DOI: 10.1111/iej.13607

INTERNATIONAL ENDODONTIC JOURNAL | WILEY

REVIEW

European Society of Endodontology position statement: The restoration of root filled teeth

European Society of Endodontology developed by: | Francesco Mannocci[1] | Bhavin Bhuva[1] | Miguel Roig[2] | Maciej Zarow[3] | Kerstin Bitter[4]

[1]Faculty of Dentistry, Oral & Craniofacial Sciences, Department of Endodontics, King's College London, Guy's Hospital, London, UK

[2]Section for Endodontology, Department of Restorative Dentistry, Universitat Internacional de Catalunya, Barcelona, Spain

[3]Private Practice, Krakow, Poland

[4]Department of Operative and Preventive Dentistry, Charité – University Medicine, Berlin, Germany

Correspondence
Paul M. H. Dummer, European Society of Endodontology, Postboks 1237 Vika, 0110 Oslo, Norway.
Email: president@e-s-e.eu

Abstract

This position statement on the restoration of root filled teeth represents the consensus of an expert committee, convened by the European Society of Endodontology (ESE). Current clinical and scientific evidence, as well as the expertise of the committee, have been used to develop this statement. The aim is to provide clinicians with evidence-based principles for decision-making on the choice of restoration following the completion of root canal treatment. By discussing the evidence in relation to key topics regarding post-endodontic restoration, a series of clinical recommendations are made. The scientific basis of the recommendations made in this paper can be found in a recently published review article (Bhuva *et al*. 2021, *International Endodontic Journal*, https://doi.org/10.1111/iej.13438). It is the intention of the committee to update this statement as further evidence emerges.

KEYWORDS

crown, endocrown, onlay, post, restoration, root filled teeth

INTRODUCTION

The restoration of the root filled tooth is an essential component of root canal treatment and should restore the tooth to function, aesthetics and protect the residual tooth structure from biological and structural failure. The range of restorative options available to clinicians has increased with advances in adhesive bonding, improved ceramics and innovation in digital scanning and fabrication processes (Alves de Carvalho et al., 2018). The numerous choices now available provide great opportunity, but also create a potential source of confusion for clinicians when deciding on the most appropriate technique and materials for the restoration of root filled teeth.

Root filled teeth may be lost due to post-treatment endodontic disease, unrestorable carious lesions, restorative failure, irretrievable cusp or crown fracture, vertical root fracture or periodontal disease. More recently, there has been a shift in endodontic outcome research, with more studies focusing on the overall survival of root filled teeth. Failure analyses of teeth in these studies include both biological (endodontic) and structural (restorative) causes (Landys Boren et al., 2015; Salehrabi & Rotstein, 2004). The findings of survival studies have demonstrated that the quantity of residual sound tooth structure (Al-Nuaimi et al., 2017; Nagasiri & Chitmongkolsuk, 2005), as well as the choice of restoration (Aquilino & Caplan, 2002; Pratt et al., 2016), are the main factors influencing the survival of

Further additions, comments and consensus by ESE Executive Board members: Dummer PMH, Duncan HF, Franco V, Galler K, Gambarini G, Kirkevang L-L, Whitworth J.

root filled teeth. These observations are a point of interest in relation to minimal intervention endodontic philosophies (Clark & Khademi, 2010; Plotino et al., 2017) and the impact these concepts may have on tooth survival. Although current evidence in respect of the validity of these concepts on survival outcomes is limited, it is hoped that future clinical research will provide relevant patient-centred data which can be used to reassess the current evidence base.

There are significant challenges in establishing meaningful conclusions from the scientific literature in relation to the impact of post-endodontic restoration on clinical outcomes, and therefore, controversies do, and will, remain regarding the most appropriate restorative procedures following the completion of root canal treatment. Study and cohort heterogeneity and the limited number of prospective clinical trials with a high level of evidence complicate the development of management guidelines. Considering these challenges, the results of well-designed survival studies, assessing patient-centred outcomes, should perhaps, lead to the reconsideration of the prognosis, and therefore, management of compromised teeth. These findings are particularly relevant to teeth with limited residual tooth structure (Al-Nuaimi et al., 2020) and also teeth with mild to moderate cracks (Leong et al., 2020), which appear to show good medium-term survival.

ESE-approved definitions and terminology/ glossary

Cracked tooth

An incomplete fracture involving dentine, which extends from the crown of the tooth in an apical direction. Cracks most commonly present in the mesio-distal plane in posterior teeth and may extend to variable depth within the crown and/or root.

