Title:

Restorative considerations of endodontically treated teeth: a literature review.

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Abstract

Aim: During the past 50 years the outcome of endodontic therapy and the factors affecting it have been the focus of over 80 clinical and laboratory studies.[1] This review of the literature focused on the importance of the various definitive restoration considerations of endodontically treatment teeth. Methods: Online search engines were used to access the published journals, the clinical relevance and level of evidence they provided was considered. Results: The different restorative options including the materials used at each stage of restoration were identified, the advantages and disadvantages of each were considered and recommendations for their use have been made. Conclusion: Inclusion of the definitive restoration at the initial endodontic treatment planning stage is imperative to provide optimal prognosis of the tooth following endodontic treatment.

Keywords: Endodontic, success, restoration, post.

Introduction

Endodontic therapy is carried out routinely on teeth with irreversibly inflamed pulps, those that have undergone complete pulpal necrosis, and those with signs and symptoms of periapical inflammation.[2] The treatment involves the removal of bacteria and all remaining necrotic pulp tissue from within the infected canal system. Once accessed via the pulp chamber, the canals are mechanically prepared to create a desirable tapered shape that has a reduced bacterial load.[3] Antimicrobial irrigants are used throughout this procedure, and often a temporary dressing such as non-setting calcium hydroxide is placed into the canals between dental visits to aid complete disinfection of the system. [4] The canal or canals are then obturated, filling the entire system three dimensionally ideally from within 2mm of the root apex to the cemento–dentinal junction.[5] Finally a coronal restoration is placed to seal the disinfected root canal from any microleakage. This process of complete disinfection followed by obturation and restoration of the tooth is essential to promote healing and prevent the occurrence of periapical periodontitis.[6]

The success rate of endodontic treatment is between 70% and 95%.[7] Many studies have looked at factors that affect the outcome of root canal treatment.[2,8,9,10] The presence of a preoperative apical radiolucency, as is seen in Figure 1, is a determining factor in the success of treatment, with higher rates of success associated where no radiolucency was present pre treatment.[2]

The length of the obturation material is important with greater rates of leakage from the oral cavity being associated with inadequate obturation or where the material has been removed clinically for post placement.[11] Kojima *et al.,* 2004 found that high failure rates were associated with insufficient filling of the root canal system; they also found that over extension of the obturation material beyond the apex does not have a detrimental effect upon the outcome of the treatment. Conversely, Phase II of the Toronto study found that over extension of the root filling material does have an adverse affect upon the outcome of treatment.[9] However, they suggest that this may due to over instrumentation and also transportation of bacteria into the apical tissues, rather than the presence of the root filling material itself.

Endodontic treatment may be carried out by the clinician in one single visit, or in multiple visits whereby a calcium hydroxide dressing is placed within the canal between visits. Studies comparing each of these approaches have shown no statistically significant difference between the two with regards to the outcome of the treatment.[12]

A further factor that affects the prognosis of a root filled tooth is the type of final restoration placed. There seems to be a difference of opinion amongst clinicians as to when post placement is indicated, and also whether the post will reinforce or weaken the tooth.[13] With so many different post systems on the market the type of post used may also affect the success of the treatment, as some are more resistant to fracture and fatigue failure than others.[14]

Unfortunately, following initial therapy up to 30% of endodontically treated teeth present with periapical periodontitis, therefore root canal treatment has failed. If this is the case retreatment is indicated using either a surgical or non surgical approach. This may affect the outcome with more rapid rates of healing initially associated with a surgical approach, although very little difference in the long term.[15]

Aims

The aim of this study was to look at the effect of the final restoration upon the outcome of initial endodontic treatment, and to provide guidance on the restorative treatment options and selection of materials available. This will hopefully allow the provision of optimal treatment planning to achieve the best possible prognosis in individual patient cases.

Method

Medline, Science direct, the Cochrane collaboration and the Blackwell synergy were all used to access the published journals.

Using the available search engines numerous studies were found relevant to the topic. Whilst all of these studies are of informative value, it is important to appreciate the strength of evidence provided, the level of evidence ranges from 1 to 5 depending on the type of study. Level 1 is a randomised control trial, which is considered the gold standard for evidence based dentistry, through to level 5 which is an expert opinion or case study.[16] The relevant studies were used in this literature review to allow the topic area to be researched and conclusions drawn.

Success or Failure?

There has been a broad spectrum of results produced upon the topic of endodontic treatment and the factors affecting it. This is largely due to different study designs, which have set different parameters to determine success or failure.[1] Early studies into endodontic outcome used radiographical findings alone to determine whether root canal treatment was a success or failure.[8,17] However, the use of radiographs without clinical consideration is clearly insufficient to assess treatment outcome. Recent studies have taken into account both clinical and radiographical findings. Phase II of the Toronto study[9] recorded outcome as either "healed" or "diseased". The absence of periapical periodontitis and any clinical signs or symptoms were considered "healed", whilst persistence or the development of a new periapical lesion and, or any clinical signs or symptoms indicated "disease".

