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Causes of endodontic failure: an integrative review

Antoine Portejoie

Dissertação conducente ao **Grau de Mestre** em **Medicina**

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Causas de insucesso endodôntico: revisão integrativa

Trabalho realizado sob a Orientação de
” Professor Doutor Pedro Bernardino”

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RESUMO

Introdução: O insucesso endodôntico é um fenómeno complexo e desconcertante que continua a ser um grande desafio na área da odontologia. Identificar as principais causas é crucial para melhorar as taxas de sucesso do tratamento endodôntico. Vários fatores podem contribuir ao seu desenvolvimento, envolvendo aspetos microbiológicos, iatrogénicos e anatómicos.

Objetivos: Identificar e compreender as diferentes causas de insucesso endodôntico. Classificar as diferentes causas consoante a severidade do quadro clínico.

Materiais e método: Pesquisa bibliográfica de artigos na base de dados *Google scholar* e *PubMed*. Após a implementação dos critérios de inclusão, foram selecionados 24 artigos.

Resultados: 8 artigos relacionam a presença de microrganismos nos canais com o insucesso endodôntico. 5 artigos destacam o preenchimento insuficiente durante a obturação ou *underfilling* como o erro iatrogénico mais comum e 4 afirmam que esquecer um canal é a segunda causa iatrogénica. Após revisão dos artigos, a causa com pior prognóstico é a fratura.

Discussão: O insucesso endodôntico está associado à presença de micro-organismos nos canais. As causas iatrogénicas e anatómicas também desempenham um papel importante. A severidade das falhas foi classificada conforme três métodos de resolução: não cirúrgico, cirúrgico ou misto.

Conclusões: O insucesso endodôntico resulta de uma interação complexa entre fatores anatómicos, microbiológicos, clínicos e técnicos. Entender as diferentes causas é essencial para melhorar os resultados do tratamento endodôntico e minimizar o risco de erro.

Palavras-Chave: “Endodontic failure” AND “Endodontic complications” AND “Failed root canal treatment” AND “Iatrogenic factors”.

ABSTRACT

Introduction: Endodontic failure is a complex and perplexing phenomenon that continues to be a major challenge in the field of dentistry. Identifying the main causes is crucial to improving endodontic treatment success rates. Several factors can contribute to its development, involving microbiological, iatrogenic and anatomical aspects.

Objectives: Identify and understand the different causes of endodontic failure. Classify the different causes according to severity.

Materials and method: Bibliographic search of articles in the Google scholar and PubMed database. After implementation of the inclusion criteria, 24 articles were selected.

Results: 8 articles relate the presence of microorganisms in canals to endodontic failure. 5 articles highlight insufficient filling during obturation or underfilling as the most common iatrogenic error and 4 state that forgetting a canal is the second most common iatrogenic cause. After reviewing the articles, the cause with the worst prognosis is fracture.

Discussion: Endodontic failure is associated with the presence of micro-organisms in the canals. Iatrogenic and anatomical causes also play an important role. The severity of failures was classified according to three methods of resolution: non-surgical, surgical or mixed.

Conclusion: Endodontic failure results from a complex interaction between anatomical, microbiological, clinical and technical factors. Understanding the different causes is essential for improving the results of endodontic treatment and minimising the risk of error.

Keywords: “Endodontic failure” AND “Endodontic complications” AND “Failed root canal treatment” AND “Iatrogenic factors”.

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RCT : Randomized Controlled Trial.

NI-TI : Nickel-Titanium.

MTA : Mineral Trioxide Aggregate.

CBCT : Cone Beam Computed Tomography.

1. INTRODUCTION

In order to preserve optimal function, endodontic therapy, also known as pulp therapy, is used to preserve the tooth's structural integrity. One of the objectives of pulp treatment is also to preserve the vitality of teeth that have been impacted by trauma or dental caries (1). The literature stated that root canal therapy has a 90–95% success rate (2).

Endodontic treatment is one of the most common procedures for the dentist (3). This chemometric preparation is intended to treat dental pulp that is inferred from bacteria and is responsible for the symptoms of the teeth (4). When endodontic treatment is not successful it is called endodontic failure. The majority of endodontic failures occurs close to the apical third (5), however the precise description of endodontic treatment failure remains unclear despite its undeniable occurrence in routine clinical practice (6). When endodontic treatment is performed incorrectly, it frequently fails. Failure can, nevertheless, occur in certain situations even when all the right procedures are followed and the highest levels of treatment quality are upheld. Endodontic failure has surely been linked to a number of significant and minor causes (3). The majority of research use radiographic results and clinical indications or symptoms of the treated teeth to assess whether endodontic treatment was successful or unsuccessful. The radiographic assessment is the primary means of determining the quality of root canal therapy. The contrast, density, taper, and homogeneity of the root canal filling quality are provided by radiographic examination (2). *The European Society of Endodontology* has guidelines that state that a radiograph showing the root apex with at least 2-3 mm of the periapical region should be taken in order to assess the effectiveness of root canal fillings (2). The preoperative state of the tooth is one of the most important factors influencing the prognosis of endodontic treatment. The tooth may have a success rate that is up to 20% lower than that of a tooth without a preoperative peri-apical radiolucent lesion if it has one (7). Nevertheless, other research revealed that the prognosis of endodontic treatment will be the same for teeth with peri-apical radiolucency and teeth without them if root canal instrumentation and fillings have been completed to the highest standard (7).

Numerous factors, such as the existence of periradicular infection and residual necrotic pulp tissue, as well as complications during root canal negotiation, such as broken instruments, mechanical perforations, under- or over-filling of the root canals, missed canals, calcification of the canal can affect the outcome of endodontic treatment (3, 8). In order to prevent or lessen the likelihood of getting another infection, endodontic therapy ultimately aids in periapical healing by hermetically closing the root canal space (9).

A clinical and radiological follow-up should be performed following every root canal procedure, preferably a year after the procedure's conclusion and at the very least six months later. Endodontic treatment failure is indicated by chronic symptoms in the patient, such as oedema, sinus tract, pain upon percussion, and pain upon palpation in the apical region (3).

There are four alternatives for treating a tooth in the event of problems following RCT: extraction, nonsurgical retreatment, surgical treatment, and doing nothing (9). This is especially true if symptoms continue despite endodontic therapy.

The main aim of this review is to identify and understand the main causes of endodontic failure in order to help dentists avoid repeating them.

2. OBJETIVES AND HYPOTHESES

The objectives of this integrative systematic review are:

- Main objective: Identify the main and frequent causes of endodontic failure.

- Secondary objective: Classify the different causes according to severity.

Null hypothesis: All the causes are equally frequent and have the same impact on the severety of the outcome.

3.MATERIALS AND METHODS

3.1. Protocol

The review protocol used was the one described in PRISMA (Preferred Reporting Items for Systematic and Meta-Analyses) recommendations.

3.2. Eligibility Criteria

This work was based on the Cochrane recommendations in response to PICO.

Table 1: PICO

P I C O	Population	All patients with failed root canal treatment.
	Intervention	Identify the causes of different endodontic failure situations.
	Comparaison	Different factors of endodontic failure.
	Outcome	Address the relative causes

Two groups were formed to rank the eligibility criteria:

- Inclusion
- Exclusion

Table 2 : ELIGIBILITY CRITERIA

INCLUSION CRITERIA	EXCLUSION CRITERIA
Articles addressing causes of endodontic failure	Duplicates
Comparative study of the prevalence of causes of endodontic failure	Reviews, meta-analyses and Systematic review
Articles published in the last 10 years	Article more than 10 years old
Clinical Research, Retrospective Study, Case Report, Comparative Study	Deciduous or animal tooth
Articles in English	

3.3. Information sources and search strategy

The following scientific Mesh terms were searched in PubMed and Google Scholar between September 2023 and March 2024: “Endodontic failure” AND “Endodontic complications” AND “Failed root canal treatment” AND “Iatrogenic Factors”.

Additional articles for the introduction and discussion were obtained with a free manual search.