Endocrown

An all-ceramic full coverage crown which includes an integrated intra-coronal extension which projects into the pulp chamber of a root filled posterior tooth.

Ferrule effect

An adequate circumferential supramarginal collar of dentine to retain an extra-coronal restoration.

1. Clinical evidence on the ferrule effect, number of cavity walls and residual tooth volume on the survival of root filled teeth

Much of the research on the survival of restorations and root filled teeth is based on the findings of laboratory studies assessing the effect of an adequate ferrule effect on biomechanical performance (Ichim et al., 2006; Juloski et al., 2012; Ma et al., 2009; Sorensen & Engelman, 1990). Clinical studies have assessed the importance of the ferrule effect, as well as the number of remaining cavity walls (Cagidiaco et al., 2008; Ferrari et al., 2012), either in combination or isolation. However, there is significant variability in how both the ferrule effect and remaining cavity walls are assessed. The height and thickness of the ferrule effect or residual walls are rarely specified, and in general, described more qualitatively. Several authors have stipulated a minimum ferrule height of at least 2 mm (Cagidiaco et al., 2008; Ferrari et al., 2012; Mancebo et al., 2010; Naumann et al., 2007), whilst other authors have assessed the performance of teeth with lesser (Setzer et al., 2011) and greater (Schmitter et al., 2007) ferrule height. A review of the literature on the ferrule effect suggested a minimum ferrule height of 1.5–2.5 mm is required (Juloski et al., 2012). Cloet et al. (2017) suggested that the ferrule effect should have a minimum thickness of 2 mm, whilst Nagasiri and Chitmongkolsuk (2005) recommended that residual walls should also be of 2 mm thickness. Interestingly, there are very little further data on this important variable.

In vivo prospective studies with a duration of 5–17 years demonstrate a correlation between the survival of restorations and root filled teeth in relation to the amount of ferrule effect and number of remaining cavity walls (Cloet et al., 2017; Creugers et al., 2005; Ferrari et al., 2012; Fokkinga et al., 2007). A systematic review on the failure rates of teeth (Naumann et al., 2018a) restored with cores or posts, with and without adequate ferrule effect, found that two of the three selected randomized studies demonstrated the positive effect of teeth with adequate circumferential supramarginal tooth structure (Creugers et al., 2005; Ferrari et al., 2012).

A prospective study on molars following root canal retreatment suggested an association between larger volumes of residual tooth structure and the percentage of favourable endodontic treatment outcomes (Al-Nuaimi et al., 2017). The 4-year survival of the same group of teeth proved that failure of root canal retreatment at 1 year was a good predictor of tooth extraction at 4 years (Al-Nuaimi et al., 2020).

2. Clinical evidence on the effect of cracks on the survival of root filled teeth

Cracks in root filled teeth should be considered as a significant factor affecting their survival. However, the diagnosis and prognostication of cracked teeth remains a

challenge for clinicians. Based on emerging research on the survival of root filled teeth with cracks, it would appear that the location and extent of cracks should not be considered in isolation when determining the prognosis.

A prospective study demonstrated 96% survival, over a 2-to-4-year period, for crowned root filled teeth with cracks extending to the level of the canal orifice and up to 5 mm beyond (Davis & Shariff, 2019). Further evidence from a systematic review of 4 retrospective studies suggested a 5-year survival rate of 84% for teeth with cracks (Leong et al., 2020).

3. Clinical evidence on the effect of tooth location and presence of proximal contacts on the survival of root filled teeth

Root filled teeth are at increased risk of structural failure as a result of tooth volume loss and the biomechanical consequences of loss of pulp vitality, as well as those of subsequent endodontic and restorative treatment. Both the functional and parafunctional stresses imparted on the root filled tooth are related to the location and presence of proximal contacts. Terminal teeth and those without proximal contacts are more susceptible to crown/root fractures, as well as complications such as core failure.

A 4-to-10-year retrospective study (Aquilino & Caplan, 2002), as well as a further 2-to-4-year prospective study (Ng et al., 2011), demonstrated that terminal teeth (last standing teeth in the arch), and those without neighbouring contacts, have inferior survival to nonterminal teeth (Aquilino & Caplan, 2002; Lazarski et al., 2001) and those with neighbouring contacts, respectively (Alley et al., 2004; Aquilino & Caplan, 2002). Root filled second molar teeth have been shown to have the greatest likelihood of catastrophic failure, necessitating extraction (Aquilino & Caplan, 2002).

4. Clinical evidence on the effect of restoration type and timing on the survival of root filled teeth

The risk of irretrievable fracture or crack development and propagation pose a significant threat to the survival of root filled tooth. As well as this, an optimal coronal seal is of significant importance.

