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Ferrule effect and its importance in restorative dentistry: A literature Review

Ahmad Yahya K. Assiri,¹ Jilani Saafi,^{2,3} Mohammed M. Al-Moaleem,^{4,5*} Vini Mehta⁶

¹Consultant Prosthodontics-Dental Implant, Abha Specialized Dental Center, Al Morouge District, Abha, Saudi Arabia

²Professor in Fixed Prosthodontics, Consultant in Prosthodontics, Kharj, Saudi Arabia

³Faculty of Dentistry Avicenna Street, Monastir, Tunisia.

⁴Department of Prosthetic Dental Science, College of Dentistry, Jazan University, Jazan, Saudi Arabia

⁵Faculty of Dentistry, University of Ibn al-Nafis for Medical Sciences, Sana'a, Yemen

⁶Department of Public Health Dentistry, Dr. D.Y. Patil Dental College and Hospital, Dr. D.Y. Patil Vidyapeeth, Pune, India

***Correspondence author:** Mohammed M. Al-Moaleem, Department of Prosthetic Dental Science, College of Dentistry, Jazan University, Jazan 45142, Saudi Arabia. Email: malmoaleem@jazanu.edu.sa

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ABSTRACT

This review aims to report the current literature on the status of ferrule in root-filled teeth, classify the different types of ferrules, highlight the biomechanical failures due to inadequate ferrule effect, and discuss the current restorative concepts according to the ferrule design principles.

Keywords: Ferrule, root canal treated teeth, types of ferrules

INTRODUCTION

The origin of the term "ferrule" is thought to come from the Latin terms in 1993 "ferrum" – iron, and "viriola" – bracelet. A ferrule is a band of the

crown material (often metal) that completely encircles the external dimensions of the tooth and lies between the most cervical dentine-core interface and the cervical crown margin, providing resistance to

dislodgement and preventing fracture.¹ The "ferrule effect" is a long-standing, accepted concept in dentistry that is a foundation principle for restoring teeth that have suffered progressive structure loss.¹ The loss of dental tissue and the weakening of the remaining structure presents a challenge in prosthetic rehabilitation.²

The most important factors in selecting the restorative approach are residual crown structure, residual root structure, and the compromised tooth reconstruction versus the value of the tooth in the treatment plan.^{1,2} Preserving intact coronal and radicular tooth structure, especially maintaining cervical tissue to create a ferrule effect, is crucial for restoring the optimal biomechanical behavior of teeth.^{3,4}

A ferrule has been defined as a 360-degree metal collar of the crown surrounded by parallel walls of the dentine extending coronal to the shoulder of the preparation.⁵ A ferrule effect is described as a band that extends the external dimension of a residual tooth structure (Figure 1). A 2-mm tooth structure should be available to allow a ferrule effect.⁶ A protective or ferrule effect could occur owing to the ferrule resistance stresses such as functional lever forces, the wedging of tapered post effect, and the lateral forces exerted during post insertion.⁵ The ferrule effect is determined from vertical and horizontal intraoral measurements using a periodontal probe with a stop. The vertical measurement is from the top of the gingival margin to the top of the remaining tooth wall at four points: mesial, distal, buccal, and lingual or palatine.²

CURRENT STATUS OF THE FERRULE EFFECT

The extent of the remaining tooth structure is among the most important and critical factors in determining the prognosis for restoring a damaged tooth. Furthermore, it has been well established that the longevity of a root-treated tooth is directly related to the amount of the remaining sound tooth material.^{7–9}

The tooth's position in the arch, ferrule size, proximal contact, periodontal support, and restoration type are survival prediction factors that should be considered when performing the post-endodontic restoration.¹⁰ An abutment is most resistant to fracture if the abutment provides substantial amounts of tooth structure, that is, of a height of 1.5–2.0 mm above the projected ferrule margin, for the ferrule or crown to grab onto.^{1,11–15} Research shows that the presence of a 1.5–2.0 mm height of tooth structure above the gingiva is more important for preventing fracture than the use of a post.^{16,17} One study concluded that 1 mm of ferrule could significantly improve fracture resistance, while some studies recommended 2 mm of ferrule height.^{15,18,19} The rule established is that a 1.5- to 2-mm ferrule height directly above the margin improves the long-term survival of endodontic-treated teeth with a post and core. Another reported that teeth with 2 mm had fractures in remote areas, posing a problem during restoration.²⁰ Some studies comparing uniform and nonuniform ferrule reported a higher fracture resistance in the uniform ferrule group,²¹ yet one study