Salehrabi and Rotstein[10] conducted an epidemiological study which considered endodontic failure to be the occurrence of an untoward event. This included the extraction, retreatment or apicectomy of the tooth following initial endodontic treatment. They measured successful treatment as any tooth that remained in the oral cavity without experiencing an untoward event. A certain drawback of this study is that the operators were not calibrated, and so their decision to provide treatment would have varied from one to another, therefore there is no uniformity in the assessment of the outcome.

"Survival" of a tooth is its retention within the dental arch; this does not however take into account clinical or radiographic data and so does not necessarily indicate "success",[18] although when considering calibration of operators this is an easier method to use.

The Role of the Definitive Restoration

Endodontic treatment removes necrotic tissue and eliminates bacteria from the root canal system to provide an environment conducive to healing.[19] Once obturated it is imperative that the disinfected root canal system is completely sealed from saliva to prevent the reintroduction of bacteria.[20] It is the role of the definitive restoration to provide this total coronal seal.

Traditionally, endodontically treated teeth were considered to be weak and brittle. Rosen[21] (1961) described them as “desiccated and inelastic”. He believed this was due to an absence of blood supply causing the teeth to become dehydrated. However, recent studies have proved this theory untrue; Sedgley and Messer[22] (1992) compared the biomechanical strength of dentine in endodontically treated teeth with their contra lateral vital tooth. This was a laboratory based study in which the 23 pairs of teeth were obtained following extraction for prosthetic reasons. From their study they concluded that, although a slight difference in dentine hardness exists (3.5%), root filled teeth are no more brittle than vital teeth.

The weakness demonstrated clinically by these teeth is now understood to be directly related to the amount of tooth structure that remains following carious destruction, previous restorations and endodontic instrumentation.[22] Reeh *et al* (1989) found that endodontic treatment alone reduced tooth stiffness by 5%, whereas the large amounts of tooth structure missing in a tooth with an MOD cavity reduced tooth stiffness by up to 63%.[23]

It follows, therefore that the role of the endodontic definitive restoration beyond providing a coronal seal must replace lost tooth structure restoring function and supporting what remains of the tooth allowing it to withstand occlusal and parafunctional forces.

The Importance of the Definitive Restoration

Several studies have shown that the provision of the definitive restoration is more important in the survival of the tooth than the endodontic therapy itself. Salehrabi & Rotstein[10] (2004) studied the outcome of 1,462,963 endodontically treated teeth. Only 3% experienced untoward events and therefore failed, of those that had to be extracted 85% had not been restored with full coronal coverage. They calculated that teeth without a definitive restoration, or those with amalgam or composite restorations were 5–6 times more likely to be extracted following endodontic treatment. Therefore, this was considered to be an inadequate treatment option for these teeth.

In accordance with these results, Fuss *et al.,*[24] (1999) found that 43.5% of extractions post endodontic treatment were due to restorative failures that either rendered the teeth unrestorable or allowed microleakage and subsequent endodontic failure. In comparison, only 21% of extractions were attributed to endodontic failure, where a satisfactory coronal restoration existed.

Vire[25] (1991) evaluated the reason for extraction of endodontically treated teeth and in concurrence with the above studies, found that 59.4% of endodontic failures were restorative in nature. They concluded that these were primarily due to crown fracture, which indicates the importance of full coronal coverage in the prognosis of endodontically treated teeth.

In a recent analysis of extracted endodontically treated teeth Zadik *et al.,* [18] (2008) found that 85% did not have full coronal coverage and that they failed largely due to cuspal fractures. These studies indicate to the clinician the absolute importance of including the provision of a definitive restoration within the endodontic treatment planning process.

Treatment Options

The final restoration provided following endodontic treatment is dictated by the amount of tooth tissue remaining and also the position of the tooth in the dental arch.[26] The functional and aesthetic requirements of the tooth must also be considered and restored. [27]

In an anterior or premolar tooth with coronal tissue loss that amounts only to the endodontic access, as demonstrated in Figure 2, a composite or an amalgam restoration is sufficient.