Timing of restoration placement

There is evidence from an 8-year retrospective study that root filled posterior teeth restored with cuspal coverage restorations within 4 months of the completion of root canal treatment are three times less likely to be extracted than those restored after 4 months (Pratt et al., 2016). Currently, no further studies assessing the timing of the cuspal coverage restoration on the survival of root filled teeth are available, and therefore, the evidence is limited.

Direct or indirect restorations

Cuspal protection of root filled premolars and molars has been reported to improve survival, reducing the risk of biomechanical failure. Whilst there is limited evidence for crowning anterior root filled teeth, clinical research has revealed a significant correlation between the survival of posterior root filled teeth and the placement of a cuspal coverage restoration. However, each case should be assessed individually with consideration of the following factors:

- tooth structure loss;
- terminal or nonterminal tooth and number of neighbouring contacts;
- presence of cracks;
- occlusal factors (excursive/protrusive guidance and presence of deflective contacts).

Sorensen and Martinoff (1984) studied 1273 root filled teeth retrospectively for up to 25 years and concluded that cuspal coverage restorations significantly improved long-term survival. A 10-year retrospective study (Landys Boren et al., 2015) including all tooth types, demonstrated that teeth restored with crowns had a higher estimated survival rate (91%) when compared with those restored with direct restorations (76%). Similarly, an 8-year retrospective study (Pratt et al., 2016) on posterior teeth concluded that teeth restored with crowns had a survival rate of 71% versus a survival rate of 58% for teeth which did not receive cuspal coverage. Aquilino and Caplan (2002) observed that root filled teeth without crowns were extracted 6 times more frequently than those with crowns, although these findings may be subject to bias, as the included teeth were not randomly allocated due to the retrospective study design. Within an observation period of 3 years, a randomized clinical trial (Mannocci et al., 2002) reported that premolars with limited loss of tooth structure restored with fibre posts and direct composite resin restorations (53 teeth) had a similar restoration failure rate (4%) to those restored with fibre posts, composite cores and full coverage crowns (54 teeth). Data provided by prospective research on the impact of indirect cuspal coverage on the survival of root filled teeth is limited to this study.

Choice of material for crowns and onlays

The rapid evolution of dental materials, particularly composite resin and ceramics has been evident over recent years. The options available for direct restoration, core materials, posts and cuspal coverage provision are more extensive than ever before.

Despite this, there have been no prospective randomized controlled clinical trials comparing different materials for the construction of crowns and onlays; there is evidence from retrospective research that the performance of metal ceramic, all ceramic and indirect composite restorations is excellent in medium-term studies of 3–5 years (Chrepa et al., 2014; Pjetursson et al., 2007; Sailer et al., 2015). Limited long-term data (25–30 years) are available for gold (Studer et al., 2000) and metal ceramic crowns (Walton, 2013). As a number of different materials are used for all ceramic crown construction, it is important to acknowledge that favourable outcomes, albeit limited, have been observed for leucite, lithium disilicate reinforced glass ceramic or alumina-based oxide ceramics. Less favourable outcomes have been observed in posterior teeth restored with glass ceramic and monolithic zirconia crowns (Sailer et al., 2015).

Endocrowns versus conventional crowns

An alternative restoration for root filled posterior teeth with significant coronal structural loss is the use of endocrowns instead of conventional restorations with posts and full coverage crowns. The latter requires preparation of a ferrule design which contributes to additional tooth structure loss during preparation, and this may negatively impact the long-term survival of the restored tooth. However, endocrowns are adhesively bonded to the dentine of the pulp chamber; consequently, adequate isolation of the prepared tooth structure during adhesive cementation of the restoration must be assured to achieve optimal long-term outcomes. In addition, this restoration type is predominantly recommended for molars. Premolars restored with endocrowns have been reported to have a significantly reduced survival rate compared to full coverage crowns, mainly due to decementation which may be attributed to the reduced available surface area for adhesive bonding (Bindl et al., 2005).

Root filled molars restored with endocrowns demonstrate similar survival rates compared to full coverage crowns with survival greater than 90% after 7 (Fages et al., 2017) and 10 years (Otto & Mormann, 2015) respectively.

Choice of material for direct restorations and cores

Minimal research exists specifically on the performance of amalgam or composite resin as direct restorations in root filled teeth. However, superior survival of root filled premolar teeth restored with direct composite restorations when compared with those restored with direct amalgam restorations was observed in a 5-year prospective clinical trial (Mannocci et al., 2005). However, of the teeth which survived, those restored with amalgam had less secondary caries than those restored with composite.

