ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 9, Issue, 05, pp.50506-50510, May, 2017

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

REVIEW ARTICLE

ROOT CANAL FAILURE - DEMYSTIFIED

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ARTICLE INFO

Article History:
Received 22nd February, 2017
Received in revised form
19th March, 2017
Accepted 29th April, 2017
Published online 23rd May, 2017

Key words:

Root canal failures, Retreatment, Reintervention, Endodontic failures.

ABSTRACT

Root-canal treatment is a therapeutic procedure performed to treat and prevent apical periodontitis when pulpal disease is considered too advanced to be managed by vital pulp therapy. A thorough conceptualization of the complex interplay between infection, inflammation and healthy tissue can help to increase the visualization of how treatment procedures might influence biological events and help in periapical disease prevention. This article highlights all the factors that can influence the final outcome of root canal treatment and the overall prognosis of the tooth following root canal treatment. Following the mechanical and biological principles along with the judicious use of inventory and continuous monitoring of practices along with skillful and meticulous planning will enable to reduce the flaws and thus increasing the chances of success root canal treatment.

Citation: Dr. Mayuri Naik, Dr. Ida de Noronha de Ataide, Dr. Marina Fernandes and Dr. Rajan Lambor, 2017. "Root canal failure - Demystified", *International Journal of Current Research*, 9, (05), 50506-50510.

INTRODUCTION

Root-canal treatment (RCT) is a therapeutic procedure performed to treat and prevent apical periodontitis when pulpal disease is considered too advanced to be managed by vital pulp therapy. Endodontic treatment failure is usually characterized by the persistence or manifestation of an apical periodontitis. A thorough conceptualization of the complex interplay between infection, inflammation and healthy tissue can help to increase the visualization of how treatment procedures might influence biological events and help in periapical disease prevention. According to studies, around 32.8% of all cases encounter procedural errors. The most common being overfilling (22.7%), followed by underfilling (8.9%). Instrument separation and apical transportation were less commonly seen (0.9% and 0.4%, resp). Anterior teeth were significantly less prone to errors than posterior teeth. (Yousuf *et al*., 2015) The failure of endodontic treatment can occur at any time up to 10 year or more after completion of treatment. The majority of the ineffectively treated teeth fail within 2 years of treatment andinfrequently more than 10 years. Hence 2-year evaluation is better than a 6 months follow-up period.

Non-surgical root canal treatment failure is diagnosed based on the following clinical and radiographic criteria:

- Presence of clinical signs (swelling, sinus, tenderness) and/or symptoms (pain of endodontic origin)
- Enlargement of existing periradicular radiolucent lesion
- Development of new periradicular radiolucent lesion
- Persistence of periradicular radiolucent lesion associated with a tooth that had RCT at least 4 years previously.

The causes of root-canal treatment failure may be summarized as follows: (Jr JFS, Siqueira 2001)

Microbial

- Intraradicular
- Extraradicular

Non-microbial

Microbiota of periapical disease (Gulabivala, 2014)

- Intraradicular microbiota associated with failed root canal treatmentis mostly comprised of Gram- positive bacteria, which are commonly coccoid facultative anaerobes; most frequently recognized species are Enterococcus faecalis, Propionibacterium, Streptococcus, Lactobacillus, Peptostreptococcus and yeasts. In endodontics, E. faecalis is a prominent dominant microorganism in root canal treated teeth with

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post-treatment apical periodontitis. It has been considered that its presence is encouraged by the use of calcium hydroxide for root canal dressing. (Portenier *et al*., 2003)

- Extraradicular microbiota associated with failed RCTincludes Actinomyces, Propionibacterium, Fusobacterium, Prevotella and Staphylococcus species.

Bacterial products, such as Sialic acid, M protein, various enzymes, cell- capsule and cell-wall constituents and particularly lipopolysaccharides, have been associated with commencement of periapical disease. Fungi such as (Candida, Aspergillus, Penicillium, Fusarium, Aureobasidium, Exophiala, Eurotium, Cladosporium) have been isolated from root canals. Other extracellular (Eucharya and Archaea) or intracellular (Viruses) life forms are associated with periapical disease. Members of the genus Methanogens are the only Archaea detected in the human body in primary and secondary root-canal infections. (Sakamoto *et al*., 2008)

Non-microbial causes (Haapasalo *et al*., 2011)

Cholesterol crystals are also commonly found in apical periodontitis. It is a steroid lipid present in human and animal cells, which can form crystals and disease progression. It forms due to degeneration of necrotic cells during chronic inflammation. Studies have shown that cholesterol crystals in the tissue attract inflammatory cells.

