ISSN Print: 2394-7489
ISSN Online: 2394-7497
IJADS 2024; 10(2): 329-332

www.oraljournal.com
Received: 27-04-2024
Accepted: 29-05-2024

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Adhesive approach for endodontically treated teeth, literature review

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DOI: https://doi.org/10.22271/oral.2024.v10.i2e.1958

Abstract
Introduction: The continuous evolution of dental materials and techniques with a tendency towards more conservative procedures, makes it necessary to reevaluate the literature on the restorative management of endodontic teeth.
Objective: To analyze the different approaches and techniques to rehabilitate endodontic teeth such as the current need for the splint effect, the use of endocrowns, adhesive partial restorations and fiber-reinforced composites.
Methodology: Literature articles were searched in the virtual databases PubMed, Google Academic and EBSCO. The following terms were used as keywords in the search: "restoration of root filled teeth "adhesive dentistry", "endodontic teeth restoration" and "ferrule effect".
Results: The need for dental posts and the ferrule effect should not be standardized in each case at day. Indirect techniques such as endocrowns and adhesive partial restorations promote a less invasive approach with predictable results when well indicated and the use of fiber-reinforced resins open the outlook for the use of direct techniques to rehabilitate endodontically treated teeth.
Conclusion: Current dentistry, through the correct use of dental materials, promotes the use of new techniques that allow different scenarios to be addressed in different ways, without having to compromise dental structure.

Keywords: Ferrule effect, dental post and core, Adhesive dentistry, endondontic restoration, endodontically treated teeth rehabilitation, endocrowns

1. Introduction
The continuous evolution of dental materials and techniques towards more conservative procedures necessitates a reevaluation of the literature on the restorative management of endodontically treated teeth (Bhuva *et al*., 2021) [9]. Despite decades of research, the question of how to restore endodontically treated teeth (ETT) can only be answered with insufficient evidence (von Stein *et al*., 2019) [40]. However, current adhesive procedures have changed the approach to these scenarios (Carvalho *et al*., 2018) [12]. Previously, the loss of remaining tooth structure after endodontic lesions compromised retention and adequate support for restoration (Martins *et al*., 2021) [29], thus suggesting the use of posts to increase biomechanical properties and enhance fracture resistance of ETT. Thanks to new adhesive restorative materials providing excellent outcomes, contemporary dentistry facilitates the conservation of dental structure, meeting the growing demand for minimally invasive treatments (Blatz, 2021) [10]. The clinician's need for various ways to rehabilitate endodontically treated teeth broadens the scope and extends the life of a tooth by no longer relying on invasive treatments like crowns and posts, instead adopting an adhesive approach to new prosthodontic approaches. The objective of this review is to compile different approaches and techniques for rehabilitating teeth with endodontic treatments and the current need for the ferrule effect and dental posts for clinical success in teeth with compromised structure, including the use of endocrowns, adhesive partial restorations, and fiber-reinforced composites.

2. Methodology

A search for articles related to the rehabilitation of endodontically treated teeth with an adhesive approach and the current need for the ferrule effect for such restorations was conducted. Articles from 2000 to 2023 were retrieved from virtual databases PubMed, Google Scholar, and EBSCO. The following terms were used as keywords in the search: "restoration of root filled teeth", "adhesive dentistry", "endodontic teeth restoration", and "ferrule effect". Additional searches were made by adding keywords related to established subtopics. Studies with *in vitro* design, case studies, and literature reviews totaling 41 selected articles were chosen.

3. Results

3.1 Impact of the Ferrule Effect and Dental Posts

The incorporation of the ferrule effect is established in the cervical region of a tooth and consists of 4 axial walls above the finish line covering 360° of the tooth circumference, with at least 0.5 to 2 mm in height and width (Santos *et al*., 2019) [36]. Although current literature suggests a positive impact of having a ferrule on the longevity and fracture resistance of ETT, evidence remains contradictory regarding the optimal ferrule configuration to provide optimal fracture resistance of an ETT (Al Sanabani *et al*., 2023) [3]. The tooth's position in the arch, ferrule dimension (length and thickness), tooth morphology, periodontal support, and occlusal scheme are important for decision-making (Assiri *et al*., 2022) [6].

3.1.1 Behavior with Dental Posts

Recent studies indicate increased survival of extensively damaged endodontically treated incisors even without a ferrule by using a fiber post with a resin composite core and full resin composite restoration (Lazari *et al*., 2018) [12]. In the absence of a ferrule, the use of posts and a core presents more favorable outcomes, and with a 1 mm thick ferrule, the use of a glass fiber post seems to be the best clinical decision (Fontana *et al*., 2019) [19]. Even with the use of posts, failure rates in anterior and posterior teeth treated with intraradicular posts are similar in short and medium-term follow-ups (García *et al*., 2019) [36], with the most frequently reported failures being related to fiber post debonding and loss of retention of single crowns and marginal gaps (Sorrentino *et al*., 2016) [38]. Despite current technologies, digitally manufactured posts and cores have the same degree of precision as conventionally manufactured ones (Piangsuk *et al*., 2023) [34]. While the ferrule effect has been a basic requirement in the restorative decision-making, its necessity as well as that of dental posts has been changing due to the demand to provide a better prognosis for ETT with compromised structures.