Clinicians have a number of choices for core placement prior to cuspal coverage restoration. Unfortunately, there are currently no randomized controlled clinical trials comparing amalgam, composite or other materials, such as glass ionomer cements, as core materials for root filled teeth restored with crowns.

5. Clinical evidence on the effect of post-placement on the survival of root filled teeth

Effect of post-placement

The use intraradicular posts in root filled teeth has been an area of much discussion and controversy. It is imperative to acknowledge that the purpose of a post is to facilitate core retention; it does not increase the strength of the root or compensate for the absence of a ferrule effect. With the evolution of ever-improving adhesive materials, fewer teeth require posts, and when indicated, there is certainly no reason for additional dentine removal to be carried out to facilitate post-placement. Therefore, posts should be placed 'passively', without mechanical preparation of the root canal space (Naumann et al., 2018b).

A systematic review on the survival of root filled teeth included eight studies in which posts had been provided. Seven of the eight studies did not report an improvement in survival following post-placement (Naumann et al., 2018a). These findings corroborate the assertion that residual tooth structure, and not the presence or absence of a post, dictates tooth survival.

Root filled teeth with no remaining coronal dentine walls have been shown to benefit from post-placement (Bitter et al., 2009; Naumann et al., 2018a) whilst teeth in the maxillary anterior region have been reported to have an increased risk of structural failure due to the shear forces they are subjected to (Naumann et al., 2005, 2008; Schmitter et al., 2011; Torbjörner & Fransson, 2004). Consequently, posts may be more beneficial in these cases, although this requires further evaluation.

In contrast to molars, premolars have less coronal tooth structure volume and smaller pulp chambers to facilitate the retention of the core placed after the completion of root canal treatment. Moreover, the endodontic access cavity increases the possibility of fracture due to cuspal deflection during function (Göktürk et al., 2018).

In summary, anterior teeth and premolars may require fibre posts more often than molars (Acquaviva et al., 2011; Ferrari et al., 2007). A recent classification system for root filled teeth (Zarow et al., 2018) recommended the use of fibre posts in anterior and premolar teeth with significantly compromised tooth structure. These recommendations are based on the findings of studies assessing the effect of remaining walls on tooth survival (Ferrari et al., 2012; Guldener et al., 2017).

Fibre or metal posts

Gold alloy or Cobalt-Chromium-based cast posts and cores have been used successfully to restore root filled teeth, demonstrating success rates of 84%–94% after 10 years (Cloet et al., 2017; Ellner et al., 2003; Ferrari et al., 2000). However, one disadvantage of their use is the additional removal of peri-cervical root canal dentine for post-space preparation and the potential risk of coronal leakage during temporization. Flexible post-systems, for example fibre posts, have been developed with the concept of facilitating more uniform stress distribution compared to higher-stiffness materials which have been purported to predispose root filled teeth to root fracture. To date, no clinical evidence exists that the use of fibre posts reduces the occurrence of root fractures *in vivo* (Figueiredo et al., 2015; Naumann et al., 2017). Further prospective clinical data has not demonstrated the superiority of either rigid or flexible posts on tooth and/or restoration survival (Cloet et al., 2017; Sarkis-Onofre et al., 2014; Sterzenbach et al., 2012). Despite one clinical trial revealing a significantly greater survival rate for fibre posts compared to metal screw posts (Schmitter et al., 2011) and a recent meta-analysis concluding significantly higher mid-term survival rates for fibre posts compared to metal posts (Wang et al., 2019) it can be concluded that currently no evidence exists that the choice of post-material affects the survival of root filled teeth.

RECOMMENDATIONS FOR THE RESTORATION OF ROOT FILLED TEETH

The development of evidence-based guidelines for the restoration of root filled teeth is complex with a multitude of factors that require consideration. However, the following recommendations are considered as general guidance, which can be used to facilitate treatment decision-making. However, clinicians are advised to consider each case individually when considering the following recommendations:

