Ferrule effect in prosthetic...



# Efeito Férula na Reabilitação Protética de Dentes Tratados Endodonticamente

Ferrule effect in prosthetic rehabilitation of endodontically-treated teeth Efecto férula en rehabilitación protesica de dientes tratados endodonticamente

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#### RESUMO

**Objetivo:** analisar o efeito da férula sobre o prognóstico de restaurações indiretas em dentes tratados endodonticamente. **Método:** foi realizada revisão da literatura nas bases de dados PubMed e Science Direct. Foram selecionados artigos publicados em inglês até o ano de 2020. **Resultados:** a férula deve ter 1,5-2 mm de altura., aumenta a resistência à fratura de dentes tratados endodonticamente e sua sobrevida. Além disso, sua altura é mais importante que instalação de retentor intrarradicular. **Conclusão:** a férula melhora as propriedades da restauração e é importante para reabilitação protética bem-sucedida em dentes tratados endodonticamente.

Descritores: Dentes tratados endodonticamente; Férula; Fibra de vidro; Reabilitação; Resistência à Fratura.

### ABSTRACT

**Objective:** to analyze ferrule effect on prognosis of indirect restorations in endodontically-treated teeth. **Method:** a literature review was carried out on PubMed and Science Direct databases. It was selected articles published in English until 2020. **Results:** ferrule must have around 1.5-2 mm in height, it increases the resistance to fracture of endodontically-treated teeth and their survival. Furthermore, its height is more important than the installation of an intra-root retainer. **Conclusion:** ferrule improves properties of restoration and is important for successful rehabilitation of prosthetics in endodontically-treated teeth.

Keywords: Endodontically-treated Teeth; Ferrule; Fiberglass; Fracture Resistance; Rehabilitation.

#### RESUMEN

**Objetivo**: analizar el efecto férula en el pronóstico de restauraciones indirectas en dientes tratados endodónticamente. **Método**: la revisión de la literatura se realizó en las bases de datos PubMed y Science Direct. Se seleccionaron artículos publicados en inglés hasta el año 2020. **Resultados**: la férula debe tener una altura de 1.5-2 mm., aumenta la resistencia a la fractura de los dientes tratados endodónticamente y su supervivencia. Además, su altura es más importante que instalar un retenedor intrarradicular. **Conclusión**: la férula mejora las propiedades de la restauración y es importante para una rehabilitación protésica exitosa en dientes tratados con endodoncia.

Descriptores: Dientes tratados endodónticamente; Férula; Fibra de vidrio; Rehabilitación; Resistencia a la fractura.

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#### **INTRODUCTION**

Restoration of endodontically-treated teeth involves a variety of treatment options and still represents challenging task for dentists. The decision to keep a tooth in oral cavity or not is determined, among other factors, by the amount of coronary remnant. It is common that such a structure is sometimes insufficient to receive a direct or indirect restoration, requiring installation of post to provide retention for future restoration (JULOSKI et al., 2012).

Oral rehabilitation aims to preserve and/or restore function and aesthetics of teeth and stomatognathic system. In this context, teeth treated endodontically with extensive coronary destruction sometimes require use of post (KUL et al., 2020). Such post can be made of metallic and non-metallic materials, besides being anatomical or prefabricated.

Coronary reconstruction dates from 18th century. Reports from 1746 demonstrate that Pierre Fauchard proposed use of wooden post on teeth that needed crown rehabilitation, believing that their use would promote reinforce and retention of restoration (JHA; JHA, 2012).

Prognosis of endodontically-treated tooth does not depend only on endodontic procedures, being greatly influenced by post-endodontic procedure. Therefore, factors such as amount of remaining dental structure, type of tooth, and occlusal load associated with it contribute to decide whether or not to use intracanal post, its type, length, and cementation (GOMES et al., 2011; SANTINI et al., 2014,).

Vital teeth have significantly different mechanical properties when compared to endodontically-treated teeth. The main changes in tooth biomechanics are attributed to loss of mineralized tissue after caries injury, fracture, or cavity preparation, including access cavity before endodontic therapy (MAGNE et al., 2017).

Three parameters are established as causes of failure of endodontically-treated teeth,

namely: periodontal, endodontic, and prosthetic. It is reported that periodontal failure of endodontically-treated teeth is 32%, the second most frequent type is prosthetic with 59.4%, whereas endodontic is the least frequently mentioned, being 8.6%. In conclusion, absence of bone anchorage, correct shielding of the treatment with adequate restoration, restorative incapacity, and incorrect indication of types of intraradicular post are able of causing tooth loss considerably more than failures in the treatment of teeth (VIRE, 1991). The choice of post must follow some principles such as preservation of dental structure, retention and resistance, recoverability, ferrule effect, and failure mode.