FIG. 1. (A) Ferrule Effect. (B) Ferrule 3-mm buccal and 0.5-mm lingual.

evaluating fiber posts reported no change in fracture resistance in uniform and nonuniform ferrule.²² Some authors have reported that ferrule placement does not improve the fracture resistance of teeth restored with cast dowels and prefabricated metal dowels.²³ While many studies demonstrate that a ferrule of 1.5–2 mm sound coronal tooth structure between the core and the finish line is more important in fracture resistance than the post design or type.^{2,12,24,25}

The tooth walls that the ferrule encircles should be at least 1 mm thick to be strong enough to contribute to the ferrule effect, although the tooth walls do not have to completely encircle the abutment if a partial encirclement contains enough tooth structure to create a substantial ferrule effect. The literature suggests that a nonuniform ferrule is still superior to no ferrule, so the concept of partial ferrule should not be ruled out.¹

The presence of a 1.5- to 2-mm ferrule has a positive effect on the fracture resistance of endodontically treated teeth. If the clinical situation does not permit a circumferential ferrule, an incomplete ferrule is considered a better option than a complete lack of ferrule.²⁶ Clinically, it is generally accepted that walls are considered "too thin" when they are less than 1 mm in thickness, such that the minimal ferrule height is only of value if the remaining dentine has a minimum thickness of 1 mm.^{27–29} Ferrules must be on sound tooth structure (not the core) and axial walls must be parallel with minimum thickness of 1 mm.³⁰ The longer the ferrule, the better, with a minimum of 1 mm height suggested by some studies.^{5,17,22} If the cervical tooth structure height is too short, crown lengthening surgery may reveal more tooth structure for the ferrule to encircle.^{31,32} But, if a tooth has been damaged by caries such that after the carious material is removed, the tooth structure has the shape of an arch that rises vertically from the gingiva and curls axially, that part of the tooth that forms the curling arch at the occlusal aspect is also not part of the ferrule tooth structure. Thus, the ferrule is assessed after removing all soft tissue and after the preparation of the tooth. A minimum sound dentine height of 1.5–2 mm between the core and crown margins was required. The final restoration provided a bracing, casing, or hugging action to improve the integrity of the endodontically treated tooth.⁹ Both amalgam and bonded composite cores required the presence of a minimum of 1.5–2 mm height of ferrule after crown preparation.³³

Compared to amalgam, composite resin with a dentine bonding agent has frequently been implicated as a material that can strengthen the tooth and reinforce cusps.^{34–37} If the remaining sound dentin (ferrule) is less than 1 mm, a casted post and core foundation was a suitable option.

BIOLOGIC WIDTH

The biologic width (BW) is commonly stated to be 2.04 mm, representing the sum of the epithelial and connective tissue measurements.³⁸ As defined by Cohen, BW is the part of the supra-crestal gingival tissues that occupy the space between the base of the gingival crevice and the alveolar crest; it includes the junctional epithelium and the connective tissue element.³⁹ It has been shown that 3 mm between the preparation margin and alveolar bone maintains periodontal health for 4–6 months⁴⁰ (Figure 2).

It has been recommended that at least 3 mm between the crown margin and the alveolar crest should be left to avoid impingement on the coronal attachment of the periodontal connective tissue.⁴¹ Therefore, if a 1.5-mm ferrule is to be achieved, at least 4.5 mm of supra-alveolar tooth structure is required.⁴² This 3 mm constitutes 1 mm supra-crestal connective tissue attachment, 1 mm junctional epithelium, and 1 mm for gingival sulcus on average. This allows for adequate BW even when the restoration margins are 0.5 mm within the gingival sulcus. BW can be identified by probing under local anesthesia to the bone level (referred to as "sounding to the bone") and subtracting the sulcus depth from the resulting measurement.⁴³



FIG. 2. (A) Biological width (Carranza et al., 13th Edition, 2018). (B) 3 mm is the minimum distance required between the future crown margin and alveolar crest.