- The presence of a circumferential ferrule is beneficial for the survival of both anterior and posterior root filled teeth. Wherever possible, clinicians should make every effort to obtain an optimal ferrule when planning indirect restorations. The absence of an adequate ferrule effect is associated with reduced tooth and restoration survival.
- In most cases, when at least one proximal wall is missing, root filled premolars and molars should be restored with cuspal coverage restorations. However, restorations should always be designed conservatively and onlay restorations utilized where appropriate, with the aim of retaining as much sound residual tooth structure as possible. Tooth reduction should be carried out according to requirements of the material used for the indirect restoration and excessive preparation must be avoided. There may be scenarios where cuspal coverage of a posterior tooth is not considered necessary, for example, in cases with only a Class 1 cavity and where the residual walls are of adequate thickness, and no cracks are present, or in scenarios where there is no opposing tooth. Clinicians should consider each case individually, having given careful consideration to the overall tooth structure loss, thickness of the residual dentine walls, tooth location, number of neighbouring contacts, absence/presence of cracks and occlusal factors. Furthermore, consideration of the impact of minimal intervention endodontic-restorative techniques may influence the decision-making process.
- Terminal teeth, particularly in patients with parafunctional habits, require detailed occlusal assessment and appropriate restorative management to prevent further complications.
- Careful attention should be paid to existing premature occlusal interferences as part of the post-endodontic restorative process.
- Cracked teeth should routinely be restored with cuspal coverage restorations following endodontic treatment. Options for cracked teeth should be discussed with patients so that they are able to make an informed decision on the prognosis and whether the tooth should be retained. Decision-making should not be solely based on the location and extent of detected cracks. Furthermore, cracked teeth require careful clinical and radiographic follow-up to monitor potential attachment and bone loss which may develop from crack propagation and which may compromise future replacement options such as implant placement.
- The placement of a post-specifically in teeth with no remaining coronal dentine walls is beneficial, particularly

in anterior and premolar teeth. However, in all other situations (including molar teeth), post-placement does not improve restoration or tooth survival. The benefit of enhanced core retention that may be achieved with post-placement should be considered against the potential dentine removal required. Additional (mechanical) dentine removal for post-placement should be avoided and 'passive' post-placement employed wherever possible.
- Currently, there is no clinical evidence that the material of the post, either rigid or flexible, affects the survival rate of root filled teeth restored with posts. If posts are adhesively luted, all steps of the designated bonding protocol should be followed. A clean and adequately prepared dentine surface appears to be more important for the success of the restoration than the choice of post-material.
- Endocrowns can be considered as an appropriate alternative to conventional post-retained full coverage restorations for root filled molar teeth, permitting greater preservation of residual tooth structure. However, it is imperative that the correct adhesive luting protocol is followed to ensure the success of these restorations.

Prospective studies assessing the survival of root filled teeth treated with minimal intervention endodontic and restorative techniques, including teeth restored with and without cuspal coverage restoration will offer insight into the effect of dentine preservation on tooth survival. It is hoped that future clinical research will provide tangible outcome studies to compare the application of these concepts with more traditional philosophies.

CONFLICT OF INTEREST

The authors confirm they have no conflict of interest.

AUTHOR CONTRIBUTION

All authors contributed equally to the development of the manuscript.

ORCID

Francesco Mannocci https://orcid.org/0000-0002-0560-1054
Bhavin Bhuva https://orcid.org/0000-0002-5413-9134
Miguel Roig https://orcid.org/0000-0002-4872-4118
Maciej Zarow https://orcid.org/0000-0001-7870-2115
Kerstin Bitter https://orcid.org/0000-0002-4458-8331

REFERENCES

Acquaviva, P.A., Madini, L., Krokidis, A., Gagliani, M., Mangani, F. & Cerutti, A. (2011) Adhesive restoration of endodontically treated premolars: influence of posts on cuspal deflection. *Journal of Adhesive Dentistry*, 13, 279–286.

Alley, B.S., Kitchens, G.G., Alley, L.W. & Eleazer, P.D. (2004) A comparison of survival of teeth following endodontic treatment performed by general dentists or by specialists. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology*, 98, 115–118.

Al-Nuaimi, N., Ciapryna, S., Chia, M., Patel, S. & Mannocci, F. (2020) A prospective study on the effect of coronal tooth structure loss on the 4-year clinical survival of root canal retreated teeth, and retrospective validation of the Dental Practicality Index. *International Endodontic Journal*, 53, 1040–1049.

Al-Nuaimi, N., Patel, S., Austin, R.S. & Mannocci, F. (2017) A prospective study assessing the effect of coronal tooth structure loss on the outcome of root canal retreatment. *International Endodontic Journal*, 50, 1143–1157.

Alves de Carvalho, I.F., Marques, S., Araújo, F.M., Azevedo, L.F., Donato, H. & Correia, A. (2018) Clinical performance of CAD/CAM tooth-supported ceramic restorations: A systematic review. *The International Journal of Periodontics & Restorative Dentistry*, 38, e68–e78.