Remaining coronary dentin should be preserved during restorative procedures to extend crown margin below the junction of the core and the rest of the tooth structure. However, clinician frequently encounters situations in which horizontal loss of the clinical crown has already occurred and this condition may lead to the need for post-core system (LIMA et al., 2010).

Therefore, ferrule effect or simply ferrule, defined as the ring surrounding remaining coronary dentin, is reported as one of the most important factors influencing fracture resistance in the final restoration (BATISTA et al., 2020). Considering this, understanding ferrule effect with or without use of fiberglass post is essential in conducting procedures that involve indirect restorations in endodontically-treated teeth; so, it is relevant and justified to carry out a literature review on this topic.

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### **METHOD**

It is a review of the scientific literature. This category of articles plays a fundamental role in continuing education because they allow the reader to acquire and update knowledge on a specific topic in a short period of time. This review was carried out on PubMed and Science Direct databases. For the search, it was selected articles published in English until 2020. It was used as Keywords the following terms Endodontically-treated Teeth, Ferrule. Fiberglass, Fracture Resistance, and Rehabilitation.

## **RESULTS AND DISCUSSION**

Although efforts to reinload structure of endodontically-treated teeth, biomechanical failures are still a critical issue. Although it is desirable and often necessary, a strengthening effect of these teeth has already been questioned in the literature (SCHWARTZ; ROBBINS, 2004).

A contributing factor to frequent dental fractures may be absence of protective feedback mechanism after pulp removal. In addition, high occurrence of fractures can be attributed to various procedures such as preparation, irrigation, and filling of the root canal system, as well as preparation and restoration of the access cavity. Thus, preserving coronary and root dental structure intact and keeping cervical mineralized tissues of the tooth in order to create a ferrule effect is crucial to optimize biomechanical behavior of the restored tooth (JULOSKI et al., 2012). The initial concept of ferrule proposed by Sorensen and Engelman (1990) elucidated to be a 360-degree metal necklace of artificial crown made around parallel walls of dentin, extending coronal to the preparation shoulder.

In this sense, parallel walls that extend in cervical-coronal direction from the preparation margin promote a ferrule, which is subsequently surrounded by a total crown provides protective effect of the tooth by reducing internal stresses, calling it ferrule effect (STANKIEWICZ; WILSON, 2002).

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Both role of intracanal post and presence of dental ferrule have been discussed for many decades. In addition, clinical impact of use of post compared to use of postless restorations with and without ferrules still needs to be thoroughly studied. This is because comparative conditions of the effects of presence or absence posts in restorations could only be evaluated when, at the same time, there were comparative clinical situations in which there is presence of ferrule or not (NAUMANN et al., 2018).

Coronal residual of mineralized tissue surrounding dental preparation between 1.5 and 2 mm in height has been cited as factor that increases resistance to dental fracture and greatly improves its survival (WATANABE et al., 2012; SKUPIEN; LUZ; PEREIRA-CENCI, 2016). In addition, the existence of this 1.5-2.0 mm height is more important to prevent fracture than installation of post, with more optimistic comparative studies reporting that there is no difference in fracture resistance when in presence or not the post in cases where there is only ideal ferrule effect (JULOSKI; APICELLA; FERRARI, 2014; SKUPIEN; LUZ; PEREIRA-CENCI, 2016); however, maximum fracture load that adhesive cemented post can receive generates possibility of reducing the need for this remaining coronary structure (MENG et al., 2007; MAHMOUDI et al., 2012).

In clinical practice, it is not always possible to count on the ideal ferrule effect, which can lead to decreased resistance to displacement of the restoration and risk of fracture. However, even though ferrule is associated with survival of teeth in clinical studies, and fracture resistance in vitro, other factors can drive prognosis of the restoration when associated with absence of ferrule, including location of the tooth in the arch, type of retainer, material used to make the direct or indirect restoration, and cementing agent (SKUPIEN; LUZ; PEREIRA-CENCI, 2016).

Few clinical studies have evaluated ferrule effect, and despite this, they confirm that the greater the presence of the amount of ferrule, the more beneficial it is for the tooth to be treated, generating lower failure rates, differently from laboratory studies that are largely carried out but also confirm this same idea (FERRARI et al., 2012; EVANGELINAKI et al., 2013; ZICARI et al., 2013; ABDULRAZZAK et al., 2014).