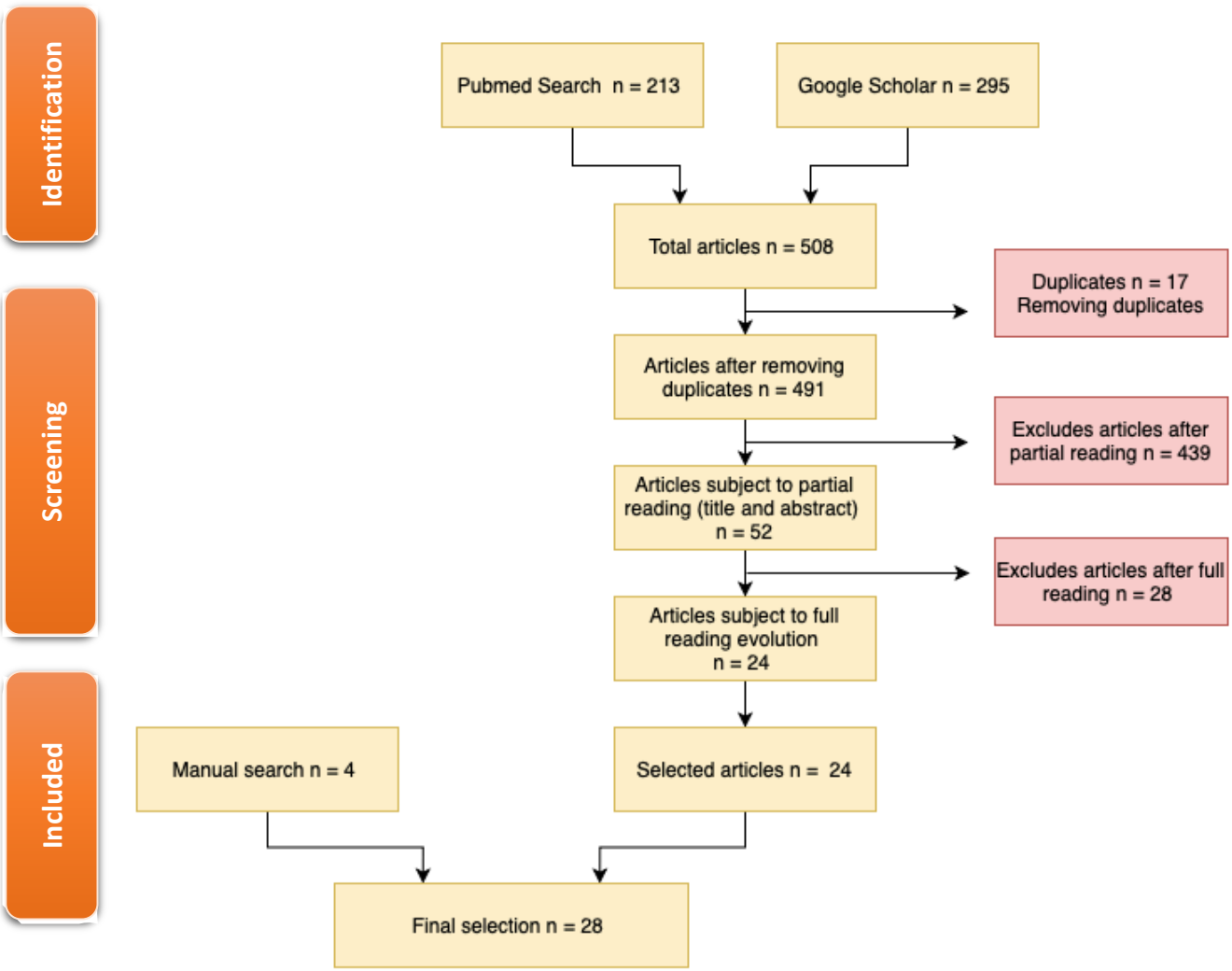

Figure 1 : PRISMA FLOW DIAGRAM OF THE SEARCH STRATEGY

4. RESULTS

4.1. SELECTION OF ARTICLES

The initial search resulted in the identification of 468 articles (2014-2024).

Database	Research strategy	Found articles	Selected articles
Pubmed	("endodontic failure"[All Fields]) OR ("endodontics/complications"[MeSH Terms]) AND (2014:2024[pdat])	**121**	**7**
Pubmed	(("root canal treatment"[All Fields]) OR ("failed root canal treatment"[All Fields]) AND (2014:2024[pdat])) OR (iatrogenic factors)	**92**	**3**
Google Scholar	(("Endodontic failure") AND ("Endodontic complications")) OR ("iatrogenic factors") OR (“Failed root canal treatment”)	**295**	**14**

Table 3: Advanced search results table

PubMed and Google Scholar were the databases used to search for articles. In total, by combining the mesh terms, 508 articles were found. 17 have been eliminated because of duplicates *(Endnote).* After applying the exclusion criteria, reading the titles and contexts, 52 articles were selected. After reading these articles, 24 were included. With the free manual search, 4 articles were added to complete the introduction and discussion.

4.2. YEARS OF PUBLICATIONS

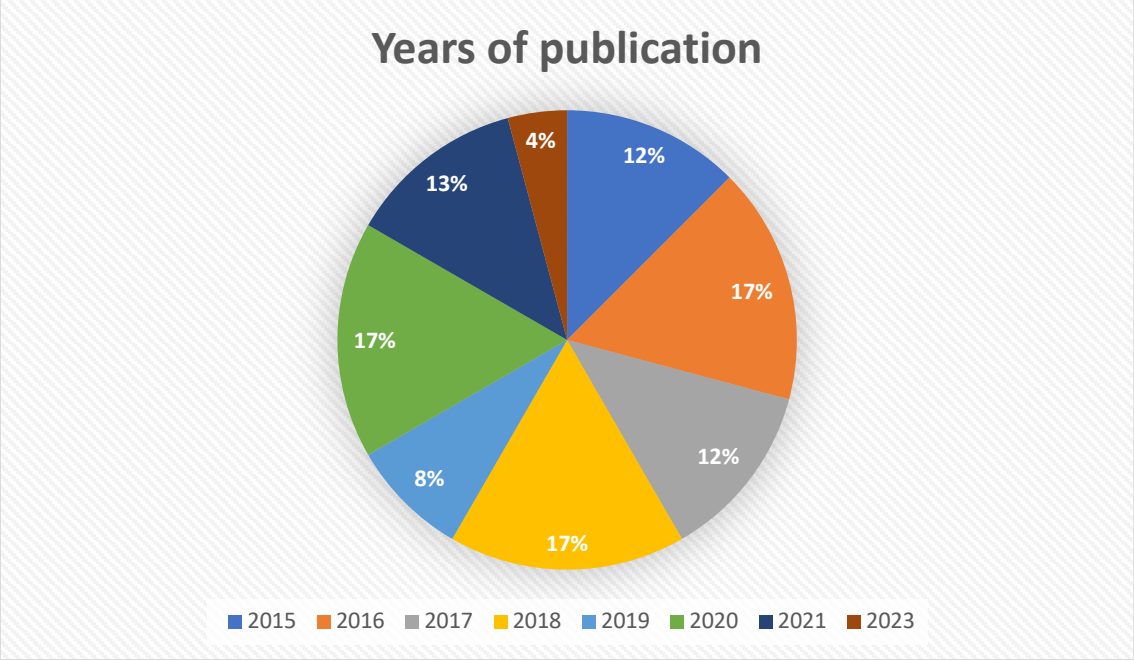

Figure 2: DISTRIBUTION BY YEAR OF PUBLICATION OF THE ARTICLES INCLUDED

The majority of the articles reviewed for this integrative review were published between 2016, 2018 and 2020.