If a more considerable amount of tooth structure has been lost the provision of a crown is indicated.[28] In this situation a post is usually required to retain a core, which in turn will retain the crown. In an anterior tooth insufficient dentine would remain to retain a crown following both endodontic instrumentation and crown preparation of the tooth.[29]

Several studies have evaluated the use of cuspal coverage restorations in endodontically treated premolar teeth with contoroversial results. On one hand, Mondelli *et al.*[30] (2009) concluded that teeth restored with cuspal coverage with condensable resin cement showed comparable results to sound teeth, whereas in similar teeth restored without cuspal coverage, lower fracture resistance values were obtained. This was in agreement with others studies that also concluded that cuspal coverage is a better option in larger cavities.[31,32] On the other hand, Mohammadi *et al*.[33] (2009) found that there was no difference in fracture resistance values in endodontically treated premolar teeth restored with direct composite either with or without fibre posts and cusp coverage, and argued that this result was in agreement with another study. [34] These results are laboratory based results, and further clinical evaluations are needed to assess outcomes of these different restoration modalities. However, premolars often require a post to retain the core because they are usually single rooted with a small pulp chamber that will not provide enough retention, therefore post placement may be necessary; obviously this is a clinical decision.

In molar teeth full coronal coverage should always be provided following endodontic treatment, as demonstrated in Figures 3a and 3b. These teeth must withstand high occlusal loads and unsupported cusps are prone to fracture. In a study of the survival of endodontically treated molar teeth, Nagasiri & Chitmongkolsuk[35] (2005) found that those without full coverage following endodontic treatment had a survival rate of 36%, 5 years post treatment. This shows that without a crown, molar teeth have a very poor prognosis following initial endodontic therapy. Similarly, in a study of 1,639 endodontically treated molar teeth restored with amalgam Hansen *et al.,*[36] (1990) observed high failure rates due to cusp fractures. They concluded from their findings that the restoration of these teeth with amalgam is an unsatisfactory form of treatment.

To retain a crown an amalgam or composite core must be built up to replace the missing coronal tooth structure. In the majority of cases post placement is unnecessary to retain the core as sufficient retention can be obtained from the larger pulp chamber and multiple roots of the molar tooth.[27]

The Post

A post does not serve to reinforce a root filled tooth, it is simply required to retain the core.[37] The prognosis of the tooth is directly related to the amount of sound tooth tissue remaining; therefore the preparation of the post space must be as conservative as possible so as not to weaken the already compromised tooth any further.[38]

The post must be sufficiently long enough to support the crown, ideally this is equal to, or longer than, the length of the crown itself.[34] In their study Sorenson and Martinoff[39] (1986) reviewed the patient records 1 to 25 years post treatment of 1273 endodontically treated teeth that had been restored with posts and cores. They found that when the post length was equal to or greater than the crown length the restoration had a 97.5% success rate. However, whilst the length of the post is important, more vital to the prognosis of the tooth is that at least 5mm of gutta percha is left apically in the root canal to allow maintenance of the coronal seal,[40] therefore post space preparation must take this into account.

Posts can either be custom made with the core constructed out of cast metal, or they can be prefabricated and cemented into the tooth with a core constructed separately. Either type of post may be parallel or tapered; the parallel posts are more retentive, which can be increased further if the post is serrated. Serrations allow the post to actively engage the dentinal walls of the prepared post space,[32] however this can increase stress within the root and so is only recommended if retention is compromised by a short root.[27] Tapered posts require less preparation as they more closely resemble the natural root morphology, therefore fewer iatrogenic perforations occur.[41] However, in a laboratory based study Standlee *et al.,*[42] (1972) found that metal tapered posts produce a wedging effect within the root therefore generating greater stresses under occlusal loads than parallel posts; this may lead to higher rates of root fracture. In accordance with this in a clinical study, Sorenson and Martinoff[34] (1986) found that the enodontically treated teeth that had been restored with cast posts and cores that were parallel experienced no failures, whereas 12.7% of those with tapered shaped cast posts and cores failed. There is a lack of high-level evidence to support the use of either parallel or taper posts. Some manufacturers, however, utilised the best of both designs and made posts with taper apical half and parallel coronal half.

Ferrule

A crucial factor in the outcome of endodontically treated teeth restored with a post and core is the provision of a ferrule. The ferrule is created by 2mm of dentine extending coronally from the margins of the crown preparation, Figure 4. This allows the crown to encircle sound dentine, as opposed to the core material, which distributes occlusal forces throughout the tooth.[41]

Pereira *et al.,*[43] (2006) found that in endodontically treated teeth restored with a post and core, the provision of a 2mm ferrule significantly reduced the likelihood of tooth fracture compared to those without a ferrule. The resistance of these teeth to fracture was further increased with the provision of a 3mm ferrule, although the difference between the two was insignificant. Considering that these teeth have already lost large amounts of coronal dentine the provision of a 2mm ferrule is sufficient.

Cast Post and Core vs. Prefabricated Post

Traditionally the use of laboratory made cast post and core systems, Figure 5a, has been advocated; Bergman *et al.,*[40] (1989) recorded a rate of failure of 1.56% of these restorations annually. They concluded from their study that the use of conventional cast post and cores in the restoration of endodontically treated teeth can be “strongly recommended”. Gomes-Polo *et al*.,[44] (2010) retrospectively evaluated the 10 year survival rate of endodontically treated teeth restored with either metal prefabricated posts versus cast metal post and cores, and found no statistical difference between them. However, in present day practice the direct prefabricated posts, Figure 5b, have become more popular as they can offer many advantages over the conventional cast systems.

