Restoration of endodontic teeth: An engineering perspective

By Gregory M. Kurtzman, USA

Introduction

Identifying the canals and ensuring them to be able to instrument and obturate the tooth is necessary to clinical success. But restoration of the endodontically treated tooth is critical to long-term success. It does not matter if we can completely the endodontic portion of treatment if the tooth cannot be restored. With this in mind, we need to look at the restoration phase from an engineering perspective to reinforce the remaining tooth so that it can manage the repetitive loading that necessitates restoration design? This article will discuss the importance of ferrule in adhesively bonded core posts and what materials are best.

Ferrule: How important is it today?

Ferrule has long been an important concept in dentistry but has been de-emphasized with the advent of modern technology. Yet this concept is as important today as it was prior to dental bonding. But what is a ferrule? A ferrule is a band that encircles the coronal dimension of residual tooth structure, not unlike the metal bands used in the past to use posts and what materials are best.

Ferrule placement provides the maximum restoration of teeth; thus it is important to remain as much tooth structure as possible, and this aids in achieving ferrule as well as maintain- ing cervically located post and core tooth where loading concentrates. Under masticatory loading, strain concentrates in the portion of teeth; thus it is important to avoid over-preparation of this portion of the tooth (Fig. 1, 2). Both endodontic treatment and preserve this area of loading at the cervical margin (Fig. 1).

Multiple studies discussing how much ferrule is required have found that teeth with at least 2.0 mm of ferrule have significantly greater long-term prognosis from a restorative standpoint than those with less or no fer- rule. Lahanm, et al, reported, “Fatigue loading of cast post and cores with complete crowns of different ferrule designs provide evidence to support the need for at least a 1.5- to 2.0-mm ferrule length of a crown preparation. Crown preparation with a 0.5-mm and 1.0-mm ferrule failed at a significantly lower number of cycles than the 1.5-mm and 2.0-mm ferrules and control teeth.” Lahman further demonstrated when loading at an off-axis di- rection, which occurs in the maxillary anterior, at the resto- rative tooth’s margin, the side where the load is originating is under tension, whereas the opposing side is under compression (Fig. 2). This repetitive loading and micro stress due to tension at the lingual margin leads to the mar- gin opening, which may lead to recurrent decay and/or failure of the restoration or coronal seal or restora- tion (Fig. 5). Additionally, if we look at strain studies by Libman and others comparing ferrule of different heights, we observe that in a fer- rule of 0.5 mm there is greater strain at the margin under ten- sion and concentrates at mid and should be considered.1, 2 Lahman, et al, stated succinctly, “The study confirms that a ferrule increases the mechanical resistance of a post/core/crown restoration.”

How much ferrule is required?

When rebuilding an endodontically treated tooth, it is best to maintain all dentin that is avail- able, even thin slivers. These thin slivers of dentin provide a strong connecting link between the core and tooth’s root and between the crown and root.3 It is important to attempt to retain as much tooth structure as possible, and this aids in achiev- ing ferrule as well as maintain- ing cervically located post and core tooth where loading concentrates. Under masticatory loading, strain concentrates in the portion of teeth; thus it is important to avoid over-preparation of this portion of the tooth (Fig. 1, 2). Both endodontic treatment and preserve this area of loading at the cervical margin (Fig. 1).

The literature supports that coronal leakage may be a ma- jor factor in failure of endodon- tic treatment.7, 8 As previously discussed, when loaded during mastication, margins with inade- quate ferrule may demonstrate micro opening on the tension side, leading to leakage over the restoration.9, 10 This initially may be observed as recur- rent decay, but as it becomes greater, the crown fails due to apical migration of oral bacteria. This is minimized when a bond- ed core or post/core is present, but given sufficient time when a ferrule of sufficient height is not present the endodontics or the restoration will fail.

Do all posts function the same?

Teeth function differently, de- pending on the material that the post is fabricated from, with metal and ceramic posts demonstrating relative to the modulus of elas- ticity of the post of the compared to the dental crown.12 When a tooth restored with a fib- er post does fail due to overload, the mode of failure is coronal, protecting remaining root and tooth structure.13 This mode of failure is the fiber post typically allows the tooth to be restored, as vertical root frac- ture is a rare occurrence. Bither reported, “Compared to metal posts, FRC posts revealed reduced fracture resistance in both the less chance of overload and failure restoratively (Fig. 4).

Detecting failure at the coro- nal seal

It is not unusual to have a patient present for a routine recall ap- pointment and the clinician or hygienist note recurrent decay at a crown margin with the pa- tient unaware of the issue. This becomes more complicated with teeth that have previously un- dergone endodontic treatment, as there is no palpable post that can warn the patient an issue is present until often extensive decay occurs or the crown dis- turns. Both Fatemi and Freeman, et al, in their published study, stated, “Fatigue loading of three different post and core de- signs with the presence of a full cast crown leads to preliminary failure of leakage at the restoration and tooth that is clini- cally undetectable.”