4.3. TYPE OF STUDIES

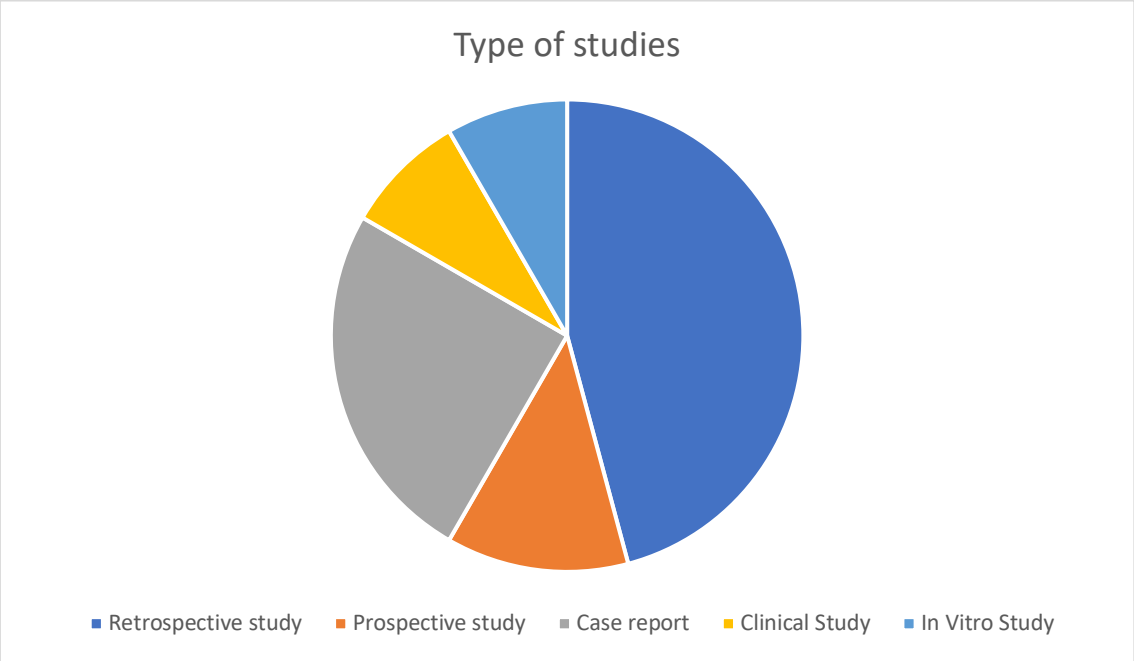

Figure 3: DISTRIBUTION BY THE TYPE OF STUDY

Mostly, the articles used are retrospective study.

4.4. RESULTS OF STUDIES

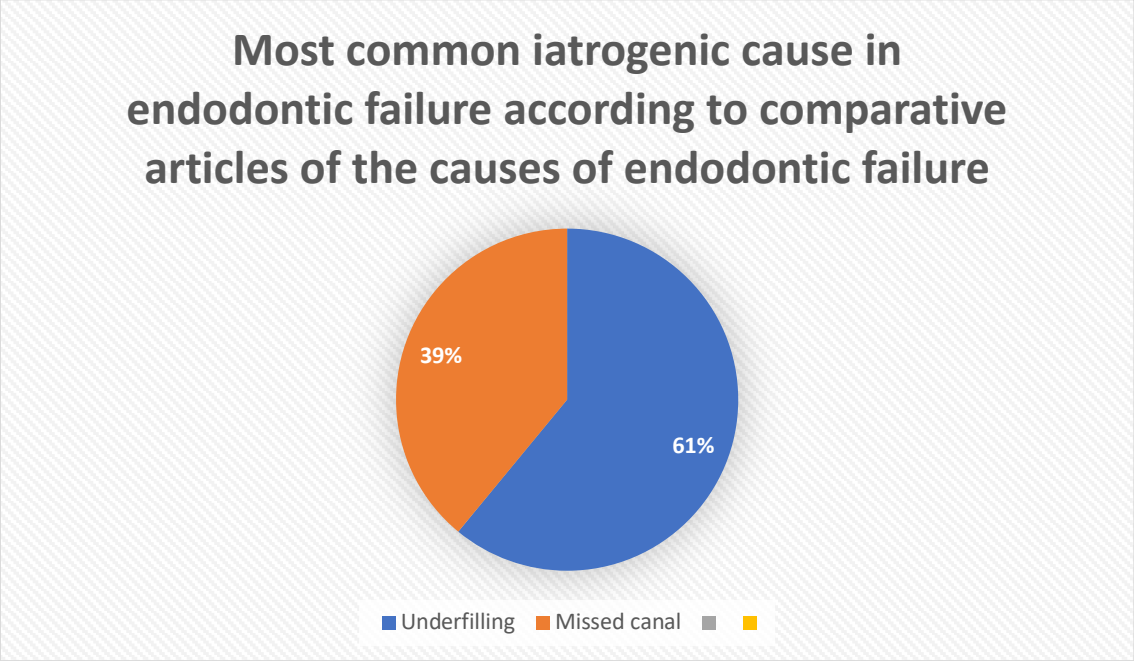

Figure 4 : DISTRIBUTION BY THE RESULTS OF STUDIES

According to the analysis of the comparative articles of the causes of endodontic failure, out of 7 articles, 5 seems to say that the main cause is underfilling and 2 articles seems to say that it is the missed channel, the main cause of endodontic failure.

4.5. TABLE OF RESULTS

Table 3 : RELEVANT DATA GATHERED FROM THE SELECTED STUDIES

Title/Authors/Years	Type of study	Population	Objective	Materials and Methods	Conclusion
« Histological evaluation of the root apices of failed endodontic cases » Pecora C et al. 2015	Retrospective Study	Adult patients who were referred for endodontic surgery	Adult patients who were referred for endodontic surgery	- Patients aged between 18 and 65 years. - Teeth with apical periodontitis that was diagnosed radiographically - The tooth could not be adequately and better managed by root-canal retreatmen	The causes of endodontic failure identified : Presence of bacterial (51%), untreated canals (11%), filling material outside root canal (4%), apex transposition and overfilling (3%), bacterial colonization of root surface (2%)
« Treatment of calcified root canals in elderly people: a clinical study about the accessibility, the time needed and the outcome with a three-year follow-up » Kiefner P et al. 2016	Clinical study	41 participants, median age: 72 years.	Determining the duration, accessibility, and results of endodontic treatment for teeth with calcified root canals in an aged participant sample at a private endodontic clinic.	There were 41 individuals who required root canal therapy. 41 teeth were treated in total, resulting in 114 successfully completed root canals.	All of the older patient's calcium root canals in this research could be accessed in a maximum of 60 minutes. Following a 3-year follow-up, the success rate was 80%.

Title/Authors/Years	Type of study	Population	Objective	Materials and Methods	Conclusion
« Complications in endodontics » Bhuva B et al. 2020	Clinical Study	3 patients: - 1 patient with periapical lesion of the tooth 26 - 1 patient with periapical lesion of the tooth 36 - 1 patient with periapical lesion of the tooth 46	Significant endodontic complications, their impact on prognosis and how to manage them.	Use of 3 teeth to illustrate the causes of endodontic failure. the causes discussed in the table are untreated anatomy, perforation, instrument separation and Ledge formation.	The first and most important step in increasing the predictability of endodontic therapy is to lower the risk of iatrogenic consequences.
« Factors that cause endodontic failures in general practices in Japan » Yamaguchi M et al. 2018	Retrospective Study	A total of 103 teeth were selected, and 76 teeth completed root-canal treatment.	The aim of this study was to identify the factors causing endodontic failures in general practices in Japan.	Medical records of eligible patients were reviewed and the factors causing endodontic failures were identified based on the diagnoses and prognoses of re-treatments.	Factors causing endodontic failure: • open apices (18/76) • missed canal (12/76) • insufficient enlargement of the root canal (10/76) • Perforation (9/76) • Fin isthmus (8/76) • Root fracture (5/76) • Transportation (7/76) • Inaccessible root apex (4/ 76) • Separated instruments (4/76)