The cast post and cores have indeed proven to be more resistant to fracture under the application of an acute load.[41] However this is no longer considered advantageous because prosthodontic restorations must be able to withstand repetitive intraoral forces not extreme loading. Therefore when post and cores fail it is usually due to chronic fatigue, not due to a single application of force.[14] If this is the case the newer direct post materials are preferable as they are more resistant to fatigue.[14]

Furthermore, the provision of a cast post and core requires two dental appointments; in between these visits a temporary post crown is cemented. The temporary post must maintain the coronal seal between visits otherwise endodontic outcome will be compromised. Fox and Gutteridge[45] (1997) studied microleakage associated with different post systems. They found no significant difference between cast post and cores or direct posts but did find that significantly more microleakage occurs with a temporary post. Therefore to avoid this risk of canal re-infection, a direct post system which is cemented immediately can be recommended. If an all ceramic or a bonded crown is required to restore the tooth, the use of a cast post and core is not recommended by manufacturers. This is because the metal in the core prevents the transmission of light through the tooth, and so does not create natural aesthetics. Direct fibre post systems are opaque or translucent, Figure 6, this allows the passage of light through the tooth and so they are much more representative aesthetically of the dentine that they replace.[38] In most clinical situations a prefabricated post can be recommended.

Post Materials

There are a number of different post materials available; traditionally stainless steel, titanium and ceramic have been used. More recently carbon and glass fibre systems have been developed, these are becoming more popular. A number of studies have compared the properties of these prefabricated posts allowing recommendations for their use to be made. Wiskott *et al.,*[14] (1995) compared the fracture resistance of different direct post systems to repetitive loading. They found that the fibrous posts (DT Lightpost and Everstick) can withstand repetitive forces twice as high as the stainless steel, titanium and ceramic posts. They also recorded differences in the mode of failure of the different post systems. They found that the fibrous posts failed as they became debonded, or the posts themselves fractured within the tooth. Conversely, the metal and ceramic posts did not fracture, but as a result caused more root fractures to occur.

Pereira *et al.,*[43] (2006) studied the fracture resistance of different post systems. During this study they also observed differences in the mode of failure. The cast post and cores failed mostly due to root fracture, whereas the direct posts with a composite core failed most commonly due to a fracture of the restoration. This is of clinical significance at the treatment planning stage as we know that these restorations will ultimately fail, so when this occurs a coronal fracture that may be re-restored is favourable over a catastrophic root fracture, where extraction is the likely outcome.

With a modulus of elasticity of 15-19 GPa dentine is structurally soft. The posts exhibit the following elasticity; quartz fibre 20GPa, glass fibre 30 GPa, titanium 100GPa, zirconia and stainless steel 200GPa.[42] Others have reported modulus of elasticity values (GPa) of 17.5 for dentine, silica-zirconium fibre 24.4, zirconia glass fibre 28.2, carbon fibre 34.4, gold 53.4, titanium 66.1, and stainless steel 108.6 .[46] This shows that the structure of the fibre posts more closely represents that of the natural root, which allows the posts to flex under functional load. This distributes the stresses generated throughout the root and therefore reduces the risk of root fracture[14] Moreover, custom modification of these fibre posts, which is sometimes advocated to enable a better fit in the prepared root canal, still gave modulus of elasticity values of 33.4 GPa.[47] The rigid metallic posts do not disperse these forces but rather transfer them directly to the end point of the post which is more likely to result in root fracture.[38] Although the less rigid posts certainly appear to perform better in these studies there are disadvantages associated with their elasticity. Forberger *et al.,*[48] (2008) found that the continuity of the margins of a crown were significantly reduced in the teeth restored with a fibre post and composite core, whereas those teeth restored with ceramic or metallic posts did not undergo significant marginal changes. This is because the increased flexibility of the fibre posts allows microscopic movements of the core and the crown (even when a ferrule is provided) which affects the cementation and crown margins. Obviously this is a contraindication to their use as it may allow microleakage to occur and therefore possible failure. Two recently carried out literature reviews concluded that the use of fibre posts as a substitute to metal and other tooth-coloured posts can be endorsed.[49,50].

Cementation

The most common cause of failure of a post and core restoration is loosening of the post which occurs in 5% of cases.[51] Retention is obtained from post selection, post space preparation and finally cementation. If decementation occurs the post and crown may be lost from the oral cavity. In this situation the tooth can usually be re-restored. However, if a microfracture occurs within the cement the coronal seal is compromised and there will be subsequent microleakage. This is a common cause of endodontic failure as the patient will not present clinically until signs of endodontic failure appear.[52] Therefore the ideal cement must provide sufficient retention and prevent microleakage.

