanical performance. A 5-mm extension presented lower intensity and a better stress distribution pattern than a 1-mm extension which presented a low fracture resistance and a high possibility of rotating the piece when in function.

Since adhesion to dentine remains a clinical challenge,[22] the literature strongly recommends the immediate dentine sealing technique which improves adhesion to dentine and minimizes microleakage.[23] Sometimes, it is also necessary to fill irregularities in the pulp chamber walls with resin composite in order to remove retentive areas that prevent sliding and adjustment of the piece.[16] The main requirement is for all surfaces (walls and cavity bottom) to be visible from one point (occlusal view), i.e., no undermined or divergent parts of the cavity are allowed.

As opposed to conventional crowns, an endocrown as an adhesive restoration does not require the margins to be placed subgingivally, resulting in less gingival inflammation and recurrent caries.[24]

Materials

Since endocrown retention mainly lies in bonding, it is crucial to use prosthetic materials that can be resin bonded to tooth tissues.[25] Initially, it was supported that endocrown restorations should only be made of reinforced ceramics, because they are adequately resistant to displacement thanks to their adhesive properties.

Among machinable materials, lithium disilicate based ceramics have aesthetic and mechanical properties, already substantiated in the literature.[20] Zirconia-reinforced silicate ceramic endocrowns demonstrate a high percentage of nonrestorable mechanical failures, something that adversely affects tooth survival.[26]

Adhesive failure is the main failure mode in endocrowns.[15] In lithium disilicate restorations, stress at the adhesive interface is slightly higher than leucite-based ones. Leucite-reinforced glass ceramic has been evaluated as an alternative to lithium disilicate for endocrown restorations, since, regardless its inferior mechanical strength, its bonding strength to dentine is similar to that of lithium disilicate.[27] For other authors, lithium disilicate and composite resins are the materials of choice, with the lithium disilicate being more resistant to fracture than composites.[28] On the other hand, composite resins are repairable in the mouth and not as abrasive to opposing tooth structures as ceramic restorations.[29] Moreover, their higher deformability could enable restorative systems to transfer limited strains to compact and spongy bone of the tooth socket.[30]

Many new CAD/CAM hybrid materials have been introduced in the market combining, according to their manufacturers, the properties of both composite resins and ceramics. In a recent study by Awanda and Nathanson,[31] it was reported that hybrid materials tend to be less brittle and more flexible compared to conventional ceramics. In addition, more accurate margins could be milled, while fewer flaws and irregularities observed optimize the restorations in case of minimal tooth preparation.[31] The unique composition of resin nanoceramic allows the material to have a modulus of elasticity (12.8 GPa) similar to that of dentine.[20] Resin nanoceramic restorations show less crack propagations and provide better fracture resistance than some of CAD/CAM ceramics.

In a recent study, Zoidis et al.[32] proposed polyetheretherketone (PEEK) as an alternative framework material for endocrown restorations. They demonstrated that the elastic modulus of the PEEK framework (4 GPa) veneered with indirect composite resin could dampen the occlusal forces thus protecting tooth structures better than ceramic materials. However, further long-term clinical evidence is required.[32]

Material characteristics may influence margin stability. Resin-based materials having a polymer matrix may allow the milling of thinner structures.[33] In contrast, the glass matrix of ceramic materials is brittle and ceramic crystallites may easily break out if the pressure of milling instruments is applied.[33] The larger the crystallites the more likely this may occur.[33] It has been reported that resin-based composite material restorations have higher marginal stability than ceramic materials.[34] However, some authors state that resin composite materials appear to have higher microleakage during time.[20]

Premolars

The use of endocrowns for premolars is not as well documented as for molars.[12] It is believed that the smaller dental structure area of the pulp chamber and consequently of the adhesive surface of premolars limits the bond strength of adhesive systems and resin cements.[12] The configuration of premolar crowns in which the

height of the piece is greater than their width may create a long lever arm, increasing the risk of adhesive rupture and displacement.[35] The lever effect is pronounced by the nonaxial forces, less present in molars but predominately received by premolars, resulting in deterioration of their fracture resistance.[13] Salis et al.[36] described a higher prevalence of fractured maxillary premolars compared with mandibular ones. Therefore, the morphologic design of the endocrown on maxillary premolars should have a flatter occlusal table so as to reduce the height of the crown and the cuspal inclines, resulting in shallower fissures to minimize cuspal deflection and the risk of fracture during mastication.[36]

