REVIEW ARTICLE Open Access

Endodontic management and outcome of non-surgical root canal treatment for radix entomolaris associated mandibular molar teeth: A scoping review of case reports

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Abstract

Radix entomolaris (RE) is an anatomical variant of the permanent mandibular molar (MM) with various complex anatomy. However, there is limited literature on the guideline on endodontic management of RE, resulting in unclear understanding on the endodontic treatment outcomes. Hence, this study aimed to map current case reports on endodontic treatment modalities, occurrence of endodontic mishaps, and outcome of MM associated with RE. A systematic search was performed in PubMed, Google Scholar, Scopus, Science Direct, PLOS, and Lilac databases for English articles published between 2000 and 2022 that met the inclusion criteria. The search yielded 1435 results; after screening was completed, only 58 articles were included in the study and critically appraised using JBI critical appraisal tool. Amongst the modifications made in endodontic management of RE were utilising angulated periapical radiograph supplemented with cone-beam computed tomography, extending the access cavity distolingually, and maintaining a small apical size of #25. There were 12% incidence of endodontic mishaps (separated instrument, ledge, missed canal, and extruded sealer) on RE. The success and survival rate of MM associated with RE were 58.7% and 40% respectively, at an average of 8.4 months. The basic management of MM with RE is similar to that of other MM. However, emphasis should be made on RE identification to prevent endodontic mishaps that can influence the endodontic treatment outcome.

Keywords: *curved canal, distolingual root, endodontic mishap, prognosis, treatment protocol*

Received:
6 May 2024
Accepted:
12 July 2024
Published Online:
31 July 2024
How to cite this article:
Mohamed Khazin, S., Mustaffa, M., Kamaruzaman, M., & Kamarudin, D. (2024). Endodontic management and outcome of non-surgical root canal treatment for radix entomolaris associated mandibular molar teeth: A scoping review of case reports. *IIUM Journal of Orofacial and Health Sciences*, *5*(2), 173-225. https://doi.org/10.31436/ijohs.v5i2.315
Article DOI:
https://doi.org/10.31436/ijohs.v5i2.315
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Introduction

Non-surgical root canal treatment (NSRCT) is one of the treatment modalities to prevent and heal apical periodontitis through chemomechanical debridement and three-dimensional obturation of the root canal system, and adequate coronal seal (Schilder, 1974). The former majorly relies on the awareness of the morphology and anatomical variations of the root canal system (Wu *et al*., 2017).

Variations of the permanent mandibular molar (MM) have been frequently reported, such as the presence of supernumerary root located lingual to the distal root, which is known as radix entomolaris (RE). RE itself has several classifications based on the

location of the cervical part (Carlsen & Alexandersen, 1990), the curvature (De Moor *et al*., 2004), and the shape and length of RE (Song *et al.*, 2010).

Due to the different RE variants, endodontic treatment may pose a clinical challenge especially in identifying, locating, accessing, and preparing the root canal system. Inadequacy in understanding the variations can cause failure in removing infected pulpal tissue and microorganisms, leading to persistent infection and post-treatment disease (Byström *et al.*, 1987), which will influence the outcome of NSRCT.

There have been numerous case reports on RE management; however, literature on the guideline for RE treatment protocol is limited. Hence, the aim of this study is to map current case reports on the treatment modification, occurrence of endodontic mishap, and outcome of NSRCT on MM associated with RE.

Materials and Method

Protocol guideline

The methodology of the scoping review adhered to the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) protocol guideline (Tricco *et al.*, 2018) (Figure 1).

Formulation of search questions

The review questions were formulated according to the PCC formulation (P: permanent mandibular molar, C: root canal treatment on RE, C: treatment modification and outcome of root canal treatment in terms of success, survival, failure, and occurrence of mishap). The questions generated for this study to guide the scoping review are as follows: “What are the endodontic modifications made to treat permanent mandibular molar with radix entomolaris?” and “Will the modifications affect the outcome of NSRCT in terms of success, survival, failure, and occurrence of endodontic mishaps?”.

Eligibility criteria and search strategy

A systematic search on case reports was performed in PubMed, Google Scholar, Scopus, Science Direct, PLOS, and Lilac databases with the latest date of search execution in August 2022. The search was limited to English publications from 2000 to 2022. The terms used in the search were ("radix entomolaris" OR "distolingual root" OR "supernumerary root") AND (“endodontics” OR "root canal treatment").

Study selection and data collection

The three stages of screening (title, abstract and full text) were done independently by two of the authors (S.M.K., M.M.). All full articles available through the initial search were analysed and the articles were selected based on the following criteria:

1. Case report or case series;
2. NSRCT conducted on teeth associated with radix entomolaris on MM;
3. Outcome of treatment mentioned with follow-up period.