The idea of minimal intervention in dentistry in order to preserve dental structure is gaining a lot of use in restoring endodonticallytreated teeth. Elderton (1988) and Simonsen (1991) described for the first time that the process of replacing restorations can result in a restorative cycle of death. The authors elucidate that defective restorations are replaced by larger ones that one day will fail again, which will consequently lead to even greater restorations or possibly post and core approach, increasing risk of complications; and eventually, in the last stage, tooth loss. In this context, preservation and conservation of dental structure is directly correlated with fracture resistance, while reduce occurrence of catastrophic failures and increase longevity of the restored tooth (CARVALHO et al., 2018).

Traditionally, direct post is used to retain adhesive core in endodontically-treated teeth. In case of decision to use direct post, the fiberglass ones seem to have many advantages (adhesion, flexibility similar to the tooth, aesthetics, among others). Despite all benefits of fiberglass post, their selection and indication are not fully understood yet. In this context, previous studies reported loss of retention as one of the main failure modes for fiberglass post cemented with resin cements (NAUMANN; PREUSS; ROSENTRITT, 2006; BITTER et al., 2009; MAGNE et al., 2017).

An in vitro study conducted by Magne et al. (2017) investigated fracture resistance in upper incisor teeth restored with ceramic crowns when there is ferrule with and without use of fiberglass post with composite resin filling cores. This study has proven that insertion of post does not increase load-bearing capacity and survival of ceramic crowns. Furthermore, in presence of the post, catastrophic failure of the teeth was often preceded by opening of a space on the margin between the core/crown interface and the root, significantly affecting survival rate; and the smallest amount of non-restorable failures was found in cores made directly from resin without installation of post, and ferrule absence was not compensated by use of fiber post.

For posterior teeth, it is demonstrated that installation of post does not significantly increase fracture resistance when compared to cases of use of composite resin filling cores directly without additional retentions (MASSA; DIAS; BLOS, 2010; MAGNE et al., 2016).

Although some studies are very promising when it comes to beneficial effect of ferrule, many controversies still surround the theme. In addition, it is not always possible to obtain uniformly heighted spherical circumference. Studies show that there is increase in fracture resistance the more remaining coronary walls there are. In addition, presence of ferrule, extent, and dimensions of these walls represent critical aspects that influence the longevity of treatments (SCHMIDLIN et al., 2010; HOU; GAO; SUN, 2013).

If the clinical situation does not offer circumferential coronary residual of at least 1.5 to

2 mm, an incomplete ferrule offers better condition than its complete absence. Their presence at the end of the prosthetic preparation can lead to more favorable fracture patterns, in addition to providing reduction in the mechanical impact of the post/core system, cementing final restoration agents, and in tooth performance. Furthermore, in teeth without coronary structure, orthodontic extrusion has been cited as option when compared to technique of surgical enlargement of crown. Finally, if none of the alternative methods for providing ferrule can be performed, available evidence suggests that poor clinical outcome is very likely to occur (JULOSKI et al., 2012).

In addition, teeth with irregular lengths restored with fiber post and full coverage with ceramic crowns prove to be more resistant to fracture than teeth with their absence, and it is desirable and suggested ferrule at least 2 mm on buccal and lingual surfaces. For this purpose, regardless of the architecture of the remaining ferrule before rehabilitation, predominant way of breaking this structure would be an oblique fracture of lingual margin to buccal one (NAUMANN; PREUSS; ROSENTRITT, 2006; DIKBAS et al., 2007).

Manufacturing a ferrule create positive effect in reducing the concentration of tension at the interface of the core with remaining dentin, besides to helping to maintain the integrity of the cement seal in the crown (LIMA et al., 2010). In this context, Libman and Nicholls (1995) already evaluated ferrule effect on integrity of the cement seal in teeth with cast crowns, reporting greater resistance to fatigue in teeth with at least 1.5 mm remaining. In addition, when ferrule is absent or extremely small, occlusal strength can generate post flexion with eventual micromovement of the core, allowing fracture of the cement line in short time leading to infiltration and dental caries (LIMA et al., 2010). In vitro studies have found that presence of ferrule effect in anterior tooth restored with fiber post alters the arrangement of loads acting on the tooth, in which those with cervical ferrule have coronal displacement of the support line during the load, reducing the effect of bending and protecting the tooth. Thus, this fact explains why teeth with ferrule effect have greater resistance to fracture (FONTANA et al., 2019).