Aquilino, S.A. & Caplan, D.J. (2002) Relationship between crown placement and the survival of endodontically treated teeth. *Journal of Prosthetic Dentistry*, 87, 256–263.

Bhuva, B., Giovarruscio, M., Rahim, N., Bitter, K. & Mannocci, F. (2021) The restoration of root filled teeth: a review of the clinical literature. *International Endodontic Journal*, 54, 509–535.

Bindl, A., Richter, B. & Mormann, W.H. (2005) Survival of ceramic computer-aided design/manufacturing crowns bonded to preparations with reduced macroretention geometry. *International Journal of Prosthodontics*, 18, 219–224.

Bitter, K., Noetzel, J., Stamm, O., Vaudt, J., Meyer-Lueckel, H., Neumann, K. et al. (2009) Randomized clinical trial comparing the effects of post placement on failure rate of postendodontic restorations: preliminary results of a mean period of 32 months. *Journal of Endodontics*, 35, 1477–1482.

Cagidiaco, M.C., García-Godoy, F., Vichi, A., Grandini, S., Goracci, C. & Ferrari, M. (2008) Placement of fiber prefabricated or custom made posts affects the 3-year survival of endodontically treated premolars. *American Journal of Dentistry*, 21, 179–184.

Chrepa, V., Konstantinidis, I., Kotsakis, G.A. & Mitsias, M.E. (2014) The survival of indirect composite resin onlays for the restoration of root filled teeth: a retrospective medium-term study. *International Endodontic Journal*, 47, 967–973.

Clark, D. & Khademi, J. (2010) Modern molar endodontic access and directed dentin conservation. *Dental Clinics*, 54, 249–273.

Cloet, E., Debels, E. & Naert, I. (2017) Controlled clinical trial on the outcome of glass fiber composite cores versus wrought posts and cast cores for the restoration of endodontically treated teeth: a 5-year follow-up study. *International Journal of Prosthodontics*, 30, 71–79.

Creugers, N.H., Mentink, A.G., Fokkinga, W.A. & Kreulen, C.M. (2005) 5-year follow-up of a prospective clinical study on various types of core restorations. *International Journal of Prosthodontics*, 18, 34–39.

Davis, M.C. & Shariff, S.S. (2019) Success and survival of endodontically treated cracked teeth with radicular extensions: a 2-to 4-year prospective cohort. *Journal of Endodontics*, 45, 848–855.

Ellner, S., Bergendal, T. & Bergman, B. (2003) Four post-and-core combinations as abutments for fixed single crowns: a prospective up to 10-year study. *International Journal of Prosthodontics*, 16, 249–254.

Fages, M., Raynal, J., Tramini, P., Cuisinier, F.J. & Durand, J.C. (2017) Chairside computer-aided design/computer-aided manufacture all-ceramic crown and endocrown restorations: a 7-year survival rate study. *International Journal of Prosthodontics*, 30, 556–560.

Ferrari, M., Cagidiaco, M.C., Goracci, C., Vichi, A., Mason, P.N., Radovic, I. et al. (2007) Long-term retrospective study of the clinical performance of fiber posts. *American Journal of Dentistry*, 20, 287–291.

Ferrari, M., Vichi, A. & Garcia-Godoy, F. (2000) Clinical evaluation of fiber-reinforced epoxy resin posts and cast post and cores. *American Journal of Dentistry*, 13, 15B–18B.

Ferrari, M., Vichi, A., Fadda, G.M., Cagidiaco, M.C., Tay, F.R., Breschi, L. et al. (2012) A randomized controlled trial of endodontically treated and restored premolars. *Journal of Dental Research*, 91, S72–S78.

Figueiredo, F.E., Martins-Filho, P.R. & Faria, E.S.A.L. (2015) Do metal post-retained restorations result in more root fractures than fiber post-retained restorations? A systematic review and meta-analysis. *Journal of Endodontics*, 41, 309–316.

Fokkinga, W.A., Kreulen, C.M., Bronkhorst, E.M. & Creugers, N.H. (2007) Up to 17-year controlled clinical study on post-and-cores and covering crowns. *Journal of Dentistry*, 35, 778–786.

Göktürk, H., Karaarslan, E.Ş., Tekin, E., Hologlu, B. & Sarıkaya, I. (2018) The effect of the different restorations on fracture resistance of root-filled premolars. *BMC Oral Health*, 18, 1–8.

Guldener, K.A., Lanzrein, C.L., Siegrist Guldener, B.E., Lang, N.P., Ramseier, C.A. & Salvi, G.E. (2017) Long-term clinical outcomes of endodontically treated teeth restored with or without fibre post-retained single-unit restorations. *Journal of Endodontics*, 43, 188–193.