Sushama and Gouri have described a new innovative parallel profile radiographic (PPR) technique to measure the dimensions of the dento gingival unit (DGU). The authors infer that the PPR technique could be used to measure the length and thickness of the DGU with accuracy, as it was a simple, concise, noninvasive, and reproducible method.⁴⁴

The subgingival placement of the crown margins may affect the periodontal tissues' homeostasis. Periodontal health is supposed to be established before assessing the BW. Completing remodeling after surgical crown lengthening procedures may require at least 6 months.⁴⁵ It can be concluded that there is a need to create a patient-/site-specific distance from the proposed margin of the restoration to the bone crest when restoring subgingivally fractured or carious teeth. This leads to more stable and healthy tissues when performing crown lengthening procedures. Therefore, using the term clinical, BW is more reliable and should be used to reestablish stability and integrity of periodontal tissues around restored teeth.³⁹ Recently, the interactions between dental crowns and the marginal periodontal tissues were analyzed in a systematic review. It was concluded that recognizing the BW, in terms of crown margin placement, is beneficial for periodontal health.⁴⁶

Ferrules should not invade periodontal attachment and, therefore, must be more than 0.4 mm from the base of the gingival crevice. However, the depth of the gingival crevice may vary from patient to patient, with the average biological width being approximately 2 mm.⁴⁷ When the restoration margin is placed too far below the gingival tissue crest, it will impinge on the gingival attachment apparatus. Constant inflammation is created and made worse by the patient's inability to clean this area.⁴³ Therefore, if a 1.5-mm ferrule is to be achieved, at least 4.5 mm of supra-alveolar tooth structure is required.⁴² When enough tooth structure does not exist, the clinician may consider two options: surgical crown lengthening or orthodontic extrusion.^{5,32,42}

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Most publications discuss the required height of ferrule; however, other design characteristics like dentine thickness, location of the remaining dentine walls, and the loads the restoration has to withstand were considered.

TYPES OF DENTAL FERRULES

Different dental ferrules include uniform ferrule, nonuniform ferrule, crown ferrule, and core ferrule.

Categories of Ferrule Based on the Risk Factors

Before preparation, a tooth should be classified, but with the desired preparation in mind. The categories are classified as¹ (Figure 3^{48}):

Category A has no anticipated risk, with sound four walls dentine remaining, a minimum height greater than 2 mm, and a thickness >1 mm.

Category B has a low risk, with a height of less than 2 mm, a thickness of 1 mm, three remaining walls with mesial or distal missing or two compromised proximal walls on a tooth that undergoes light lateral loads and a light lateral load.

Category C has medium risk, with compromised buccal or lingual wall on a tooth that undergoes light lateral loads and compromised proximal walls on a tooth that undergoes heavy lateral loads.

Category D has a high-risk, compromised buccal wall and lingual wall, two remaining adjacent walls or one wall, and a compromised buccal or lingual wall with heavy lateral loads.

Category E lacks any walls, meaning no ferrule is present, and the tooth is nonrestorable.

Biomechanical Failures Due to Inadequate Ferrule Effect

Risk assessment for failure can be performed so that the practitioner and patient can better understand the prognosis of restoring a particular tooth.¹ The predominant cause of failure of endodontically treated teeth is a fracture, and the fracture resistance of endodontically treated teeth to horizontal and vertical forces is related to the amount of healthy dentin remaining. The ferrule effect has a crucial influence on fracture resistance, especially in decoronated teeth.^{49,50} Beyond 3 mm of ferrule tooth structure height, there is little improvement in abutment fracture resistance.^{51,52}

A ferrule can potentially improve the biomechanical stability of a tooth by "shifting" the



FIG. 3. Schematic representation of ferrule categories.