Success of restorations in endodonticallytreated teeth must be evaluated not only regarding survival rates of the restoration, but also and more important in view of the survival rate of the teeth and their possibility of being portrayed from the restorative point of view after failure that may occur. The most common types of failures described in the literature are repairable and catastrophic failures. Repairable failures are: cohesive, cohesive/adhesive fracture, minor damage, splinters or cracks in the underlying tooth structure; catastrophic failures, on the other hand, are critical and involve tooth/root fracture leading to the need for extraction (ZICARI et al., 2013; CARVALHO et al., 2018).

As already mentioned, resistance to fracture of endodontically-treated teeth depends on the length of the ferrule; and in this way, in its absence, ideal restorative material must provide behavior that avoids fractures in the roots of severely destroyed teeth. In this regard, there are different materials that make up intraradicular post, among them the already known cast metal cores, and the most recent ones made from zirconia and fiber. Although zirconia and fiber posts are popular contemporary materials, search for ideal support material continues (LAZARI et al., 2018; KUL et al., 2020).

Beck et al. (2010) reported that, although zirconia posts have greater fracture resistance than of fiber, catastrophic fractures are more commonly associated with those while repairable fractures are seen with fiber posts. Therefore, such differences were attributed to the lower to

closest

modulus of elasticity of fiber posts that comes dentin. Nevertheless, vertical catastrophic failures cannot always be avoided

even with use of fiberglass posts, even with modulus of elasticity lower than those of cast metal alloy (LAZARI et al., 2018). Thus, in general, presence of posts negatively affects tooth failure modes (KUL et al., 2020).

In addition to all these features already mentioned for maintaining this mineralized dental structure and traditional approaches with installation of an intraradicular post and rehabilitation of the tooth with indirect restoration, for example, there is possibility of more conservative adhesive approaches, with change of the current paradigm in relation to the use of postless procedure.

Modern techniques for anterior and posterior teeth with ferrule have been studied and proved to be efficient even without use of post and only making of filling cores with composite resin. Teeth with a minimum of 2 mm of ferrule have been restored without posts in combination with the formation of composite resin core, and in opposition to the concept of using post and core, this technique seems to be closer to the biomechanical behavior of the natural tooth. For that, additional procedures can be used in order to increase the adhesive strength of the restoration with the tooth (MAGNE et al., 2017; CARVALHO et al., 2018).

Among these strategies, it is possible to list the immediate dentin sealing (IDS), and use of indirect composite resin. In this context, the set of elements that constitute the restoration (tooth, filling core, adhesive interface, and crown) has been mentioned in promoting behavior that mimics properties of dentin-enamel junction. In addition, precision on conduction of minimally invasive techniques helps to delay the restorative cycle of death (PASCAL MAGNE, 2005; NAUMANN et al., 2018; CARVALHO et al., 2018).

In many situations, the amount of coronary dentin remaining is too small to support occlusal loads applied on the installed prosthetic crown by itself. Therefore, it is possible to verify that presence of ferrule has beneficial effect for both clinical and in vitro studies. Investigations conducted by Skupien, Luz, Pereira-Cenci, et al. (2016) through meta-analysis report that presence of ferrule reduces stress applied on dentin for both metallic and non-metallic posts. The author also finds that non-metallic posts tend to behave more regularly than the metallic ones, fact associated with the modulus of elasticity similar to dentin, generating better distribution of loads.

In this regard, Eraslan et al. (2009), evaluating the stress generated in anterior teeth with different ferrule height in fracture resistance tests, demonstrated that the greater the ferrule height, the less stress generated in dentin. In this study was evaluated fiberglass and zirconia posts. However, results of differences in stresses were not so expressive.

Regarding modulus of elasticity factor, Boschian et al. (2006),studying these characteristics for different materials that constituted posts and stresses transferred to dental structures reported that materials with greater elastic modulus than dentin are able of causing dangerous and not homogeneous stresses in root dentin. This study concluded that the configuration that best preserves the integrity of the root, post, and core is when fiber post are used. In this same sense, Maroli et al. (2017) reported that high elastic modulus materials used strongly modulate the biomechanical behavior of the tooth.

Magne et al. (2017) state in their study that presence of coronary dentin of at least 2 mm increases intrinsic resistance of the installed core, and the technique is more benefic. In this research, they tested the resistance of upper incisor teeth with and without ferrule with installation or not of fiberglass post, reporting

that best results were achieved in presence of ferrule and filling empty coronary chamber with composite resin. The authors further elucidate that this technique allows more closely to imitate structure and biomechanical behavior of natural tooth, in contrast to the concept of post and core, in which post will be present at the pulp site mechanically without function. In addition, optimized adhesion procedures such as immediate dentin sealing and high resistance of nano-hybrid composite resin used, may have influence on the teeth that have been tested; generating, at the end, cohesive tooth-core-crown set.