Disagreements on study inclusion were discussed until consensus was obtained. The reasons for article rejection were recorded (Figure 1).

Data were extracted by both reviewers independently using a customized data collection sheet. The data collection sheet was piloted on several articles and modified accordingly until a final format was agreed upon by the authors. The extracted data were classified into 6 groups: Demographic data of patients, pre-operative factors, diagnostic method to determine presence of RE, treatment protocol, mishap, and outcome (Supplementary Table 1). Any disagreement was discussed, and data were excluded if agreement could not be reached.

Appraisal for included studies

The methodological quality of the included studies was assessed by two authors (S.M.K., M.M.) using the Joanna Briggs Institute (JBI) Critical Appraisal Tools: Checklist for Case Reports (Moola *et al.,* 2020) (Supplementary

Table 2). JBI Critical Appraisal Tool incorporate appraisal of research evidence, to determine the possibility of bias in the research design, conduct, and analysis. Kappa score among the authors showed a high level of agreement on the included studies (κ > 0.90).

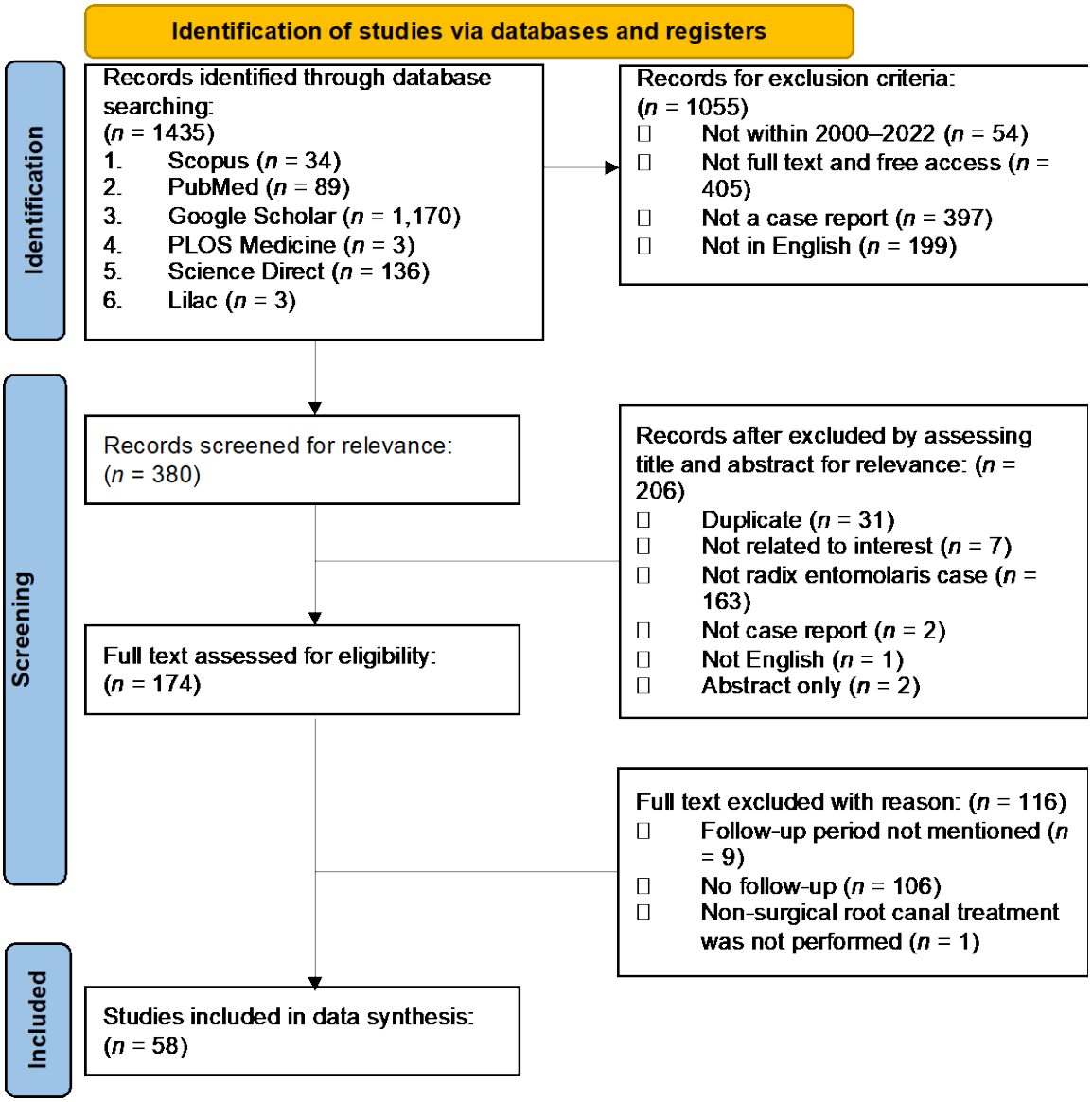

Figure 1. Flow diagram of the study according to PRISMA-ScR protocol guideline.