Adhesive Luting

Luting procedure influences the effectiveness of endocrown restorations, with proper bonding being paramount to extend the mechanical performance and longevity of the restoration during oral function.[37] A recent *in vitro* study by Ghajghouj et al.[21] evaluated the microleakage in endocrowns using three different types of resin cement (Panavia V5, Relyx Ultimate, GC cement). Panavia V5 was found to have the least microleakage, a result in agreement with a study by Muller et al.,[38] which reported that Panavia V5 cement contains hydrophilic aliphatic dimetracrylate and not phosphate or hydroxyl groups, or alkaline fillers, which explains why it attained the lowest water absorption. Similarly, Trajtenberg et al.[39] showed that Panavia V5 had less microleakage than Relyx Unicem and GC cement at both the enamel and dentine margins, which may be due to differences in the pH of the acidic primers between the two cement monomers. Gregor et al.[37] showed that the VMH values of the dual-polymerizable resin cement and the light-polymerizable restorative composite resin irradiated for 3 × 90 seconds with high-irradiance LED lamp through 7.5 mm-thick endocrowns reached at least 80% of the control VMH values. This means that both materials can be adequately polymerized when they are used for luting thick indirect restorations.[37]

Advantages

From a biomimetic perspective, the preservation of tooth structure is of utmost importance in maintaining the balance between biological, mechanical, adhesive, functional, and esthetic parameters.[40] The main advantage of endocrowns is related to the fact that it does not require root dentine removal in order to gain retention, thus preventing the risk of recontamination during disobturation.[41] Additionally, during an endodontic failure, reinterventions can be performed more easily.[41]

The saddle shaped pulp floor in molars along with the quality of the adhesive materials provide good stability, when conditions are met[16] and so additional preparation is not needed.[42] According to Fages and Bennasar,[16] this is the reason why a post, which may weaken root canals due to tooth tissue loss during drilling, is no longer needed.

Conventional restorations are fabricated with materials of different elastic moduli, i.e., metals or glass-reinforced fibers for the post portion and resin composites/ceramics for the core/crown portion.[12] Considering that the stiffness mismatch between dentine, luting cement, and restorative system may influence stress distribution (the higher the number of interfaces between distinct materials, the lower the stress distribution), the monoblock nature of endocrowns would support more stress loading than the multi-interfacial nature of conventional restorations.[12]

What is more, the supragingival margins facilitate plaque control, clinical inspection, and preservation of periodontium with minimal involvement of the biological width.[43]

Indications

When up to one half of the coronal tooth structure is missing, complete occlusal coverage is achieved conservatively using an endocrown.[44] Endocrowns are indicated when there is excessive loss of coronal dental structure and limited interocclusal space, something that makes it impossible to obtain sufficient ceramic thickness over the metal or composite core.[13] They are especially indicated in cases of inadequate clinical crown length and extensive loss of dental tissues in which an adequate ferrule cannot be applied.[10] Last but not least, endocrowns may be the solution to limitations regarding the use of intra-radicular posts, such as short or curved roots, calcified or narrow root canals, fracture of an instrument.[16] Regarding premolars, endocrowns are indicated when the cementation surface area is sufficient, meaning when supragingival walls of 1 to 2 mm height and at least of 2 mm thickness are present and the pulp chamber is at least 3 mm deep.[16] However, this approach requires the presence of healthy cervical enamel so that adhesive procedures can be more effective.[45] Besides, according to a study by Govare and Contrepois,[46] all failures in clinical studies on premolars were due to loss of adhesion and hence were repairable.