Traditionally Zinc Phosphate and Polycarboxylate were the luting cements of choice.[50] These create micromechanical retention between the post and root dentine. In a clinical study Oilo *et al.,* [53] (1984) found no significant differences in the behaviour of the two cements.

Composite resins are now used more often in post cementation.[54] They offer numerous benefits over the traditional systems, as they are able to bond to the dentine and also to zirconia and fibre posts, therefore increasing retention and reducing microleakage.[55] In support of this, Reid *et al.,*[52] (2003) found that metallic posts cemented with zinc phosphate showed significantly more microleakage than ceramic or fibre posts cemented with composite resin cement, however this could be due to the type of post or the effect of the cement. A further advantage of the resin cements is that they possess a modulus of elasticity closer to that of dentine, reducing stress generated at the interface between the post and the dentine and therefore reduces rates of root fracture.[56]

Unfortunately, due to the lack of access, impaired moisture control and the multiple stages involved, the application of the resin cements is more technique sensitive than the conventional cements.[55] Their application also involves consideration into the choice of endodontic irrigants being used, as hypochlorite, EDTA and also eugenol containing sealers all affect the final bonding strength achieved by the composite resin.[57] To remove a stage in the process of their application, self etching resin cements have been developed. To further facilitate the polymerisation of cements, dual cure resins have also been developed. These allow the initiation of the setting reaction to occur by light which then continues chemically ensuring that the most apical cement will set.[54] These dual cure systems have the added benefit of a prolonged setting time which consequently reduces polymerization shrinkage stresses within the root.[57]

Although the use of resin cements is more time consuming and dependent upon correct application to achieve satisfactory bond strength, Naumann *et al.,*[55] (2008) suggested that the traditional non adhesive cements can be unreliable under repetitive functional loads.

The core

The core build up restoration replaces the bulk of the coronal tooth structure. Materials available for this purpose include amalgam, composite resin and glass ionomer. Each of these can be retained by a post, pin or the pulp chamber.[58]

Composite resin bonds to the remaining tooth structure by use of a bonding agent, this increases core retention. However, microleakage is associated with composite resin restorations and although this has been reduced by bonding agents, it still cannot be fully eliminated.[59] Glass ionomers adhere to enamel and dentine and therefore gain direct retention. They also release fluoride and so have anticariogenic properties, which has led to their increasing use as a core material.[58] Amalgam has conventionally been the material of choice; Nayyar *et al.,*[60] (1980) found that additional retention and resistance form could be gained by extending the amalgam 2- 4mm into the root canal system. Recent developments of amalgam bonding systems have helped to ensure that amalgam can continue to be widely used clinically as a core material.[59]

In a laboratory based study Combe *et al.,*[61] (1999) compared the mechanical properties of the three core materials. They found that 1 hour after restoration placement the amalgam was significantly weaker than the other materials. This is because amalgam requires up to 24 hours setting time, reaching only half its maximum compressive strength at 1 hour.[62] Therefore this material cannot be considered as a suitable core material if full compressive strength is required immediately. However, after 24 hours, when setting was complete the amalgam had the highest compressive strength; composite performed similarly although was not as strong, whilst glass ionomer was the weakest of the materials. From their study Combe *et al.,*[61] (1999) concluded that amalgam is the core material of choice if allowed to fully set before loading and that glass ionomer cement is unsuitable for large core build up restorations particularly in posterior teeth.

In another comparison of the three core materials, Gateau *et al.,*[58] (1999) found that amalgam was significantly more resistant to repetitive forces than both composite and glass ionomer which also showed significant differences. They again concluded that glass ionomer cement was not suitable as a core restoration material.

This shows that where clinically permitted amalgam is the core material of choice. However, if composite is indicated, as is the case when there is a need for aesthetics or combined with a fibre-post, it has proven to be satisfactory for this purpose.

Following the replacement of the missing coronal dentine the core is now ready to receive full coronal coverage therefore completing the definitive restoration.

Conclusion

To enable clinicians to offer optimal endodontic treatment planning, it is important that they have a broad knowledge of the subject area and of the factors that will affect treatment outcome. Treatment options will ultimately depend on clinical findings in each individual patient case but these can be based upon evidence gained from the literature, which will provide a sound knowledge of the topic that can then be applied to the clinical situation.

Through investigation of the literature this study has shown the importance of the definitive restoration upon the outcome of endodontic treatment. It has shown that the inclusion of the final restoration at the initial endodontic treatment planning stage is essential, allowing the full course of treatment to be undertaken and completed from initial endodontic therapy to full coronal coverage, where necessary. This will provide the best possible prognosis for the non vital tooth.