Title/Authors/Years	Type of study	Population	Objective	Materials and Methods	Conclusion
« Clinical and radiological analysis of the causes for endodontic treatment failure » Nešković J et al. 2017	Retrospective Study	79 teeth • 36 multirooted tooth • 43 singlerooted tooth	Study the causes of primary endodontic treatment failure and assess possibilities for retreatment of teeth with failed endodontic treatment.	2 group : • The first group included teeth without periapical lesions (28 teeeth) • The second group included teeth with visible signs of periapical tissue damage (51 teeth)	• Short filling (65.8% of cases) • Untreated Canals (25.3%) • Non-homogeneous obturation with correct length (5.1%) • Fractured instrument (3.8%)
« Assessment of Various Causes for Root Canals Failures in Study Population » Kumar M et al. 2019	Retrospective Study	78 patients, A total of 140 endodontic treated teeth were included	understand the main causes of endodontic failure	Take information about age and gender. Use of intraoral periapical to check presence or absence of radioguide lesion, quality of obturation, presence of forgotten root canal	The most reason of ailure endodontic are missed canal, inadequate obturationand fractured coronal obturation

Title/Authors/Years	Type of study	Population	Objective	Materials and Methods	Conclusion
« Evaluation of the Causes of Failure of Root Canal Treatment among Patients in the City of Al-Kharj, Saudi Arabia » Mustafa M et al. 2021	Retrospective Study	250 patients of both genders were involved in the study	Evaluate the causes of failure of endodontic treatment among patients in the Saudi Arabian city of Al-Kharj.	Criteria confirming the failure of the endodontic treatment were pain, tenderness on pressure, periapical radiolucency, and sinus tract. Patients were selected by convenience sampling methods	Ier molars were the most commonly affected tooth in the failure of endodontic treatment. Cause of fail endodontic: Inadequate filling of the root canal (36.8%), missed canals (14.4%), over-extension root canal fillings (12.8%), perforations (9.6%), Broken isntrument (8.8%), endodontic access preparation related (2.4%)
« Causes of root canal treatment failure: A prospective study in Makkah City, Saudi Arabia » Aljabri M et al.	Prospective Study	131 patients in the Western region of Saudi Arabia and included patients with failed RCT aged 16 years or older without any systemic disorder.	identify the causes of root canal treatment (RCT) failures in Makkah City.	This study used patients aged 16 years or over with failure endodontic. Exlusion criteria: <16 years	Endodontic treatment failures mostly occurred in underfilled root canals, andcoronal leakage. Premoalr have the higher failure. the most common factor for root canal failure: underfilling (71.0%), coronal leakage (42.7%), over filling (16.8%), missed canal (16%), itrogenic (6.1%), anatomic (1.5%) and leaked canal (1.5%)

Title/Authors/Years	Type of study	Population	Objective	Materials and Methods	Conclusion
« Radiographic study of the problems and failures of endodontic treatment » Akbar I et al. 2015	Prospective Study	Populations of 100 patients with 100 teeth and 130 root canals	We seek to understand the causes of endodontic failure by radiographic visualization	Table 1: Reasons of endodontic treatment failures according to teeth and root canal fillings. Data are shown in n (%) Table 2: Frequency (percent) of various reasons of endodontic treatment failures of root canal fillings.	the causes of endodontic failure are from the most frequent to the least frequent: Under filling (46.9%), Poor filling (28,5%), Perforations (13%), lack of fillings in the canal (4,6%), separated instrument (3,1%), coronal leakage (0,8%).
« The Factors Responsible for Endodontic Treatment Failure in the Permanent Dentitions of the Patients Reported to the College of Dentistry, the University of Aljouf, Kingdom of Saudi Arabia » Iqbal A et al. 2016	Retrospective Study	90 patients, with post endodontic treatment .The patients were randomly selected from the OPD. They were divided into three age groups: group-1 (21-30 years); group-2 (31-40 years); group-3 (41-50 years).	determine the different factors responsible for endodontic treatment failure in permanent dentitions of the patients.	The teeth with vertical root fracture, perio-endo lesions, split crown and badly broken down unrestorable teeth were excluded from the present study.	Frequency and percentage of the factors responsible for endodontic failure by radiographic evaluation: Broken instruments (6.6%), untreated root canals (12.2%), unfilled and missed canals (17.7%), underfilled canals (33.3%), overfilled canals (10%), perforations (5.5%), poor coronal restorations (14.4%)

Title/Authors/Years	Type of study	Population	Objective	Materials and Methods	Conclusion
« Analysis of Cause of Endodontic Failure of C-Shaped Root Canals » Kim Y et al. 2018	Retrospective Study	This study was approved by the Institutional Review Board of Seoul St. Mary's Hospital. 417 patients who were referred to the department of conservative dentistry for endodontic microsurgery, 42 C-shaped root canals who had undergone intentional replanting surgery were added to the study	The aim of this study was to analyze various characteristics and classifications of C-shaped root canals and to assess the causes of endodontic failure of C-shaped root canals	Table 1 & 2: Classification of C-Shaped Channel Configuration Table 3: Percentage of possible causes of failure in anterior endodontic Table 4: Representative photos of various causes of endodontic failure Table 5: SEM images of the resected root end of the C-shaped root canals. Comparative study with statistical analysis to understand the most common cause of endodontic failure of C-shaped root canals	To reduce endodontic failure of C-shaped root canals, it is necessary to know the precise morphology of C-shaped. Endodontic failure cause: - A leaky channel (45.2%) - An isthmus (23.5%), - Untreated channel (9.5%), - Overfilling (7.1%) - Iatrogenic problems (7.5%)
« Management of Iatrogenic Errors Furcal Perforation » Aidasani G et al. 2018	Case Report	29 year old patient	We seek to understand the management of iatrogenic perforations at a coronal and middle third of the root, below the alveolar margin.	The treatment plans were as follows: - Repair of perforation with trioxide mineral aggregate (MTA) - Strengthening of remaining dental structure - Cleaning and shaping followed by filling - Post-endodontic restoration.	Conservative approach should be considered first with proper diagnosis, advanced biomaterials, and operator skills; the outcome is more predictable thus improving the prognosis.

Title/Authors/Years	Type of study	Population	Objective	Materials and Methods	Conclusion
« Novel navigation technique for the endodontic treatment of a molar with pulp canal calcification and apical pathology » Shi X et al. 2017	Case Report	29-year-old woman	understand the possible tools when there is a calcified tooth	Provides a new method for treating a molar that has apical disease and pulp canal calcification.	Treatment for teeth with apical disease and pulp canal calcification using guided endodontics seems to be both clinically beneficial and safe.
« Deviation in Simulated Curved Canals Prepared with Reciproc and ProTaper Systems » Dos Santos Marotta P et al. 2016	Retrospective Study	40 teeth	use of Reciproc and ProTaper Systems during déviation root canal	Two different groups of Endo Training Blocks were employed. One set of people used an instrumentation system with reciprocal movement and one instrument, called Reciproc; another set used a system with continuous rotation to the right and a series of instruments, called ProTaper, for preparation.	When compared to a single instrument with reciprocal movement, the results indicate that continuous mechanised instrumentation with prior and progressive cervical preparation in the apical direction, using specific files, tends to perform a more adequate preparation with less risk of displacing the original canal.

Title/Authors/Years	Type of study	Population	Objective	Materials and Methods	Conclusion
« Root Canal Stripping: Malpractice or Common Procedural Accident— An Ethical Dilemma in Endodontics » Ciobanu I.E et al. 2016	Case Report	Case report 1 : A 67-year-old male patient, complaining of acute, pulsating pain in the mandibular left first molar Case report 2 : A 52-year-old male patient.	Understanding whether dental perforation is a professional misconduct or a procedural accident; how to minimize perforation	the four-topic method (medical indications, patient preferences, quality of life and contextual characteristics) described by Jonsen et al. was used to focus on specific aspects and to relate the circumstances of the cases to their underlying ethical principles.	The anatomy and morphology of the root canal as well as the elastic properties (memory form) of modern endodontic instruments plays an important role in the success of the access cavity.
« Access to Original Canal Trajectory after Deviation and Perforation with Guided Endodontic Assistance » Casadei B.D et al. 2020	Case Report	Patient E.E.S.G.O, female, 37 years old, with calcified canal of the sec-ond right upper premolar.	This case report describes an endodontic treatment where there was an intercurrence, generating deviation and perforation.	Figure 1: Radiographic images showed that the instrument was outside the original canal pathway resulting in perforation Figure 2: CBCT showing resorption in the periapical region and perforation in the apical third. Figure 3: The correction of the previous deviation Control 1 year later.	The guided endodontic technique should be used in the case of a calcified canal or false path, CBCT can be important for 3D visualisation. CBCT takes important aid in the treatment of accidents andcomplications in endodontics.