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interfaces that resist stresses from weak tooth, core, and post interfaces to a strong tooth, core, and post interface located at the ferrule margin.⁵³ Akkayan B reported that 2- and 3-mm ferrule significantly improved fracture resistance compared to teeth with less/no ferrule.¹⁵ Regarding the effect of the ferrule on fracture mode, it has been reported that teeth with 2-mm ferrule failed in a "catastrophic" manner.²⁰ With anterior maxillary teeth, occlusal forces tend to contact the lingual surfaces, putting the cingulum areas under tensile force and the facial areas under compressive force.^{54–56}

Maxillary anterior teeth support flexural stresses, where rigidity is the most important characteristic. They are loaded nonaxially, and preserving the cingulum's ferrule tooth structure is important since this provides resistance to tensile forces.¹⁷ Anterior teeth with deep overbite and parafunction are at a higher risk of failure. Posterior teeth have to support compressive loads, where elasticity is the most important characteristic, so they are loaded occluo-gingivally. Fractures due to ferrules are based on the type of post used. Nonrepairable fracture is seen with less than 2-mm ferrule and cast post and core localized below CEJ. Repairable fractures are seen with a 2-mm ferrule using a fiber-reinforced post and localized above the cement-enamel junction.^{3,23}

The cast dowel with a 2-mm ferrule had a high fracture resistance, leading to a nonrepairable fracture. Without ferrule, fiber posts had a high incidence of repairable fracture.⁴⁸ Abutments not in occlusion or opposed by denture teeth (which have 20–25% of the chewing force of natural teeth) require less ferrule tooth structure to be biomechanically stable. Cantilevered abutments that have to close wide interproximal spaces or single abutments that are thin in cross-sections at the gingiva, such as premolars or mandibular incisors, will be under higher torque forces and require more ferrule tooth structure.^{57,58}

Some conclusions can be drawn from studies. Extensively damaged teeth cannot be considered

reliable as abutments for fixed or removable dentures (especially long-span fixed bridges and distal extensions of removable dentures) or cantilevers or patients with severe bruxism and clenching habits.^{59–62} It has been recommended that at least 3 mm between the crown margin and the alveolar crest should be left to avoid impingement on the coronal attachment of the periodontal connective tissue.⁴¹ Therefore, if a 1.5-mm ferrule is to be achieved, at least 4.5 mm of supra-alveolar tooth structure is required.⁴² In a situation in which enough tooth structure does not exist, the clinician may consider two options: surgical crown lengthening or orthodontic extrusion.^{5,14,32}

Crown Lengthening

If the destruction of the tooth structure renders a sufficient ferrule unachievable, crown lengthening or orthodontic extrusion should be performed.⁶³ Surgical crown lengthening⁶⁴ or orthodontic extrusion combined with endodontic-orthodontic⁶⁵ and prosthodontics treatment of fractured teeth should be considered with severely damaged teeth to expose additional tooth structure to establish a ferrule. Although crown lengthening allows a ferrule, it also leads to a much less favorable crown-to-root ratio and increased root leverage during function. Creating a ferrule with orthodontic extrusion may be preferred. Although the root is effectively shortened, the crown is not lengthened.^{63,64}

Disadvantages of surgical crown lengthening treatment are an increase in crown/root ratio caused by the reduced effective root length and the increased effective crown length. Reduced volume of root dentine that remains,^{31,32,66} besides crown lengthening on the tooth with conical roots, may add dentin height, but the dentin width at the margin may not be adequate.⁶⁷

In the anterior zone, surgical crown lengthening of a single tooth has a negative aesthetic impact, particularly in medium and high smiles, making forced tooth eruption via orthodontic extrusion the technique of choice when clinical crown

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lengthening is needed in isolated teeth in the anterior zone.⁶⁸

Orthodontic extrusion is a predictable procedure and, combined with fiberotomy and gingival recontouring, allows an optimal relation between the gingiva and the restoration margin. Orthodontic extrusion is more accessible to achieve in maxillary teeth than in the mandible.⁶⁹ From a biomechanical point of view, bone support reduces when orthodontic extrusion is performed. Still, the coronal lever arm does not change crown lengthening and/or an orthodontic extrusion presents a dilemma as crown lengthening surgery may result in a poorer crownto-root ratio, compromised aesthetics, loss of the inter-dental papilla, and a potential compromise of the support of the adjacent teeth. On the other hand, a questionable tooth is part of a wider restoration, especially if in a strategic position. Extraction and implant options should be considered. In cases where implants are already planned, and the tooth under consideration is between them, its strategic value could be reduced. Even teeth with a questionable prognosis may be considered for extraction.⁷⁰ However, this approach should be considered only in selected cases, and the specific tooth/teeth preservation should always be considered first.^{71,72}