Bacchi et al. (2019), evaluating whether ferrule effect influences biomechanical behavior of mandibular premolars, treated endodontically with use of cast metal cores with and without ferrules, and teeth with fiber post in the same conditions. They verified that ferrule provided higher values in fracture resistance regardless of the type of post used. Their findings demonstrate better results of repairable failures in groups without ferrule. The authors found that in absence of ferrule, the main maximum stresses are predominantly concentrated in cervical portion of the tooth structure, while for teeth with ferrule, mainly with use of metal cores, in which 70% of irreparable fractures were observed, stresses were observed in the region of the ferrule and along the root structure.

Threfore, it is possible to verify how there are controversial results on the subject in the literature. But verifying in general that ferrule has benefits in restorations of these teeth.

Regarding the quantity (height) and type of dental wall (buccal, lingual and/or proximal) of the ferrule in studies using fiber post as retainer, it is possible to state that non-uniform ferrule height, varying between 0.5 mm in proximal and 2 mm in buccal and lingual surfaces, was less effective in preventing failures in investigations of tests with static load than cases of uniform ferrule with 2 mm. In addition, differences in strength after load tests are observed when comparing irregular 2 mm ferrule formed by buccal or lingual walls or in cases of ferrule interrupted by absence of proximals walls (TAN et al., 2005; NAUMANN; PREUSS; ROSENTRITT, 2006).

However, such conclusions are not unanimous and this can be demonstrated in the study by Figueiredo et al. (2019), who checked that the architecture of the ferrule did not affect biomechanical behavior of incisor teeth restored with fiberglass posts under cyclic loading. The authors tested fracture resistance between different ferrule patterns, observing teeth without ferrule, and teeth with 2 mm ferrule that were separated into teeth with ferrule on buccal, teeth with ferrule on lingual, ferrule with ferrule on lingual and buccal, and teeth with all the walls.

These distinct results patterns may be associated with applied testing methodology, presence of bias and limitations of the studies. During oral function, teeth are subjected to dynamic masticatory and thermal loads. This subcritical load can lead to a slow process of incremental structural degradation, usually called fatigue, that is not always reproduced in studies (MA et al., 2009).

In this context, study conducted by Valdivia et al. (2018) submitted bovine incisor teeth with fiber posts installed with 2 mm ferrule and teeth without ferrule, cemented with resin cement and restored with ceramic crowns at 20,000 thermal cycles and 2,400,000 mechanical cycles before testing to simulate aging for 10 years of activity in oral cavity. The authors found that when a single root tooth is subjected to load applied along the long axial of the tooth, the greatest elastic stress occurs on lingual surface of the coronal third of the root. In this way, maintenance of adhesive integrity is decisive for transference of stress/deformation. In addition, presence of a large number of bubbles and voids in resin cement layer can increase stress concentration, favoring failures in the post/root

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interface. Thus, it is important to be careful when inserting resin cement into the root canal when installing the post. Teeth without ferrule showed significantly less fracture resistance than teeth with ferrule.

Absence of ferrule is capable of increasing stress at root dentin/cement/post interfaces. Therefore, the lower resistance to fracture of teeth without ferrule is consequence of both increased stress and tension in root dentin and detachment of the post. In addition to Valdivia et al. (2018) other studies found similar results in their investigations (SANTOS-FILHO et al., 2008; JULOSKI; APICELLA; FERRARI, 2014; VERÍSSIMO et al., 2014).

In vitro studies evaluating fracture load of teeth treated endodontically with installation of

different posts demonstrate higher values of fracture resistance than clinically can happen, with standard deviations that should be considered in these conclusions. Thus, further studies applying load tests should be carried out to predict fatigue behavior of these restored teeth. In addition, other factors such as loading changes in direction, pH, humidity and temperature when carrying out tests to mimic natural function conditions of teeth are difficult to control in these in vitro tests. Therefore, there is still need for methods or techniques that allow detailed description of the fractured surface of such teeth (FONTANA et al., 2019).

## CONCLUSION

Endodontically-treated teeth show better fracture resistance behaviors when ferrule is present. Ferrule effect is beneficial in endodontically-treated teeth, but additional care in post installation procedures should be taken in attempt to improve their mechanical behavior. Besides that, use of fiberglass posts is feasible on anterior and posterior teeth. In addition, further studies with similar parameters to functional conditions of the teeth in oral cavity should be used and tests should be carried out for real comparison of the results of the studies with each other.

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