Title/Authors/Years	Type of study	Population	Objective	Materials and Methods	Conclusion
« Comparison of bacterial coronal leakage between different obturation materials » Mobarak A et al. 2015	In Vitro Study	60 single-canaled lower premolars.	Examine the differences in coronal bacterial leakage between obturation materials.	- Group I: obturation was done using CPoint and Endosequence bioceramic sealer using single-cone technique. - Group II: obturation was done using Protaper Group III: obturation was done using Protaper gutta percha and Adseal resin sealer; - Group IV: obturation was done using Protaper gutta percha and MTA Fillapex sealer; - Group V and VI : used as positive and negativecontrol	The best coronal seal was produced by CPoint using endosequence bioceramic sealer, while MTA Fillapex produced the worst. The lateral condensation approach may be substituted with the CPoint obturation system.
« Comparison of MicroLeakage in Root Canals Containing Separated Rotary Instruments using MTA and Biodentine Barrier – An in-vitro study » Nshenoy D.S et al. 2021	In Vitro Study	88 single-rooted human mandibular premolars	The purpose of this study was to evaluate how well MTA and Biodentine sealed the root canal when they were positioned coronal to the instrument separated in the apical area.	Different group: - GROUP I: MTA plug + cold lateral condensation (CLC) of Guttapercha. - GROUP II: MTA plug + warm vertical condensation (WVC) of Guttapercha. - GROUP III: Biodentine + cold lateral condensation (CLC) of Guttapercha. - GROUP IV: Biodentine + warm vertical condensation (WVC) of Guttapercha.	Both MTA and Biodentine Barrier exhibit the materials' strong sealing capabilities.

Title/Authors/Years	Type of study	Population	Objective	Materials and Methods	Conclusion
« Controversies and portential medical liability of unintentional canal overfilling of root canal tratments and retreatments in teeth with periapical » Scarlatescu S.A et al. 2023	Retrospective Study	58 patients who presented 79 teeth with periapical radiolucency	Examine the possibility of inadvertent overfilling on the long-term radiographic results of root canal therapy and retreatments following warm vertical condensation, carried done by two endodontists, on teeth with periapical radiolucency.	The patients had clinical and radiological surveillance for a minimum of one year, and in certain instances, for up to nine years. The results were decided by two impartial assessors after they evaluated the radiographs.	When using heated condensation procedures, a "puff" of sealer is increasingly the standard of care, although gross overfilling may result in medical responsibility. The outcome of root canal treatment with unintentional canal overfilling registered the best results in the first two years.
« The fate of overfilling in root canal treatments with long-term follow-up: a case series » Malagnino V.A et al. 2021	Case Report	Six endodontic overfilling patients with good clinical results over a 35-year radiographic follow-up period.	Understand the overfilling impact of root canal treatment	The current case series details six root canal procedures whereby unintentional overfilling of gutta-percha and root canal sealant occurred. Periapical radiographs were taken of the patients' teeth on a regular basis to assess the results throughout long-term follow-up.	An inadvertent overfilling of gutta-percha and root canal sealer in the periapical tissues may not have a negative impact on the long-term results of root canal therapy, given appropriate disinfection and a 3D seal of the apical third.

Title/Authors/Years	Type of study	Population	Objective	Materials and Methods	Conclusion
« Efficacy of manual and mechanical instrumentation techniques for removal of overextended root canal filling material » Aslan T et al. 2017	Retrospective Study	80 premolar teeth (mandibular)	Examine the effectiveness of manual and mechanical instrumentation methods for removing overextended root canal filling material, such as the ProTaper Universal retreatment system, Mtwo retreatment system, Reciproc system, and Hedström files.	80 overfilled teeth were randomly assigned to four equal groups (n = 20) for removal of the root filling material: Group 1: ProTaper Universal retreatment files. Group 2: Mtwo retreatment files. Group 3: Reciproc system. Group 4: hand files.	The Mtwo (30%) and hand files (30%) had a higher success rate for removing overextended guttapercha than the ProTaper (20%) and Reciproc (10%).
« New Approach in the Management of Vertical Root Fracture with the Help of Biodentine and CBCT » Baranwal ,H.C et al. 2020	Case Report	A 35-year-old male patient with fracture problem.	study the importance of CBCT and biodentine in the management of vertical root fracture.	We study the case of a 37-year-old patient, a preoperative analysis is first made. the use of CBCT and biodentine is then highlighted. Finally, a post-operative analysis is done.	- For teeth that are endodontically or nonendodontically treated, CBCT can be helpful in the early diagnosis of vertical root fracture. - In the current case study, combination treatment produces both functional and aesthetically pleasing results.

Title/Authors/Years	Type of study	Population	Objective	Materials and Methods	Conclusion
« Comparative Study of Treatment Outcome in Apecectomies With or Without Root-end Filling » Ajayi et al. 2018	Prospective Study	Patients of Dental Hospital of the Obafemi Awolowo University Teaching Hospitals Complex during 12 months. there are 53 patients in this study	Examine the differences in the treatment results between apicectomy procedures and apicectomy with and without retrograde root-end filling.	Patients were randomly placed in 2 groups. - Group A: Apicectomy without root-end filling - Group B: Apicectomy with root-end filling	Despite having a better success rate, apicectomized teeth without root-end fillings were not statistically significant.
« Relationship Between Unintentional Canal Overfilling and the Long-term Outcome of Primary Root Canal Treatments and Nonsurgical Retreatments: a Retrospective Radiographic Assessment » Goldberg F et al. 2019	Retrospective Study	220 root canal treatments.	Analyse the radiographic results of root canal therapy and retreatments with accidental overfilling of the root canal in the past.	The long-term result was ascertained by two calibrated observers after they assessed the radiographs.	The kind of extruded material, its resorption, or its persistence had no bearing on the result of root canal therapy including accidental canal overfilling. There was no correlation between the extruded material's persistence and a good or bad result.

The main results are as follow:

The main cause of endodontic failure is bacteriological, which may be intraradicular or extraradicular. All endodontic failures related to the dentist; will allow the formation or retention of bacteria that will promote endodontic failure (2,5,6).

➔ Iatrogenic mistakes are the cause of endodontic failures, which are categorised based on their frequency (2,5,6):

1) Untreated channels and underfilling: Untreated channels are found to be the second leading cause of endodontic failure, after underfilling (2,3,7,9,10). 46.9% of endodontic failures were caused by underfillings, according to a study by *Iqbal A et al.* But in terms of channel forgetting, *Mustafa M et al*. (3) report that it is present in 14.4% of cases, whereas *Yamaguchi M et al*. found that it is 15.8% of cases. In studies that understand the causes of underfilling and channel forgetting, underfilling is more frequent as with *Aljabri M et al*. study (9), *Iqbal A et al.* (7). 33.3% under-filling and 17.7% channel forgetting are highlighted in *Azhar's* study. *Aljabri M et al.* (9), these results can be completed by the study of *Aljabri M et al.* with 71% endodontic failure related to underfilling and 16.8% due to a channel forgetfulness (9).

2) Then there is overfilling: It can be considered one of the most common causes of endodontic failure. In the study of Iftikhar Akbar et al.; overfilling is responsible for 13% of endodontic failure (2), this can be joined by the study *of Iqbal A et al.* (7) and *Mohsen K. Aljabri et al.* (9) which define respectively è 10% and 16,8% overfilling as a cause of endodontic failure.