The treatment options have been summarised to show that where coronal tissue loss is minimal, anterior and premolar teeth may be restored with amalgam or composite. However in all molar teeth and those anterior and premolar teeth with significant loss of coronal tissue, that is a common feature of endodontically treated teeth full coronal coverage is recommended to achieve the best possible outcome.

Investigation into the different post systems, has shown there are advantages and disadvantages of each. Serrated posts appear to be contraindicated in most situations, as do the tapered metal posts. Cast post systems appear to create an unnecessary risk of microleakage into the disinfected root canal system, as a temporary post and core system is required which does not maintain the coronal seal adequately.. Of the prefabricated post systems the recently developed fibre posts have shown numerous advantages over the metallic and ceramic posts; they are resistant to repetitive forces twice that of the conventional systems and they exhibit more clinically preferred modes of failure. All of the of the literature researched is in favour of these more modern fibre post systems, although no long term clinical studies exist at present. The literature has highlighted the absolute importance of a ferrule when using any of these post and core systems. It significantly increases the resistance of the crowned tooth to fracture, and therefore every effort must be made to create a 2mm ferrule, even if crown lengthening is necessary.

Investigation into post cementation has shown that the use of resin cements is recommended over traditional zinc phosphate and polycarboxylate materials. Conversely, for core build up restorations amalgam is the material of choice, where aesthetics is not a concern, exhibiting favourable mechanical properties over composite resin and glass ionomer cement. Retention of the amalgam core in this case is best utilised utilising the Nayyar[61] technique. For anterior and premolar teeth the best combination when a post and core system is required, is achieved through the combination of a fibre post with a composite core build-up. Following the core build up restoration full coronal coverage can then be provided, completing the endodontic and restorative treatment as one, therefore giving the best possible treatment with regards to achieving a successful outcome.

References

1. Friedman S. & Mor C. The success of endodontic therapy – healing and functionality. CDA Journal 2004;32:493-503.

2. Sjogren U, Hagglund B, Sundqvist G, Wing K. Factors affecting long term results of endodontic treatment. J Endod 1990;16:498-504.

3. Kreisler M, Kohnen W, Beck M, Alhaj H, Christoffers AB, Gotz H, Duschner H, Jansen B, D'Hoedt B. Efficacy of NaOCl / H_2O_2 irrigation and GaAIAs lasers in decontamination of root canals in vitro. Lasers Surg Med 2003;32:189-196.

4. Wang QQ, Zhang CF, Yin XZ. Evaluation of bactericidal effect of Er, Cr: YSGG and Nd: YAG lasers in experimentally infected root canals. J Endod 2007;33:830-832.

5. Kojima K, Inamoto K, Nagamatsu K, Hara A, Nakata K, Morita I, Nakagaki H, Nalamura H. Success rate of endodontic treatment of teeth with vital and non vital pulps: A meta analysis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2004;97:95-99.

6. Shipper G & Trope M. In vitro microleakage in endodontically treated teeth using new and standard obturation techniques. J Endod 2004;30:154-158.

7. Weigner R, Axmann-Kremar D, Lost C. Prognosis of conventional root canal treatment reconsidered. Endod Dent Traumatol 1998;14:1-9.

8. Storms JL. Factors that influence the success of endodontic treatment. J Can Dent Assoc 1969;35:83-97.

9. Farzaneh M, Abitbol S, Lawrence HP, Friedman S. Treatment outcome in endodontics – The toronto study. Phase II: Initial treatment. J Endod 2004;35:302-9.

10. Salehrabi R. & Rotstein I. Endodontic treatment outcomes in a large patient population in the USA: An epidemiological study. J Endod 2004;30:846-850.

11. Brosco VH, Bernardineli N, Torres SA, Consolaro A, Bramante CM, Moraes IG, Garoia RB. Bacterial leakage in root canals obturated by different techniques. Part 1: microleakage evaluation. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003;105:48-53.

12. Sathorn C, Parastios P, Messer HH. Effectiveness of single versus multiple visit endodontic treatment of teeth with apical periodontitis: A systematic review and meta analysis. Int Endod J 2004;38:347-355.

13. Eckerbom M. & Magnusson T. Restoring endodontically treated teeth: A survey of current opinions among board certified prosthodontists and general dental practitioners in Sweden. Int J Prosthodont 2001;14:245-249.

14. Wiskott HW, Nicholls JI, Belser UC. Stress fatigue: Basic principles and prosthodontic implications. Int J Prosthodont 1995;8:105-116.

15. Weyant R. Little difference is found between surgical and non surgical approaches for treatment of periradicular lesions following endodontic therapy. J Evidence Based Dental Practice 2007;7:151-152.

16. Torabinejad M, Kutsenko D, Machnick TK, Ismail A, Newton CW. Levels of evidence for the outcome of nonsurgical endodontic treatment. J Endod 2005;31:637-646.