CLINICAL PROCEDURE FOR THE DIAGNOSIS AND TREATMENT OF DAMAGED RCT TEETH

A thorough clinical examination is necessary to evaluate patient-related factors (systemic conditions, medication, social habits, and expectations), occlusion, and endodontic and periodontal issues. It is recommended that before restoring a tooth, a thorough review of the occlusal pattern, as well as functional and parafunctional forces, is performed, as these will influence the success of the final restoration of the particular tooth.⁹ The evaluation of the residual crown structure and residual root structure are paramount factors influencing the success of a restoration.

Periodontics can measure BW and transgingival probing, which may help determine the dimensions of the junctional epithelium and connective tissue attachment,⁴⁵ or indirectly by a bite wing X-ray to assess if the tooth structure is insufficient to allow adequate soft tissue attachment. To achieve access to the remaining tooth structure, it is important to remove in the pre-prosthetic step all periodontal infection plaque, all caries, old defective restorations, and old restoration with secondary caries. Remove all restorative materials and evaluate the remaining dentine height, thickness, and locations. However, evaluating the thickness of the remaining sound dentine teeth that have already been restored with posts and/or cores is difficult. A second bite wing may be necessary after removing all soft tissues. We should remember that the ferrule is the amount of the sound dentine above the finish line, and it is not the remaining structure. Hence, another aspect that should be considered is that a real evaluation is logically performed after final preparation according to the retainer. Some authors commence their procedure for full coverage with minimal initial preparation. However, a decrease in dentine width at the margin is inevitable after the tooth is further prepared for a new margin so that the practitioner can adjust the plan to make sure that the maximum thickness and height of the remaining tooth structure are preserved.1

In other words, for example, after a minimal prep for full coverage, the length and thickness of the ferrule were, respectively, 3 and 2 mm. After achieving the final preparation ensuring an optimum balance between aesthetic needs and structural durability, the dimension of the ferrule can decrease to, respectively, 1.5 and 1 mm. Therefore, a modification in the procedure will be mandatory, and a post will be used to retain the core restoration. On the other hand, there is no consensus related to the preparation of RCT teeth for full coverage, which recommends starting with an initial prep or achieving the final prep before restoration, and there is no consensus regarding the preferred type of final restoration for endodontic treated teeth.⁷³

Protocol Guidelines for the Treatment Plan for Restoring Root-Filled Teeth

This is a protocol guideline to help the clinician to select the most appropriate treatment plan for restoring root-filled teeth. Treatment and tooth structure must be assessed to ensure a good longterm prognosis. The decision-making process in the restoration of root-filled teeth is complex, and the following factors should be considered during the treatment plan:

- 1. Tooth position in the arch related to axial or lateral loads (light or heavy) based on the tooth and occlusal scheme type.
- 2. Amount and quality of tooth structure, ferrule length, width, and situation.
- 3. Anatomy of the involved teeth.
- 4. Function of the selected teeth, either a separated crown or an abutment for a bridge.
- 5. Position and location of the finish line.

For all the following classes and when the practitioner will perform a full coverage restoration with subgingival margin and if the sulcus probes 1.5 mm or less, the restorative margin could be placed 1.5 mm below the gingival tissue crest. If the sulcus probes more than 1.5 mm, the restorative margin can be placed at half the depth of the sulcus.³ If the sulcus is greater than 2 mm, a gingivectomy could be performed to lengthen the tooth and create a 1.5mm sulcus. Then, the patient can be treated as per rule 1.^{74,75}

The following are examples of the different ferrule classes.

Class 1

The value is positive as the top of the remaining tooth is above the gingival margin and includes the following:

Ferrule effect: Height of remaining tooth ≥ 3 mm at four locations (mesial, distal, buccal, and lingual or palatine).

- Category A or B.
- Remaining root length: At least as long as the future crown height plus 5 mm for the apical seal.
- The thickness of the remaining tooth walls ≥ 2 .