3) The broken instrument in the root canal is another example of cause of endodontic failure and it is due to the separation of the instrument during the root canal preparation. In the study of *Iqbal A et al. (*7); the broken

instrument is the cause of 6.6% of endodontic failure. Similarly in the research of *Yamaguchi M et al*. (10), where it seems to say that 5.2% of the causes of endodontic failure are related to the broken instrument. Only *Iftikhar Akbar* (2) seems to say that the broken instrument is only responsible for 3.1% of endodontic failure.

4) Coronal-leakage is another main cause of endodontic failure, it is due to bacteriological infiltration at the coronal level (9,11). In *Akbar I et al.* study, coronal-leakage appears to be only responsible for 0.8% of endodontic failure. This is in contradiction with the studies *Aljabri M et al.(*9) and *Iqbal A et al.*(7) which seem to say that coronal leakage is responsible for 42.7% and 14.4% of endodontic failure respectively.

5) Other endodontic failures are also main causes including edged root canals, fracture and perforation.

   The anatomy of the tooth can complicate the treatment of the tooth including calcifications and isthmus.

Resolution of each endodontic failure seems possible, but it does not guarantee a 100% success.

This resolution can be assembled globally by using 3 dimensions imaging will allow the practitioner to better understand the ductal anatomy and then adapt its endodontic reprocessing.

5. DISCUSSION

5.1 MICROBIAL FACTOR

One of the most frequent reasons for endodontic failures has been observed to be the persistence of microorganisms in the apical region of the root canal system (3,4,5). Research has indicated that endodontic disinfection treatments may not always eliminate germs found near dentinal tubules, ramifications, deltas, abnormalities, and isthmuses (5). This could provide the microorganisms a chance to survive and, depending on a few variables, cause failure (5). In keeping with the previous investigation, we also found that microbial colonies in the canal space contributed to endodontic failure in about 3.6% of the cases (3). 51% of the causes of endodontic failure are due to the presence of bacteria and debris in the canal according to the study of *Pecora C et al.* (5).

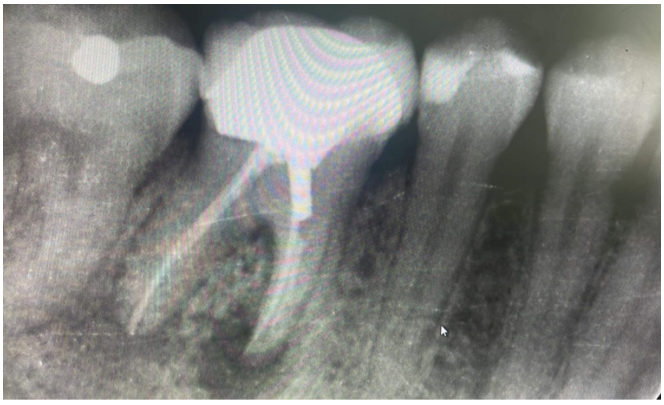

Figure 5 : Periapical radiograph showing periapical lesion

(Reference: Dr De Oliveira)

5.1.1 EXTRARADICULAR INFECTION

A combination of mechanical instrumentation, irrigation with different devices, and administration of antimicrobial medications in the root canal can be used to break up biofilms and reduce microorganisms (12). Moreover, 86.7% of the bacterial species found in extraradicular biofilms were also found in the root canal of the same teeth (10).

Certain root-filling materials like contaminated gutta-percha cones, can initiate a foreign body reaction if they are displaced into the periradicular tissues. The cellulose component of paper points and cotton wool may contribute to failure of root canal treatment if they come in contact with the periradicular tissues (5).

5.1.2 INTRARADICULAR INFECTION

After endodontic treatment, an unfilled gap in the apical portion of the root containing an infected canal is likely to sustain periradicular inflammation or induce a persistent intraradicular infection (5). It is therefore important to understand that intraradicular infection is associated with the forgetfulness of a root canal or incomplete instrumentation (12).

The endodontic error related to the microorganism can be due to the anatomical difficulty, such as apical ramification, root perforation, calcified canal and other morphologic irregularities (3,4).

After endodontic treatment, there are 4 post-operative complications related to microorganisms: the microorganisms remained or reestablished in the root canal, the responses of foreign bodies in the apical tissue, the microorganisms that survived in the apical tissues outside the canal system and finally the periapical cyst (9).

According to the articles, microorganisms are therefore the primary origin of endodontic failure (2,5,6).

5.2 IATROGENIC CAUSES

5.2.1 PERFORATION

The probability of endodontic failure depends on the location and size of the perforations that can cause bacterial colonization, so it is necessary to quickly find a way to resolve this constraint to avoid bacterial proliferation (3,10,13). For long-term success, it is important to disinfect the area where the perforation is located, as well as the perforation canal system (13).

In some studies endodontic failure related to perforations is located around 9.6% (3), notably in the studies of *Yamaguchi M et al.,* out of 78 teeth having undergone RCT, 9 (11.8%) are due to perforation (10), while in the study of *Iqbal A et al.*; a study of 90 patients only 5 patients (5.5%) had an endodontic failure of a perforation (7).

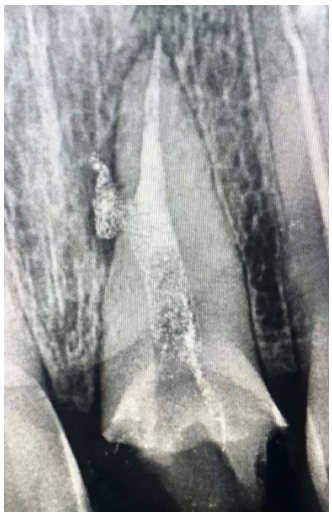

Figure 6 : Periapical radiograph showing perforation

(Reference: Dr Gatrio)

It is important that the dentist perform a preoperative analysis before the endodontic treatment to avoid any perforation.

The potential for root perforation can be detected by sudden bleeding and pain during root canal instrumentation or post-preparation in teeth. (13).

Fuss and trope classify the different type of perforations (13):

Type of Perforations	Perforation characteristics
• Fresh perforation	Favorable prognosis. Treated under aseptic conditions as soon as possible.
• Old perforation	Questionable prognosis. Possibility of emancipation of microorganism
• Small perforation	Favorable prognosis. Presence of traumas in the tissue, however, is minimal. In addition, it is easy to seal
• Large perforation	Questionable prognosis. It is demonstrated post-operatively, with a large amount of trauma to the tissue and it is difficult to provide optimal sealing, as well as contamination by bacteria, or coronal leakage along the temporary restoration.
• Coronal perforation	Favorable prognosis.
• Crestal perforation	Questionable prognosis. The level where epithelial fixation occurs in crestal bone
• Apical perforation	Favorable prognosis. Attachment of epithelial tissue to the apical bone.

TABLE 4 : Classification of the different type of perforations according to Fuss and Trope (1996)

Because of their unique root structure, mandibular molars are the most vulnerable to perforations (14). Every root canal has a different degree of curvature.

5.2.2 UNTREATED ROOT CANAL AND UNDERFILLING

One of the main reasons for root canal treatment failures is thought to be the operator's inability to identify and treat every canal. (2,3,5,7). Unprepared root canal tissue may contain germs and necrotic tissue, which could make therapy ineffective (7,8).
Premolars and molars are the most common teeth to have this observation (7). The bulk of endodontic treatment failures in *Iqbal A et al.* study were found in the maxillary molars (44.4%), mandibular molars (20%), and maxillary premolars (15.5%) based on the analysis of data pertaining to individual teeth (7).

Underfilled (33.3%) and unfilled (17.7%) root canals were the most frequently noted issues in *Azhar I et al.* study that resulted to the failure of endodontic treatment (7). A radiographic definition of under-filling is when the radiographic apex is more than 2 mm away (2,7). Underfilling of root canals is frequently the consequence of poor irrigation of the root canal system and incomplete chemometric preparation, which typically results in erroneous working length measurements and endodontic failures. The second most frequent reason for endodontic treatment failure was found to be unfilled canals (7).