17. Seltzer S, Bender IB, Turkenkopf S. Factors affecting successful repair after root canal therapy. J Am Dent Assoc 1963;67:651-662.

19. Zadik Y, Sandler V, Bechor R, Salehrabi R. Analysis of factors related to the extraction of endodontically treated teeth. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;106:e31-e35

19. Siqueira JF, Rocas IN. Clinical implications and microbiology of bacterial persistence after treatment procedures. J Endod 2008;1:1157-1290.

20. Kayahan MB, Malkondu O, Canpolat C, Kaptan F, Bayirli G, Kazazoglu E. Periapical health related to the type of coronal restoration and quality of root canal fillings in a turkish subpopulation. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;105: 58-62.

21. Rosen H. Operative procedures on mutilated endodontically treated teeth. J Prosthet Dent 1961;11:973-986.

22. Sedgely CM, Messer HH. Are endodontically treated teeth more brittle? J Endod 1992;18:332-5.

23. Reeh ES, Messer HH, Douglas WH. Reduction in tooth stiffness as a result of endodontic and restorative procedures. J Endodon 1989;15:512-6.

24. Fuss Z, Lustig J, Tamse A. Prevelance of vertical root fractures in endodontically treated teeth. Int Endod J 1999;32:283-6.

25. Vire DE. Failure of endodontically treated teeth: Classification and evaluation. J Endod 1991;17: 338.

26. Caplan DJ, Kolker J, Rivera EM, Walton RE. Relationship between number of proximal contacts and survival of root canal treated teeth. Int Endod J 2002;35:193-9.

27. Nandini VV, Venkatesh V. Current concepts in the restoration of endodontically treated teeth. J Indian Prosthodont Soc 2006;6:63-7.

28. Robbins JW. Guidelines for the restoration of endodontically treated teeth. J Am Dent Assoc 1990;120:558-566.

29. Schwartz RS, Robbins JW. Post placement and restoration of endodontically treated teeth: A literature review. J Endod 2004;30:289-301.

30. Mondelli RF, Ishikiriama SK, de Oliveira Filho O, Mondelli J. Fracture resistance of weakened teeth restored with condensable resin with and without cusp coverage. J Appl Oral Sci. 2009;17:161-5.

31. Fennis WM, Kuijs RH, Barink M, Kreulen CM, Verdonschot N, Creugers NH. Can internal stresses explain the fracture resistance of cusp-replacing composite restorations? Eur J Oral Sci. 2005;113:443-8.

32. Plotino G, Buono L, Grande NM, Lamorgese V, Somma F. Fracture resistance of endodontically treated molars restored with extensive composite resin restorations. J Prosthet Dent. 2008;99:225-32.

33. Mohammadi N, Kahnamoii MA, Yeganeh PK, Navimipour EJ. Effect of fiber post and cusp coverage on fracture resistance of endodontically treated maxillary premolars directly restored with composite resin. J Endod. 2009;35:1428-32. Epub 2009 Aug 28.

34. Mannocci F, Bertelli E, Sherriff M, Watson TF, Ford TR. Three-year clinical comparison of survival of endodontically treated teeth restored with either full cast coverage or with direct composite restoration. J Prosthet Dent. 2002;88:297-301.

35. Nagasiri R, Chitmongkolsuk S. Long-term survival of endodontically treated molars without crown coverage: A retrospective cohort study. J Prosthet Dent 2005;93:164-170

36. Hansen EK, Asmussen E, Christiansen NC. In vivo fractures of endodontically treated posterior teeth restored with amalgam. Endod Dent Traumatol 1990;6:49-55.

37. Fradeani M, Aquilano A. Barducci G. Aesthetic restoration of endodontically treated teeth. Pract Periodontics Aesthet Dent 1999;11:761-8.

38. Morgano SM. Restoration of pulpless teeth: Application of traditional principles in present and future contexts. J Prosthet Dent 1996;75: 375-380.

39. Sorenson JA, Martinoff JT. Clinically significant factors in dowel design. J Prosthet Dent 1984;73:439-444.

40. Bergman B, Lundquist P, Sjogren U, Sundquist G. Restorative and endodontic results after treatment with cast posts and cores. J Prosthet Dent 1989;61:10-5.

41. Stankiwic N, Wilson P. The ferrule effect. Dent Update 2008;35:222-228.

42. Standlee JP, Caputo AA, Collard EW, Pollack MH. Analysis of stress distribution by endodontic posts. Oral Surg Oral Med Oral Pathol 1972;33:952-960.

43. Pereira JR, Ornelas F, Conti PCR. Effect of crown ferrule on the fracture resistance of endodontically treated teeth restored with prefabricated posts. J Prosthet Dent 2006;95:50-4.