Anterior teeth: May not require posts but need direct reconstruction. Also, in anterior teeth, fiber posts are often luted for functional rather than adhesive reasons to increase rigidity.⁷⁶ Beautiful ceramic restorations require a thickness of at least 1.5 mm at the margins to allow for adequate aesthetics.⁷⁷

Posterior teeth: If the remaining walls after final preparation allow for retaining restoration material (composite, amalgam, GI modified by adjunction resin), a metal or fiber post is not needed because pulp chamber and canals provide adequate retention for a core build-up.

If the remaining walls after final preparation are insufficient to allow retention of restoration material, root-filled molars and some anterior teeth may not require posts (Figure 4).

Class 2

This class should have the following;

• Ferrule effect: Height of the remaining tooth 0.5–2 mm or width of the remaining tooth walls 1.5–2.5 mm with visible



FIG. 4. (A) First lower premolar with ferrule height equal to 4 mm (blue arrow) and thickness of ferrule equal to 2 mm (red arrow). (B) After restoration by composite.

margins or 1.2–1.5 mm with nonvisible margins.

• Compromised tooth structure (<50% structure).

Anterior maxillary teeth have to support flexural stresses, and fiber posts are often luted for functional reasons to increase biomechanical properties.⁷⁸ In some cases, the restorative core material fills the pulp chamber. It extends 2–3 mm into the coronal root canal, followed by a full-coverage crown called "the Nayyar core technique." The pulp chamber and the extension into the roots to act as dowel and core⁷⁹ (Figure 5).

Premolars may require posts more often than molars because they are more likely to be subjected to lateral forces during mastication⁸⁰; premolars may function either as molars or anterior teeth. If the sulcus probes 1.5 mm or less, the restorative margin could be placed 0.5 mm below the gingival tissue crest. If the sulcus probes more than 1.5 mm, the restorative margin can be placed at half the depth of the sulcus. But, if the sulcus is greater than 2 mm, a gingivectomy could be performed to lengthen the



FIG. 5. (A & B) Direct plastic core composite resin following Nayyar principles.

tooth and create a 1.5-mm sulcus. Then, the patient can be treated as per the rule.^{1,74,75} Bonded composite cores require the presence of a minimum of 1.5–2 mm height of ferrule after crown preparation.³³ If the remaining sound dentin (ferrule) is less than 1 mm, a casted post and core foundation is a suitable option.

Class 3

In this type, certain requirements, such as:

- Ferrule effect: Height of the remaining tooth <0.5 mm or width of the remaining tooth wall <1.2 mm at future margin level with deep fractures and periodontal complications.
- Remaining root length: Equal crown height plus 3 mm for the apical seal.

A fiber post or a casted post and core might be placed only after orthodontic or surgical crown lengthening. This decision depends on the tooth's position in the arch and the amount of the remaining ferrule after finalizing the preparation (Figure 6).

Class 4

A ferrule is not possible (by crown lengthening either periodontally or orthodontically) because of the following:

- Compromised biological width.
- The crown/root ratio is unfavorable.
- No predictable outcome and uncertain treatment results.
- It should be extracted and replaced by a prosthesis, as shown in Figure 7.

CONCLUSION

According to the literature reviewed, preserving as much ferrule as possible is paramount when restoring severely compromised teeth and a risk-benefit analysis must be done to determine the



FIG. 6. (A) Ferrule <0.5 mm. (B) Surgical crown lengthening. (C) Casted post and core.



FIG. 7. (A) Lack of ferrule and poor coronal structure (crown/root ratio unfavorable extraction was indicated). (B & C) Poor thickness of ferrule and decrease in dentine width at the margin is inevitable after the tooth is further prepared. Extraction was indicated.

procedure. The tooth's position in the arch, ferrule dimension (length and thickness), tooth morphology, periodontal support, and occlusal scheme are all important for decision-making. This classification is a guideline in the decision-making process for restoring severely decayed teeth. In teeth with no coronal structure, orthodontic extrusion should be considered rather than surgical crown lengthening to provide a ferrule.

ETHICAL STANDARDS STATEMENTS

There was no ethical clearance required for the literature review.

CONFLICT OF INTEREST

None.

INFORMED CONSENT

Not Applicable.

AUTHORS' CONTRIBUTIONS

All authors put in the same effort in collecting data, arranging the study, and writing the manuscript.

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