4. Endocrowns

4.1 Indications and Dental Preparation

Typically, an ETT undergoes cuspal coverage to prevent fractures, which is challenging in cases where the tooth is severely damaged. Therefore, an uncommon reconstruction type, endocrowns, has been opted for (Mezied *et al*., 2022) [30]. Endocrowns are a type of monoblock restoration that utilizes the pulp chamber and remaining coronal dental structure as retention. They require caries-oriented preparation, capitalizing on both adhesion and retention of pulp chamber walls, and are highly indicated in molars treated endodontically in cases with minimal interocclusal space and curved or narrow root canals (Papalexopoulos *et al*., 2021) [31], showing a more favorable failure mode than inlay restorations (Kassis *et al*., 2021) [24].

4.1.1 Material of Choice

Adding the ferrule effect to the preparation design of an endocrown has no significant effect on the mean pre-cementation marginal gap, fracture resistance, or failure mode of monolithic zirconia endocrowns cemented to endodontically treated molar teeth (Bamajboor *et al*., 2022) [7]. Regarding other materials, endocrowns made with resin have shown *in vitro* studies to have similar or superior fracture resistance and fewer catastrophic failures compared to those made with lithium disilicate (Beji *et al*., 2021) [8]. However, in short-term *in vivo* studies, lithium disilicate reinforced ceramic presented fewer complications and required fewer interventions compared to zirconia and hybrid ceramics (El-Ma'aita *et al*., 2022) [16]. Despite this, the mechanical performance of monolithic zirconia has been better than that of other ceramic crowns, however, monolithic zirconia presents a higher rate of catastrophic failures of dental structure (Dartora *et al*., 2021) [14]. Compared to conventional impressions and production techniques, digital workflow is more predictable and reliable, as it reduces errors and improves fit accuracy (Abduljawad *et al*., 2022) [1]. Endocrowns have expanded the range of possibilities for restoring ETT; however, further studies are needed to observe their long-term behavior in the anterior sector.

5. Adhesive Partial Restorations

5.1 Advantages

The development of adhesive techniques has minimized the biological cost of bonded indirect restorations (Gerdolle *et al*., 2022) [22]. Tissue removal required for post placement is often cited as the primary disadvantage with their use (Tribst *et al*., 2021) [39], leading recent studies to focus more on direct or indirect adhesive partial restorations, which ensure greater preservation of healthy tissues than traditional fixed complete crowns (Dioguardi *et al*., 2021) [15]. While cuspal coverage restorations should still be considered an integral part of the treatment plan for endodontically treated teeth (Chen *et al*., 2021) [13], nowadays, an analysis of the amount of residual coronal dentin can be evaluated horizontally and vertically to decide the type of restoration chosen for DTE reconstruction (Ferrari *et al*., 2022) [18].

5.1.1 Future Outlook

During a 3-year observation period, the clinical performance of endodontically treated teeth restored with lithium disilicate partial crowns was not significantly affected by the use of a fiber post or tooth type, whether premolar or molar (Ferrari *et al*., 2019) [17]. With the addition of adjuncts to rehabilitation such as deep margin elevation, indirect restorations continue to have a good survival rate. As CAD-CAM scanning evolves, it is expected to be possible to measure intracoronal volumetric changes in dental structure, especially in the pericervical region of the tooth (Mannocci *et al*., 2022) [28]. The most biomimetic way to restore a DTE will be through the use of partial adhesive restorations, provided they are indicated. Their clinical performance is good, and with new CAD-CAM technologies, they are expected to improve further.

6. Fiber-Reinforced Resins

6.1 Composition

A popular biomimetic restoration technique recommends

replacing enamel with glass or hybrid ceramic (Säilynoja *et al*., 2021) [35] and dentin with short fiber-reinforced composite (SFRC) due to its high toughness and similarity to the tissue it is replacing (Alshabib *et al*., 2022) [4]. In the quest to improve fracture resistance properties in anterior restorations, the incorporation of fibers into traditional restorative composites was proposed. Although various fibers such as carbon fibers, kelvar fibers, vectran fibers, glass fibers, and polyethylene fibers have been suggested, they all exhibit high aesthetic and fracture resistance properties (Patnana *et al*., 2020) [32].

6.1.1 Properties

Fiber or particle reinforcement significantly enhances the physical, mechanical, thermal, and tribological properties of the dental resin matrix (Yadav & Kumar, 2019) [41]. The use of these resins as a base material can prevent restoration fracture due to the effectiveness of fibers in halting cracks (Alshabib *et al*., 2022) [4].

6.1.2 Clinical Performance

Restorations combining an everX Flow composite fiber-reinforced core and a conventional composite surface layer showed promising performance regarding fracture behavior (Lassila *et al*., 2020) [26]. The use of SFRC as a core material with conventional surface layer composite to reinforce anterior crown restoration proved to be a promising strategy for future testing (Lassila *et al*., 2022) [25]. Despite their qualities, indirect restorations provided greater clinically acceptable performance and less need for reintervention, but both indirect and direct restoration types showed good survival rates when applied appropriately (Skupien *et al*., 2016) [37].

Direct restorations once contraindicated for DTE can now be a viable option and could be the future of restorations for this type of tooth. They are viable, more cost-effective, and faster in the clinical setting.

7. Conclusion

With advances in adhesive restorations today, classical concepts for rehabilitating DTE have been evolving. The need for dental posts and the ferrule effect should not be standardized today. Alternatives to dental crowns, in indirect techniques like endocrowns and adhesive partial restorations, provide predictable and less invasive outcomes, and the use of fiber-reinforced resins could be the future of DTE rehabilitations with direct techniques in the dental chair.

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How to Cite This Article
Barreto DAP, Lerma LGG, Palencia PG, Fierro NC. Adhesive approach for endodontically treated teeth, literature review. International Journal of Applied Dental Sciences. 2024;10(2):329-332.