Ichim, I., Kuzmanovic, D.V. & Love, R.M. (2006) A finite element analysis of ferrule design on restoration resistance and distribution of stress within a root. *International Endodontic Journal*, 39, 443–452.

Juloski, J., Radovic, I., Goracci, C., Vulicevic, Z.R. & Ferrari, M. (2012) Ferrule effect: a literature review. *Journal of Endodontics*, 38, 11–19.

Landys Boren, D., Jonasson, P. & Kvist, T. (2015) Long-term survival of endodontically treated teeth at a public dental specialist clinic. *Journal of Endodontics*, 41, 176–181.

Lazarski, M.P., Walker, W.A. III, Flores, C.M., Schindler, W.G. & Hargreaves, K.M. (2001) Epidemiological evaluation of the outcomes of nonsurgical root canal treatment in a large cohort of insured dental patients. *Journal of Endodontics*, 27, 791–796.

Leong, D., de Souza, N.N., Sultana, R. & Yap, A.U. (2020) Outcomes of endodontically treated cracked teeth: a systematic review and meta-analysis. *Clinical Oral Investigations*, 24, 465–473.

Ma, P.S., Nicholls, J.I., Junge, T. & Phillips, K.M. (2009) Load fatigue of teeth with different ferrule lengths, restored with fiber posts, composite resin cores, and all-ceramic crowns. *The Journal of Prosthetic Dentistry*, 102, 229–234.

Mancebo, J.C., Jimenez-Castellanos, E. & Canadas, D. (2010) Effect of tooth type and ferrule on the survival of pulpless teeth restored with fibre posts: a 3-year clinical study. *American Journal of Dentistry*, 23, 351–356.

Mannocci, F., Bertelli, E., Sherriff, M., Watson, T.F. & Pitt Ford, T.R. (2002) Three-year clinical comparison of survival of endodontically treated teeth restored with either full cast coverage or with direct composite restoration. *The Journal of Prosthetic Dentistry*, 88, 297–301.

Mannocci, F., Qualtrough, A.J., Worthington, H.V., Watson, T.F. & Pitt Ford, T.R. (2005) Randomized clinical comparison of endodontically treated teeth restored with amalgam or with fiber posts and resin composite: five-year results. *Operative Dentistry*, 30, 9–15.

Nagasiri, R. & Chitmongkolsuk, S. (2005) Long-term survival of endodontically treated molars without crown coverage: a retrospective cohort study. *Journal of Prosthetic Dentistry*, 93, 164–170.

Naumann, M., Blankenstein, F., Kiessling, S. & Dietrich, T. (2005) Risk factors for failure of glass fiber-reinforced composite post restorations: a prospective observational clinical study. *European Journal of Oral Sciences*, 113, 519–524.

Naumann, M., Preuss, A. & Frankenberger, R. (2007) Reinforcement effect of adhesively luted fibre reinforced composite versus titanium posts. *Dental Materials*, 23, 138–144.

Naumann, M., Reich, S., Nothdurft, F.P., Beuer, F., Schirrmeister, J.F. & Dietrich, T. (2008) Survival of glass fiber post restorations over 5 years. *American Journal of Dentistry*, 21, 267–272.

Naumann, M., Schmitter, M., Frankenberger, R. & Krastl, G. (2018a) Ferrule comes first. Post is second!" Fake news and alternative facts? A systematic review. *Journal of Endodontics*, 44, 212–219.

Naumann, M., Schmitter, M. & Krastl, G. (2018b) Postendodontic restoration: endodontic post-and-core or no post at all. *Journal of Adhesive Dentistry*, 20, 19–24.

Naumann, M., Sterzenbach, G., Dietrich, T., Bitter, K., Frankenberger, R. & von Stein-Lausnitz, M. (2017) Dentin-like versus rigid endodontic post: 11-year randomized controlled pilot trial on no-wall to 2-wall defects. *Journal of Endodontics*, 43, 1770–1775.

Ng, Y.L., Mann, V. & Gulabivala, K. (2011) A prospective study of the factors affecting outcomes of non-surgical root canal treatment: part 2: tooth survival. *International Endodontic Journal*, 44, 610–625.

Otto, T. & Mormann, W.H. (2015) Clinical performance of chairside CAD/CAM feldspathic ceramic posterior shoulder crowns and endocrowns up to 12 years. *International Journal of Computerized Dentistry*, 18, 147–161.