44. Gómez-Polo M, Llidó B, Rivero A, Del Río J, Celemín A. A 10-year retrospective study of the survival rate of teeth restored with metal prefabricated posts versus cast metal posts and cores. J Dent. 2010;38:916-20. Epub 2010 Aug 14

45. Fox K, Gutteridge DL. An in vitro study of coronal microleakage in root-canal-treated teeth restored by the post and core technique. Int Endod J 1997;30:361-8.

46. Plotini G, Grande NM, Bedini R, Pameijer CH, Somma F. Flexural properties of endodontic posts and human root dentin. Dent Mater 2007;23:1129-1135.

47. Grande NM, Plotini G, Ioppolo P, Bedini R, Pameijer CH, Somma F. The effect of custom adaptation and span-diameter ratio on the flexural properties of fiber-reinforced composite posts. J Dent 2009;37:383-389

48. Forberger N, Gohring TN. Influence of the type of post and core on in vitro marginal continuity, fracture resistance, and fracture mode of lithia desilicate-based all ceramic crowns. J Prosthet Dent 2008;100:264-273.

49. Goracci C, Ferrari M. Current perspectives on post systems: a literature review. Aust Dent J. 2011;56:77-83

50.Tang W, Wu Y, Smales RJ. Identifying and reducing risks for potential fractures in endodontically treated teeth. J Endod. 2010;36:609-17

51. Goodacre CJ, Bernal G, Rungcharassaeng K, Kan JYK. Clinical complications in fixed prosthodontics. J Prosthet Dent. 2003;31:31-41.

52. Reid LC, Kazemi RB, Meiers JC. Effect of microleakage testing on core integrity and post microleakage of teeth restored with different post systems. J Endod 2003;29:125-131.

53. Oilo G, Dahl BL, Gjeitanger. Clinical study of two luting cements used on student treated patients: An interim report. J Prosthet Dent 1984;52:518-522.

54. Bouillaguet S, Troesch S, Wataha JC, Krijci I, Meyer JM, Pashley DH. Microtensile bond strength between adhesive cements and root canal dentin. Dent Mater 2003;19:199-205.

55. Naumann M, Sterzenbach G, Rosentritt M, Beuer F, Frankenberger R. Is adhesive cementation of endodontic posts necessary? J Endod 2008;34:1006-10.

56. Li ZC, White SN. Mechanical properties of dental luting cements. J Prosthet Dent 1999;81:597-609.

57. Hayashi M, Ebisu S. Key factors in achieving firm adhesion in post- core restorations. Japanese Dental Science Review 2007;44:22-28.

58. Gateau P, Sabek M, Dailey B. Fatigue testing and microscopic evaluation of post and core restorations under artificial crowns. J Prosthet Dent 1999;82:341-347.

59. Tjan AHL, Grant BE, Dunn JR. Microleakage of composite resin cores treated with various dentine bonding systems. J Prosthet Dent 1991;66:24-9.

60. Nayyar A, Walton R, Leonard L. An amalgam coronal radicular dowel and core technique for endodontically treated posterior teeth. J Prosthet Dent 1980;43:511-4.

61. Combe EC, Shaglouf AMS, Watts DC, Wilson NHF. Mechanical properties of direct core build up materials. Dent Mater 1999;15:158-165.

62. Chern Lin JH, Chen KI, Ju CP. Particle size effect on structure and properties of dispersed Pd-containing dental amalgam. Biomaterials 2002;23:597-608.

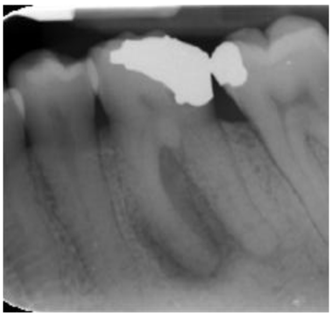

Figure 1: The presence of preoperative periapical radiolucency reduces the success rate of endodontic treatment from 96% (where no pre operative periapical radiolucency is present) to 86%.[2]

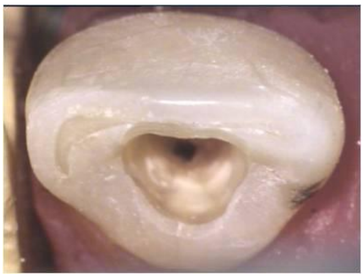

Figure 2: Access cavity only; the root canal filling can be sealed with a lining material and a composite restoration placed.

Figures 3a and 3b: Replacement of class II amalgam restoration with gold shell crown in an endodontically treated molar.

Figure 4: A ferrule has been created on this upper central incisor; 2mm of dentine extends coronally from the crown preparation margin.

Figure 5a and 5b: Custom made posts are made from metal alloys, prefabricated posts can be stainless steel, titanium, ceramic or glass fibre.

Figure 6: Natural aesthetics created using a quartz fibre reinforced post and composite core system.