Cellulose containing materials and plant cells can cause a chronic inflammatory reaction in the periapical tissue. Studies have revealed that the presence of cellulose from paper points in such lesion; as well as cotton pellets. Contamination of paper points and cotton pellets with bacteria will further aggravate the inflammatory response. Plant cells from vegetables could be pushed down the canal to the periapical region, which could also elicit an inflammatory reaction.

Classification

Causes of endodontic treatment failures can be classified as
A) Preoperative causes
B) Intraoperative causes
C) Postoperative causes

A)Preoperative causes

1) Incorrect diagnosis

Failure to establish the nature, source and cause of the infection will lead to incorrect treatment resulting in non-resolution of the initial complaint and perhaps creating additional problems. It can be due to poor case selection, poor prognosis, judged by misinterpretation or lack of information, either clinical or radiographic. (Duigou, 2004)

2) Developmental defects

Defects due to invaginations of the coronal or radicular tissues can occur during tooth development. Occasionally, developmental grooves, e.g. palato-gingival groove may be deep enough to communicate with the periapex or provide a niche for microorganisms from oral environment to infect the tooth in a retrograde manner. (Naik *et al*., 2014)

3) Orthodontic tooth movement (Gulabivala and Naini, 2014)

RCT during orthodontic treatment is challenging as the diagnosis can be affected because of pulpal or periradicular pain, being confused by discomfort due to tooth movement. Use of rubber dam is difficult; access cavity preparation can be compromised since tooth inclination can become confusing during tooth movement. Working length determination can be compromised by apical root resorption, which may be altered further during the following visit, as well as difficulties in controlling placement of root-filling material at the canal terminus.

4) Traumatic injuries. (Gulabivala *et al*., 2014)

Cemental tear occurs commonly in men and is associated with acute or chronic trauma. They cause periodontal inflammation, abscess formation and deep probing defects. They are also found in root-treated teeth with posts. The stress in conjunction with the apical extent of the post may result in a cemental crack. The periodontal breakdown can also trigger a periapical inflammation. Teeth that have undergone RCT following trauma are likely to develop resorption affecting the overall prognosis.

5) Anatomical Variations.

Presence of excessively curved canal, lateral canals, calcifications, inaccessible accessory canals & complex internal anatomy can prevent favorable prognosis post RCT.

6) Internal resorption.

These teeth are difficult to treat since over extension of the filling, lack of adequate density and compaction of obturation can be an important issue. As these unobturated areas can serve as a nidus for bacterial proliferation.

7) Antibiotic resistance

Indiscriminate use of antibiotics can result in development of resistant bacterial strains. Enterococci, particularly E.faecalis and E.faecium were shown have multidrug resistance to benzylpenicillin, ampicillin, clindamycin, metronidazole and tetracycline but were only sensitive to erythromycin and vancomycin. This highlights the importance of restricting the use of antibiotic to cases where they are specifically indicated. (Fouad, 2002)

8) Radiographic Technique (Duigou, 2004)

A common mistake is made when radiographic film is exposed with the rubber dam in place, which causes improper alignment leading to difficulties during root canal access and instrumentation due to misjudgment of canal location. It can also be caused by incorrect use of the film positioner, which could cause problems such as distortion (elongation and foreshortening) and poor clarity. Incorrect intra-oral film placement could cause a radiograph not to reveal periapical area and hence obscure the periapical lesion. Location of the anatomical apex in 50-98% of roots may be ambiguous radiographically hence an apex locator should be used to confirm the working length determination.

9) Systemic diseases.

Systemic diseases can interfere with the regenerative capacity of bone. Paget's disease, hyper parathyrodism, hyperthyroidism, and osteoporosis along with other parameters like age, nutrition, hormones, chronic disease, stress and dehydration affect the periapical repair. It negatively influences local tissue resistance and hampers healing potential.

B) Intraoperative causes

1) Tooth Isolation (Duigou, 2004)

Use of rubber dam is an essential practice of endodontic treatment. Avoidance of using rubber dam during RCT or its inefficient placement is itself a procedural error. The rubber dam serves as a barrier in maintaining a sterile and dry working field, thus preventing bacterial and salivary contamination. It also improves the access and visibility. It can efficiently help to control the ingress of microorganisms in the canal intraoperatively through salivary leakage as well improves access and visibility thus reducing the chances of missed canal and instrumentation errors.

2) Access preparation. (Duigou, 2004)

Incorrect access opening includes incomplete caries excavation, excessive removal of sound tooth structure, presence of unsatisfactory restorations, inadequate access of the pulp space, establishing incorrect angulation of the tooth, contamination of the working field, incomplete removal of the pulp chamber roof, missed canals and damaging the chamber floor and walls. All of these can cause serious consequences on the outcome of RCT.