Pjetursson, B.E., Sailer, I., Zwahlen, M. & Hämmerle, C.H. (2007) A systematic review of the survival and complication rates of all-ceramic and metal–ceramic reconstructions after an observation period of at least 3 years. Part I: single crowns. *Clinical Oral Implants Research*, 18, 73–85.

Plotino, G., Grande, N.M., Isufi, A., Ioppolo, P., Pedullà, E., Bedini, R. et al. (2017) Fracture strength of endodontically treated teeth with different access cavity designs. *Journal of Endodontics*, 43, 995–1000.

Pratt, I., Aminoshariae, A., Montagnese, T.A., Williams, K.A., Khalighinejad, N. & Mickel, A. (2016) Eight-year retrospective study of the critical time lapse between root canal completion and crown placement: its influence on the survival of endodontically treated teeth. *Journal of Endodontics*, 42, 1598–1603.

Sailer, I., Makarov, N.A., Thoma, D.S., Zwahlen, M. & Pjetursson, B.E. (2015) All-ceramic or metal-ceramic tooth-supported fixed dental prostheses (FDPs)? A systematic review of the survival and complication rates. Part I: Single crowns (SCs). *Dental Materials*, 31, 603–623.

Salehrabi, R. & Rotstein, I. (2004) Endodontic treatment outcomes in a large patient population in the USA: an epidemiological study. *Journal of Endodontics*, 30, 846–850.

Sarkis-Onofre, R., Jacinto, R.C., Boscato, N., Cenci, M.S. & Pereira-Cenci, T. (2014) Cast metal vs. glass fibre posts: a randomized

controlled trial with up to 3 years of follow up. *Journal of Dentistry*, 42, 582–587.

Schmitter, M., Doz, P., Rammelsberg, P., Gabbert, O. & Ohlmann, B. (2007) Influence of clinical baseline findings on the survival of 2 post systems: a randomized clinical trial. *International Journal of Prosthodontics*, 20, 173–178.

Schmitter, M., Hamadi, K. & Rammelsberg, P. (2011) Survival of two post systems–five-year results of a randomized clinical trial. *Quintessence International*, 42, 843–850.

Setzer, F.C., Boyer, K.R., Jeppson, J.R., Karabucak, B. & Kim, S. (2011) Long-term prognosis of endodontically treated teeth: a retrospective analysis of preoperative factors in molars. *Journal of Endodontics*, 37, 21–25.

Sorensen, J.A. & Engelman, M.J. (1990) Ferrule design and fracture resistance of endodontically treated teeth. *Journal of Prosthetic Dentistry*, 63, 529–536.

Sorensen, J.A. & Martinoff, J.T. (1984) Intracoronal reinforcement and coronal coverage: a study of endodontically treated teeth. *Journal of Prosthetic Dentistry*, 51, 780–784.

Sterzenbach, G., Franke, A. & Naumann, M. (2012) Rigid versus flexible dentine-like endodontic posts-clinical testing of a biomechanical concept: seven-year results of a randomized controlled clinical pilot trial on endodontically treated abutment teeth with severe hard tissue loss. *Journal of Endodontics*, 38, 1557–1563.

Studer, S.P., Wettstein, F., Lehner, C., Zullo, T.G. & Schärer, P. (2000) Long-term survival estimates of cast gold inlays and onlays with their analysis of failures. *Journal of Oral Rehabilitation*, 27, 461–472.

Torbjörner, A. & Fransson, B. (2004) A literature review on the prosthetic treatment of structurally compromised teeth. *International Journal of Prosthodontics*, 17, 369–376.

Walton, T.R. (2013) The up to 25-year survival and clinical performance of 2,340 high gold-based metal-ceramic single crowns. *International Journal of Prosthodontics*, 26, 151–160.

Wang, X., Shu, X., Zhang, Y., Yang, B., Jian, Y. & Zhao, K. (2019) Evaluation of fiber posts vs metal posts for restoring severely damaged endodontically treated teeth: a systematic review and meta-analysis. *Quintessence International*, 50, 8–20.

Zarow, M., Ramírez-Sebastià, A., Paolone, G., de Ribot, P.J., Mora, J., Espona, J. et al. (2018) A new classification system for the restoration of root filled teeth. *International Endodontic Journal*, 51, 318–334.

How to cite this article: European Society of Endodontology developed by: Mannocci, F., Bhuva, B., Roig, M., Zarow, M. & Bitter, K. (2021) European Society of Endodontology position statement: The restoration of root filled teeth. *International Endodontic Journal*, 54, 1974–1981. https://doi.org/10.1111/iej.13607