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The elastic modulus refers to the mechanical resistance of a material to strain on loading at the cervical. (Image/Provided by Dr. Gregorio McCoy)

As stress concentrates at the api- cal tip of the metal post due to its higher modulus of elasticity than the post’s root, vertical root fracture is a frequent occur- rence. This may result in a catastrophic fracture of the re- storation, leading to torque at the cervical area and the resulting vertical root fracture. Because metal posts are stiffer (higher modulus of elasticity) than the dentin of the root, stress concentrates at the post’s api- cal tip, leading to vertical root fracture, while core posts are more flexible equal to or greater than the root (lower modulus of elasticity), stress concentrated at the cervical region, leading to horizontal fracture of the post and core, and typically the tooth can be salvaged. The elastic modulus refers to the relative rigidity of the material. The stiffer the material, the higher its relative modulus. When two different materials are placed together, such as when a post is placed into a tooth’s root, the elastic modulus is inflamed by whichever of the materials is stiffer. Dentin averages a modu- lus of elasticity of 1.73 ± 0.38 GPa, with glass fiber posts at 24.4 ± 7.4 GPa, titanium posts at 945 ± 96 GPa, prefabricated stainless steel at 896 ± 10.7 GPa and cast high noble gold posts at 55.4 ± 4.5 GPa. Cast posts fabricated from no- ble or base metals have higher modulus then high noble alloys and approach stainless-steel modulus in their relative stiffness. Fiber post materials have

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Fig. 1. Strain analysis of a posterior tooth demonstrating concentration of strain on loading at the cervical. (Image/Provided by Dr. Gene McCoy)

Fig. 2. A maxillary anterior tooth is loaded during mastication, tension and compression occur at the crown’s margins. (Image/Provided by Dr. Gregory M. Kurtzman)

Fig. 3. Opening of the margin on the tension side may lead to time to recur- rent decay or restoration and endodon- tic failure.

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Fig. 4. Difference of intensity of strain and location related to ferrule height during occlusal loading (Libman).

Fig. 5. Comparison of load distribution of fiber post, cast metal post and prefabricated metal post.

Fig. 6. Tooth restored with a fiber post demonstrating coronal horizontal frac- ture supracrestally, typically seen with teeth restored with fiber posts when overinstrumented.

Fig. 7. Vertical root fracture of a tooth restored with a metal post.

Fig. 8. Comparative modulus of elastic- ity of different post materials.

Fig. 9. The posterior tooth demonstrating concentration of strain on loading at the cervical. (Image/Provided by Dr. Gene McCoy)
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an elastic modulus that more closely approaches that of dentin. The deflection of fiber and metal posts was re-
spectively four and seven times higher than that of dentin, and there is still debate on whether a post strengthens the tooth.20 The higher modulus of elasticity and the concomitant lack of stress relieving negative factor, giving rise to considerably higher stress levels resulting in fracture. When no ferrule was present, the prefabricated metal post/composite combina-
tion generated greater cervical stress than cast post and cores. Yet, the ferrule seemed to can-
cel this effect and provided appropriate restorative reconstruction material on the intensity of the stresses. With a ferrule, the elastic component of re-
construction material had no impact on the level of cervical stress. 

The material the post is fabricated from should have the same modulus of elasticity as the root dentin to distribute the applied force evenly along the length of the post and the root and not con-
centrate them at the apical tip of the post. An inlay post, where that when components of different rigidities are loaded, the more rigid component is capable of restor-
ishing or previously restored teeth will require a core buildup and the composite bonded within the coronal (supragingival) portion, 

In the presence of a root canal post, cervical stress was lower where ferrules were used, leading to the possibility of re-
suming greater cervical stress than the fiber posts, but a post was placed in the middle of the cusp width present. When the preparation was reduced by removing the remaining restorative material invades the width of the cusp leaving half of the tooth structure missing, more extensive restoration is in-
dicated. Moderate tooth structure missing or previously restored

Fig. 11. Significant tooth missing or previously restored following endodontic treatment

Fig. 12. Multiple fiber posts placed into a molar to both the remaining tooth structure and the original tooth structure.

Conclusion

For restoration of endodonti-
cally treated teeth, an adequ-
ate view is needed to ensure long-term survival. Ferrule is often overlooked in today’s age of adhesive dentistry, but it is as critical today as it was in the past. Prefabricated fiber posts are being used to affect survival of the tooth, and the literature supports use of 2.0 mm of ferrule. This is critical in maxillary anterior teeth due to the direction of load-
ing during mastication. Additionally, how we restore the remaining tooth plays a role in potential issues in the long term. Metal posts are being used less frequently due to vertical root fractures that can occur when the tooth is over-killed, and the direction has increasingly moved to the use of fiber posts, which mimic the roots modulus of elasticity. When teeth restored with a fiber post are overloaded, fracture typically occurs in the coronal (supragingival) portion, leaving sufficient tooth remain-
ing to affect survival of the tooth, and the literature supports use of 2.0 mm of ferrule. This is critical in maxillary anterior teeth due to the direction of load-
ning during mastication.

References

3. Editorial note: The full list of references is available from the publisher.