3) Altered canal space

Calcifications can obscure canal orifices and prevent complete negotiation of canals. Thus they can harbor microorganisms, which could ultimately lead to treatment failure. The chronic inflammatory response to caries results in calcification. If chelators and lubricants are not adequately used than the rupture of calcifications is difficult.

4) Missed canal (Duigou, 2004)

Canals that are left untreated may contain infected tissue, which could encourage persistent inflammation and pain even if remaining canals are well debrided and obturated. Canals can remain undetected due to poor access and visibility, lack of knowledge of the internal tooth anatomy and/or not thoroughly inspecting for presence of extra canals; considering that all the canals have been located. (Cantatore *et al*., 2009) This can also occur due to presence of calcification on the pulpal floor and refraining use of magnification and other aids of locating canal orifices. Infected laterals canals, which are not debrided and obturated, can cause post-treatment disease.

5) Poor debridement

Inadequate debridement of root canals is an important cause of RCT failure. Irrigant functions include lubrication, flushing out of debris, chemical disintegration of residual pulp tissue, removal of smear layer and chemical degradation of microorganisms. Use of irrigants along with the proper agitation technique can significantly reduce the bacterial load. Failure to employ adequate irrigation practices can result in failure following endodontic treatment.

6) Excessive hemorrhage

Excessive hemorrhage when occurs during extirpation of an inflamed pulp along with instrumentation beyond the tooth apex will result in mild inflammation, due to hematoma formation and accumulation of blood. The extravagated blood cells and fluid, if not resorbed by macrophages will cause delay of repair and extravasated blood will act as a nidus for bacterial growth.

7) Foreign body reaction (Gulabivala, 2014)

Foreign material may get lodged in the periapical tissue and cause irritation and inflammation, allowing delay or prevention of healing. It can enter the periapical tissue via root canal when the tooth is left open to the oral cavity or during endodontic procedures, also by traumatic injury through the mucosa or during periapical surgery. Foreign material can have microbes/biofilm attached to its surface and provide a scaffold for further microbial growth in the tissues. Foreign material may also elicit a giant cell response to secrete inflammatory mediators in a chronic effort to clear the area of foreign material.

8) Treating the Incorrect Tooth (Duigou, 2004)

Treatment of the wrong tooth due to lack of concentration of the operator, especially while operating under rubber dam will not lead to resolution of the initial problem even if the RCT is perfect, amounting to failure of treatment.

9) Inadequate canal preparation

Adequate canal preparation is required to facilitate thorough irrigation and provide a satisfactory shape with resistance and retention form to contain the obturation material. The final preparation size should provide an apical size of approximately 0.5mm, 3 mm from the apex (Hsieh *et al*., 2007). If these objectives are not achieved than RCT could fail due to inadequate debridement and defects of obturation.

10) Over-instrumentation (Duigou, 2004)

Unwarranted instrumentation will severely weaken the root and can lead to perforation or fracture. A strip perforation can occur during the excessive instrumentation along the concave walls. This can occur with excessive use of rotary instruments, non pre-curving instruments and use of excessive force while instrumenting. It results in physical trauma to periapical tissue, transportation of necrotic and infected canal contents along with infiltration of dead and living microorganisms into the periapical area which could encourage persisting infection, bleeding into the root canal providing nutrients to intracanal bacteria, increase in the size of foramen size, increased risk for extrusion of irrigants filling materials.

11) Ledge Formation (Duigou, 2004)

Ledges are formed by the use of files that are too large, small access cavity or inability to pre-curve instruments when

preparing the canal. Ledge formation if undetected could lead to perforation and also difficulties during obturation.

12) Mechanical perforation

It is a mechanically created point of access in the root for bacteria to establish itself. Perforation can occur due to misjudgment of canal anatomy, non precurving of instruments, inadequate access cavity preparation, use of excessive force during instrumentation or use of large files in small canals. If left untreated they can create communication between the periodontium and the tooth or with the saliva allowing ingress and harboring of microorganisms. (Duigou, 2004)

13) Blockage (Duigou, 2004)

Canal blockage and resultant loss in working length occurs due to accumulation of organic debris in the apical region, due to insufficient irrigation / recapitulation of the canal during instrumentation.

14) Loss of Working Length (Duigou, 2004)

Loss of working length can eventually lead to overfilling or underfilling of root canal. This occurs due to inability to achieve reproducible reference points. Avoiding usage of rubber stops, not using precurved instruments, avoiding the use of directional point on the rubber stopper or not using reliable and reproducible angles while taking radiographs can lead to loss of working length.

15) Separated Instruments (Duigou, 2004)

Instrument fracture can occur due to excessive use of files without replacement or failure while following the principle of sequential instrumentation. Presence of broken instrument in an unprepared canal prevents access to the apical portion and hampers thorough cleaning of the root canal system. If not retrieved it can allow proliferation of microbes leading to persistent periapical inflammation.