In his study, *Aljabri M et al.* shows that out of a sample of 131 patients with endodontic failure, 71% had an underfilling (9). According to the *European Association of Endodontists,* root canal that is fully filled, with no space between the filling and the canal wall and tapered from the crown to the apex is considered adequate according to the *European Association of Endodontists*.

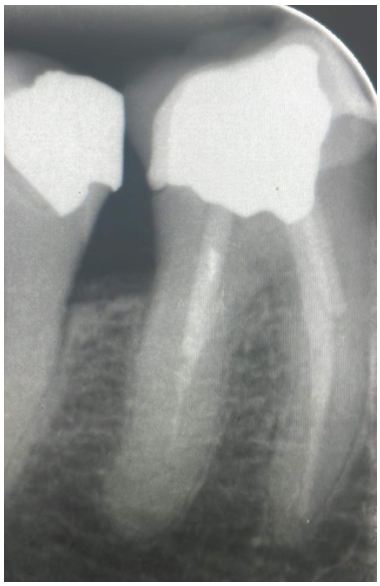

Figure 7 : Periapical radiograph showing underfilling

(Reference: Dr De Oliveira)

5.2.3 LEDGED ROOT CANALS

A common issue that can make it challenging, if not impossible, to reach the working length is deviation from the original trajectory during root canal negotiation and shaping (8,15).

Variations can be caused by tooth architecture, curvature, canal location, and instrumentation technique, among other things (8). The use of NiTi alloy in endodontics is crucial to preventing difficulties, especially when it comes to preserving the original canal's trajectory during mechanical preparation and lowering the possibility of deviations (15). Of course, there are more elements to consider when selecting the perfect tool, such flexibility, resistance to fracture, the ability to clean the canals, and positive therapeutic outcomes from clinical studies (15).

5.2.4 FRACTURES

In different methods of obturation, a certain condensation pressure is applied to the walls of the root canal. If this pressure is too high, cracks formed in the dentin can lead to a vertical fracture of the tooth (16). According to *Pecora C et al.,* the

apical dentin may experience microfractures due to vertical condensation. This may be a significant contributing factor to endodontic failure, particularly if it remains undiagnosed.

The occurrence of fractures in permanent or temporary restorations can lead to exposure of the filling material and recontamination of the exposed canals. The infection can occur sequentially: intraradicular infection followed by extraradicular infection induced by diffusion via the apical foramen or lateral canals. Furthermore, radiography and clinical examination by themselves are not often sufficient to identify bacterial colonization of these microfractures. This result reaffirms the need for the dentists to use extreme caution when choosing the size of their spreaders and the amount of pressure they apply (5).

In the study of *Neskovic J et al.*, of 140 treatments with endodontic failure, 35% are due to a coronal fracture (6), and in the article by *Pecora C et al.;* microfracture is the cause of 8% of endodontic failure (5).

5.2.5 CORONAL-LEAKAGE

In endodontics, coronal restoration is considered to be the main factor influencing endodontic treatment, it is this restoration that, on the one hand, reinforces the isolation of the treated canals and, on the other hand, gives the tooth adequate strength, reducing the likelihood of it fracturing (17). Microleakage is described as the diffusion of bacteria, oral fluids, ions, and molecules into the tooth and the filling material interface (9,11).

In the study of *Aljabri M et al.,* out of a sample of 131 patients, 56 (42.7%) patients had an endodontic treatment failure caused by coronal leakage (9) and in the *Akbar I et al*. studies, 1 in 130 teeth (0.8%) has an endodontic failure that is related to coronal infiltration (2). We shouldn't rule out the potential of salivary coronal leaked. The most frequent biological reason for endodontic failure, according to *Mustafa M et al.* research, was residual irritants in the pulp region of

a tooth that had undergone inadequate endodontic treatment; in this case, a salivary leak may have played a role (3).
Consequently, a better success rate will result from the combination of proper coronary repair and excellent endodontic therapy (3).

Poor root canal obturation may have a positive outcome in *Iqbal A et al.* research (2,7), provided the coronal repair is of high quality. Conversely, a tooth with a poorly done coronary repair but a well-prepared, well-cleaned root canal system could fail quickly (2,3,7). The periapical health of teeth treated with endodontic therapy is positively impacted by the quality of the coronary repair (2,9).

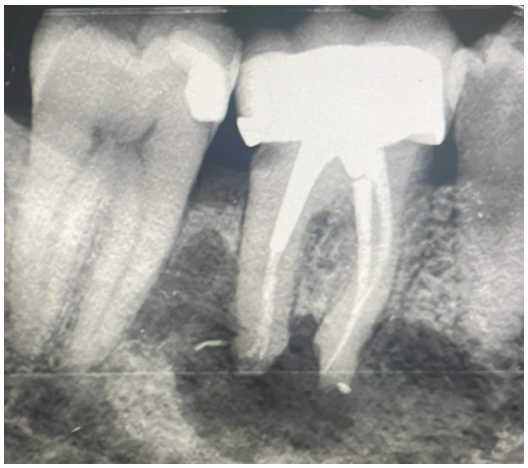

Figure 8 : Periapical radiograph showing coronal-leakage

(Reference: Dr De Oliveira)

5.2.6 BROKEN INSTRUMENT

When a root canal instrument breaks and stays inside the canal might impede additional cleaning, shaping, and filling (2,6,18).

Effective and lucid communication is necessary in order to mitigate the likelihood of a grievance. In many situations, an immediate referral to a specialist may be required (2,18). Instrument separation can be caused by torsional failure, cyclic fatigue, or both in instruments that are powered by engines or by hand. When an instrument rotates in a curved canal under repeated compressive and tensile

loads, cyclic fatigue happens. When the file tip binds in the canal while the instrument is still rotating, torsional failure happens. According to the article *Bhuva B et al.*, the broken instrument frequency in endodontic failure is between 0.7% and 7.4% (18).

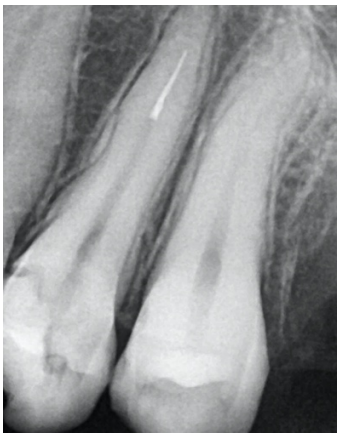

Figure 9: Periapical radiograph showing a broken instrument.

(Reference: Dr Gatrio)

This can be confirmed after analysis of different studies that highlight the frequency of broken instrument in endodontic failure:

Author:	Percentage of failure related to broken instrumentation:	Population:
Yamaguchi M et al. (10).	5,2%	Out of 76 teeth with a problem, 4 teeth are due to instrument separation (10).
Neskovic J et al. (6).	3,8%	-
Akbar I et al. (2).	3,1%	Out of 130 teeth with a problem, 4 teeth are due to instrument separation (2).
Iqbal A et al. (7).	6,6%	Out of 90 teeth with a problem, 6 teeth are due to instrument separation (7).

TABLE 5: Article comparison on the percentage of endodontic failure related to broken instrument.

The multi-planar curvatures commonly found in the mesial roots of molar teeth appear to be susceptible to instrument fracture, the teeth that seem to be most often impacted are the mandibular molars, according to the available research (5).

5.2.7 OVERFILLING

There have been many discussions over endodontic standards of treatment as a result of the overfilling problem (11,19). A three-dimensional filling known as overfilling occurs when a little portion of the material protrudes over the apical foramen. These obturation materials may behave as foreign entities when they are extruded past the apex, causing histological responses varying from mild peri radicular inflammation to more severe periodontal ligament necrosis (11,19). Applying a large amount of sealant or applying it deeply is not recommended since the gutta-percha cone should function as a true piston and result in excessive filling (11). The decrease in overfilling success rates reported in the literature is mostly caused by a persistent infection in the root canal space and the lack of a sufficient 3D joint at the apex, which provides food for the remaining bacteria (11,20). It is not directly related to the extruded material in periapical tissues.