Contraindications

In case of severe dental tissue removal in which after preparation the finish line of the endcrown is completely below the cement-enamel junction, the use of an endocrown may not be appropriate because of the increased risk of tooth fracture and the decreased retention of the restoration. Hence, in this case, restoring the endodontically treated tooth with the conventional way would be more proper.[45]

Furthermore, when there is evidence of increased functional and lateral stresses, as evident with steep occlusal anatomy, wear facets, or parafunction, full-coverage crown with or without post is the treatment of choice.[18] Similarly to premolars, incisors, and canines receive higher nonaxial forces when compared to the more axially oriented forces that posterior teeth face during the function.[12] So, the former would receive greater stresses than the latter, increasing the chance for failure. This may explain the lack of clinical and *in vitro* studies on anterior teeth. In any case, case selection is critical for ensuring clinical success with endocrowns.[17]

Discussion

The material interfaces with different moduli of elasticity represent the weak point of restorative systems, as the toughness/stiffness mismatch influences the stress distribution.[47] Moreover, many classical indications for conventional crowns are nowadays questioned.[48]

The restorative procedure performed with the conventional crown, the resin composite filling core, and the glass fiber post attempts to reproduce the biomechanical behavior and the esthetics of the enamel as well as the resilience of the dentine. Endocrowns preserve root tissue and limit internal preparation of the pulp chamber respecting its anatomic shape. They use ceramic throughout the entire extension of the cavity; however, they do not mimic dentinal tissue mechanically because of its rigidity.[20]

Ideal bonding inside the root canal is still a challenge and the degradation of the resin-dentin interface with time is inevitable. Besides, the peculiar anatomy of the root canal intensifies some other concerns during the adhesive application, such as moisture control or smear layer management.[49] Moreover, the anatomy of the canals offers an extremely unfavorable surface geometry for the relief of the

shrinkage stresses developed during resin cement polymerization. The C-factor (bonded/unbonded surfaces ratio) in a long and narrow root canal can exceed 1,000, hindering any resin flow during hardening.[50]

Clinical studies showed that the bonding system was retained on the intaglio surface of loosened endocrowns and failed at the dentine interface. Several phenomena can account for this situation. First, the presence of sclerotic dentin in the pulp chamber can result in poorer adhesion than with sound dentin. Then, the high elastic modulus of some materials, such as ceramic may transmit undamped stresses at the tooth-to-material bonded interface. Finally, when the residual height of the walls is low (less than 2 mm), this could also have a negative impact.[46]

Due to the risk of root fracture when using a post and core buildup approach, the direct bonding of an all-ceramic restoration to the residual tooth structure of nonvital tooth appears advantageous.[48] However, in teeth with almost no coronal tooth substance left, a post and core buildup with resin-based composite having physical properties close to those of dentine could be more favorable.[51]

Ferrule, typically found in conventional crowns, described as a "bracing mechanism" of the restoration around the cervical tooth structure,[52] may cause the loss of sound enamel and dentin tissues that would be important for proper bonding,[53] while endocrowns are usually prepared without ferrule.

Taking into consideration that the greater the occlusal thickness of the restoration the higher the fracture resistance of the system, endocrowns are more prone to resist occlusal loading than conventional crowns. Indeed, the thickness of the occlusal portion of endocrowns varies from 3 to 7 mm, in contrast with conventional ones in which it varies from 1.5 to 2 mm.[54]

Last but not least, regarding material choice for endocrown fabrication, nanofill composite resins boast a modulus of elasticity similar to that of dentine, thus retaining high fracture resistance and limiting irreparable fractures. However, decreasing elastic modulus reduces stress in the dentine while it increases tension at the interface, leading to risks of debonding and detachment of the prosthesis. As it has been shown, endocrowns are more prone to debonding than fracture, so materials with the greatest adhesion values such as lithium disilicate, are the best choice. The esthetic properties of this material are unrivaled by composite resin not to mention the fact that ceramics age better and have a lower plaque retention.[46]

Conclusion

- Endocrowns are a viable restorative technique for endodontically treated teeth, proven from both *in vitro* and *in vivo* studies, demonstrating similar success percentages to conventional restorative techniques.
- The literature suggests their use in molars, but more studies are needed in order to be established as a suitable technique for premolars and anterior teeth.
- The preparation of an endocrown does not resemble that of a conventional crown, as its retention mainly depends on adhesive cementation.
- Their fabrication should be carried out with materials that can be bonded to the remaining tooth structure with resin cements. Lithium disilicate and composite resin have been favored from the existing literature.
- There are certain indications and contraindications regarding endocrowns and a careful case assessment is needed.
- More clinical studies are needed in order to further verify endocrowns clinical performance.

Clinical Significance

Traditional techniques demanding additional healthy tooth substance removal in order for a post to be placed should be reconsidered, as contemporary materials and techniques can provide dentists with solutions that offer more conservative approaches with equal probability for long-term success.

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