16) Improper obturation (Duigou, 2004)

Poor apical density of filling material can occur due to failure of positioning the compacting instrument adequately into the apical portion of the canal creating substandard compaction.It can also occur due to incorrect canal taper and shape or using a large compacting instrument or straight instrument for a curved canal.Failure also occurs, when gutta-percha does not obliterate the canal space laterally due master cone binding tightly in the middle or coronal part of the canal. Hence accessory cones fail to reach apical extent of the canal on lateral condensation. (Dow and Ingle, 1955)

17) Under extended filling

Ideally, the extent of obturation should be 1-2 mm short of the apex. Under-filling will result in periapical inflammation by allowing proliferation of microorganisms in the unfilled canal. The can occur due to insufficient canal taper resulting in an inadequate apical placement of compaction instrument. Also not coating sealer uniformly around the gutta-percha, inability to place the accessory points to the complete working length, using fine accessory gutta percha points that kink when positioned apically, incorrect choice of large compaction instruments, using undue amount of canal sealer or sealer that has set too quickly forming a hard mass, dentine chips packing in the apical root canal, inability of positioning the master cone to the apical extent and lack of consistency in heating the core filler.

18) Over extended filling.

This involves extending the root canal obturating material past the apical constriction of the root. It has been testified that even in the absence of microbes and endotoxins, root-filling substances can provoke a foreign body reaction, development of periapical lesions. Large quantities of filling materials in the tissues caused bone necrosis and resorption. The foreign body reaction resulted in persistence of breakdown and driven by the toxicity of the macrophaged material. The breakdown products have an unfavorable effect on the proliferation and viability of periapical cells necessary for repair. Overfilling can occur due tofailure to confine filling material within anatomic tooth boundaries due to an absence of apical stop or minor constriction. Inappropriate selecting of master cone (Duigou, 2004), inability to accurately determine the working length, using high compaction forces during obturation, use of excessive sealer and compaction instrument positioned too far apically.

19) Microleakage of saliva (Svensa, 2004)

Periapical periodontitis may be caused by ingress of bacteria or endotoxins(inflammatory mediators). It has been shown that bacterial endotoxins can infiltrate the root canal system quickly and easily. It can occur due to:

Poor coronal restorations including fixed crowns allow bacteria or endotoxins to penetrate the root canal and induce periapical inflammation.

After post space preparation only the apical portion of the root canal obturation functions as barrier against diffusion of microrganisms, which can subsequently contaminate the canal and lead to bacterial colonization on the walls of the apical portion of the root canal. This can occur when the apical obturation is not well condensed, dislodgement of apical filling during post space preparation and the length of the apical obturation is less than 3 mm.

Microleakage after post cementation caused significantly greater leakage in provisional restorations prior to luting of cast posts and cores. Thus extended time between canal preparation and post cementation can increase microleakage.

Provisionalrestorations, in teeth undergoing RCTshould provide the best possible seal to prevent salivary contamination.

20) Technical difficulties.

Endodontics requires use of multiple instruments and material inventory to achieve the mechanical & biologic objective of RCT. Negligence in observing these objectives will result in treatment failure.

C) Post operative causes

1) Vertical Root Fracture (VRF) (Duigou, 2004)

VRF occur due to occlusal wedging forces and/or excessive lateral forces being created with compaction instruments, post placement, occlusal forces, wedging of restorations, expansion of retrograde filling materials, placement of multiple accessory cones requiring increased insertion of spreader, corrosion from metal posts causing a wedging action and weakened root canal walls from over-instrumentation. Curved roots or roots with deep facial and lingual grooves with narrowmesiodistal width are prone to fracture. The effects of VRF on the periodontium could be destructive and irresolvable.

2) Sliver points corrosion and corrosion products from posts.

Currently silver points are considered obsolete as they can produce Silver sulphides, silver carbonates, silver sulphate, and silver amine sulphate amide hydrate after corrosion, which can cause persistent periapical inflammation. Copper from the corrosion product migrates towards the dentin attached soft tissue, which can result in root fracture.

3) Failure after root canal retreatment.

The chance for second failure after non-surgical retreatment is more and might require surgical retreatment. Failure may even occur after apicoectomy and apical curettage. There can be leakage of blood and periapical exudate from the retrograde filling due to inadequate thickness and compaction or quality of material used (Daokar and Kalekar, 2013). Thus it can be concluded that a plethora of factors are involved in facilitation of a successful endodontic treatment. Following the mechanical and biological principles along with the judicious useof inventory and continuous monitoring of practices along with skillful and meticulous planning will enable to reduce the flaws and thus increasing the chances of success root canal treatment.

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