5.3 ANATOMIC CAUSES

5.3.1 CALCIFIED ROOT CANAL

Data about the root canal treatment of teeth with calculus are scarce (21). Regretfully, calcification in the root canal can impede access and make root canal therapy more difficult (8,21,22). Calcification, which is frequently linked to dental traumas including caries, trauma, and certain iatrogenic events, is caused by dentinogenesis deposition and blood circulation issues inside the pulp (22). Therapy is not always necessary for calcification, but if it coexists with apical disease, inflammation needs to be managed (22). In these situations, creating a suitable access cavity and locating the canal orifices can be extremely difficult, which increases the risk of fracture and severe tooth tissue loss, both of which

increase the failure rate (21). It can also be difficult and time-consuming to reach full working length and establish patency (21). Nonetheless, one of the primary conclusions of the research by *Kiefner P et al.* is that calcified root canals can be accessible. In 90% of these root canals, full working length was attained, as shown by a radiograph and an electronic apex finder. Endodontic treatment is indicated when radiographic examination reveals a severely calcified root canal that is associated with apical periodontitis and symptomatology (21).

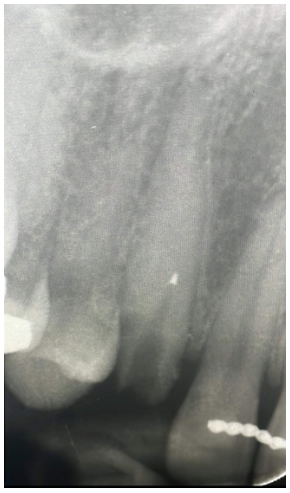

Figure 10 : Periapical radiography with calcified dental canal.

(Reference: Dr De Oliveira)

5.3.2 ISTHMUS

The isthmus, which is a little space that between two root canals, often has pulp tissues (5). The main and accessory canals (isthmus) have many branching and anastomoses due to the intricate anatomy of the canal system, which makes it impossible to treat or obturate using standard tools, materials, and procedures (5,6).

In the studies of *Yamaguchi M et al.,* out of 78 teeth having undergone an RCT, 8 are due to an isthmus (10.5%) (10). Even when not apparent on the X-ray, the noninstrumented portion of the endodontic cavity can include bacteria and necrotic tissue (6). This anatomic structure is not a distinct entity, but rather a component of the root canal system (5). According *to Pecora* C et al. untreated isthmus affects 21% of teeth (5).

5.4 CLASSIFICATION OF THE DIFFERENT CAUSES

In this second part we have classified the different causes according to the conservative aspect of their resolution. Severity is determined according three types: surgical, non-surgical or mixed.

5.4.1 SURGICAL METHODS:

FRACTURE:

The treatment for vertical root fractures is extraction of the tooth followed by a dental prosthesis or implant. The broken fragments are joined by different types of bonding systems or bioceramic cements (23).

5.4.2 NON-SURGICAL METHODS:

CORONAL-LEAKAGE:

The shorter the time between preparing the access cavity and the definitive restoration, the less leakage there will be. Basic precautions taken during each stage of treatment can prevent this complication and guarantee endodontic success.
Coronal leakage is like a silent killer that infiltrates discreetly and causes extensive damage (24,25).

CALCIFICATION AND ISTHMUS:

Guided endodontics has been shown to be a safe and predictable method for locating and accessing the remaining canal (8,21,22). Combining an intra-oral scan with CBCT data to create a model for guided access cavity preparation and root canal localization (8,21,22) is another cutting-edge method for treating teeth

with calcifications. This approach also improves the accuracy of guided drilling for the creation of access guides (8). Here, CBCT is used to visualize hard and soft tissue in three dimensions, giving dentists more information to create direct view printing (22).

To prevent reinfection of the isthmus, a full seal is required (12). In these situations, access to the infected fin isthmus and accessory canals for cleaning may have been made possible by identification using a three-dimensional picture obtained using CBCT (10).

PERFORATION:

A variety of materials, including MTA, biodentine, dentine chips, bioceramic, and calcium-enriched material, can be employed to address the perforation issue (13). When it comes to sealing, MTA (and other bioceramic materials) is highly recommended and performs better than other materials (14).

Hydrophilic particles, primarily dicalcium silicate, aluminum tricalcium, and silica oxide, together with other mineral oxides, are included in most of the bioceramic materials (13).

Because of its high pH of 12.5, antibacterial qualities, and exceptional biocompatibility, these materials encourage the growth of the cementum and bone production (13,14). It is advised to use rotating NI-TI files during instrumentation to prevent any perforations. This material's flexibility and torsion resistance have enhanced the design features of endodontic instruments, lowering mistakes and enabling the best possible preservation of the root canal anatomy (14).

EDGED ROOT CANALS:

During a canal deviation, it is advised to use the guided access. In fact, it enables perception to penetrate the visible light point of the canal located in the CBCT at the proper angle and direction. As a result, it has been possible to clean and model the radicular canal in its entirety and to encourage the repair of the deviation and the foraging zone (8). The use of NITI instrument seems more than recommended during curved channels to avoid false trajectory (15).

UNTREATED CANAL AND UNDERFILLING:

To reliably find every root canal in each tooth, coaxial illumination magnification achieved with an operational microscope or high magnification loupes combined with a solid grasp of pulp chamber anatomy are necessary (5). Non-surgical retreatment may be an option for teeth with untreated canals or underfilling.
Small volume CBCT scanning can be used to successfully identify unlocated canals before treatment (18). For the purpose of altering the pulp chamber and locating elusive channels, instruments such specialized ultrasonic and endo tracer burs are indispensable (5).

5.4.3 MIXED METHODS (The mixed method includes surgical and non-surgical treatments):

BROKEN INSTRUMENTS:

The location of the shattered instrument, the length preserved, and the kind and material of the instrument all play a role in the clinical decision. Carefully weighing these variables as well as the relative hazards of each management approach is necessary (18).
A surgical microscope or high magnification magnifiers with suitable coaxial lighting are highly suggested for successful instrument removal since they provide clear visualization of the canal (18). Most of the time, specifically made ultrasonic tips are used to remove the instrument. First, a circumferential staging platform is made around the instrument's coronal section. The instrument is subsequently subjected to ultrasonic energy in order to be removed. The end of the instrument that is fixed into the dentin of the channel walls may not be adequately reached by ultrasonic energy when the instrument fragment is long. Instrument removal devices, which are essentially made with a suitable-sized tube that sits on the instrument, can be employed in these situations.
The tube and the attached instrument are unscrewed together once the instrument is pressed up against the tube's interior (18).

The use of a bypass is an important technique when there is a fractured instrument, as it allows the instrument to be bypassed and the canal to be obturated (18).

OVERFILLING:

The resolution of overfilling may be surgical and non-surgical.
Apicectomy is the most common surgical treatment for over-filling, and it may be linked to surgical intervention. During periapical surgery, an apicectomy is the removal of the tooth's apical section along with any soft tissues that are connected (26).

At the non-surgical level they seem to exist different way as hand instruments, rotary instruments, ultrasonics, lasers, solvents and microdebriders (27,28).

6. LIMITATIONS

There are not enough comprehensive articles covering all cases of endodontic failure, which has complicated our research.

We used articles of case report, which limits a large sample to determine some cause of endodontic failure.

It was very difficult to find articles comparing the different treatment failures and their resolutions.

This is a vast subject which is not easy to deal with because it encompasses several disciplines such as dentistry and periodontology.

7. Conclusion

After reviewing the articles, the null hypothesis is rejected, since each cause will have a different impact on the patient's prognosis and all causes are not equally frequent.

Based on the information found, a series of factors contribute to the failure of endodontic treatment.

The microbiological component is responsible for many failures, even in canals with good preparation and obturation.

The main iatrogenic cause of endodontic failure is underfilling.

According to the authors, the cause that leads to the worst-case scenarios with worst prognosis is the fracture, requiring extraction most of the times.

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