Results

Search results, study selection, and data extraction

Initially, 1,435 articles with the search terms were identified in the literature search. The studies were then assessed based on the inclusion and exclusion criteria, resulting in 380 potentially eligible studies for inclusion. The titles and the abstracts of the articles were screened to select for the relevant studies to be included in the review, and only 174 articles were eligible. After full-text screening, another 116 articles were excluded because no follow-up period was mentioned or NSRCT was not performed. Hence only 58 articles qualified to be included in the review (Figure 1).

Study characteristics

The 58 articles included were case reports on NSRCT of MM with RE published between 2000 and 2022 with follow-up period between 0.5 to 24 months (SD = 5.73). The case reports detailed 75 treated cases from various countries (Figure 2) on patients with age between 10 and 56 years old (SD = 11.801). The types of RE treated were type I (n = 5), type II (n = 2) and type III (n = 7) based on the classification by De Moor *et al.* (2004). Out of 75 cases, 23 were of tooth that has been endodontically initiated or treated previously and 11 were associated with missed canal. The characteristics of the included studies are reported in Table 1.

Figure 2. Distribution of cases reported based on country.

Diagnosis of radix entomolaris

From the 75 cases, 71 cases investigated the presence of RE (Table 2), where 94.7% of them used intraoral periapical radiograph (IOPA). Some reports supplemented the IOPA with pulpal floor observation using a dental operating microscope (DOM) (14.7%), cone-beam computed tomography (CBCT) (16%), spiral computed tomography (5.3%), or panoramic radiograph (6.7%). Five cases reported on utilising modified IOPA angulation with mesial angulations instead of distal angulations.

Table 1. Characteristics of included case reports (N = 75).

No	Author (date)	Demographic data			Pre-operative factor			Treatment		
		Age, Gender	Race and Country	Medical condition	Tooth	Diagnosis	Findings	Canal preparation method	Obturation method	Post-endodontic restoration
1	Abella *et al.* (2011)	52 F	Caucasian, Spain	Healthy	46	Symptomatic irreversible pulpitis, normal apical tissue	RE type: III Cavity: Class I Pre-op pain: Yes	Isolation: Rubber dam Coronal flare: PTU rotary files Glide path: K-file Canal prep: Mtwo rotary files Irrigation: 4.2% NaOCl Needle: Closed end	Final irrigation: 17% EDTA and 4.2% NaOCl Activated: Passive US Obturation: Thermoplasticised GP Sealer: AH plus	Orifice seal: Flowable resin composite Definitive restoration: Indirect resin composite
2	Agarwal *et al.* (2019) (Case 1)	18 F	Not mentioned, India	Healthy	46	Pulpal necrosis, symptomatic chronic apical periodontitis	Cavity: Class I (grossly decayed) Pre-op pain: Intermittent upon mastication Mobility: No PPD: Normal TTP: Yes	Isolation: Rubber dam Coronal flare: PTU SX rotary file WLD: Apex locator and IOPA Canal prep: PTN rotary files to X2 Irrigation: Normal saline,	Final irrigation: 2% CHX Activated: US Obturation: Cold lateral compaction Sealer: AH Plus	Dressing: IRM Definitive restoration: Plan for crown but patient refused

								3% NaOCl, 17% EDTA Intracanal medicament: CaOH		
3	Arora *et al.* (2018) (Case 1)	27 M	Not mentioned, India	Not mentioned	46	Previously treated, apical periodontitis	Cavity: Class II Pre-op pain: Severe upon eating and drinking	Glide path: K-file 15 WLD: Apex locator and IOPA Canal prep: PTN rotary files Irrigation: 1.3% NaOCl Visit: Single	Final irrigation: 17% EDTA Obturation: Cold lateral condensation	Definitive restoration: Resin composite
4	Attam *et al.* (2012) (Case 2)	22 M	Indian, India	Not mentioned	36	Pulpal necrosis, chronic apical periodontitis	Cavity: Class II (disto-occlusal) TTP: Yes PPD and mobility: Normal	Glide path: K-file 15 WLD: IOPA Canal prep: PTU rotary files Irrigation: 1% NaOCl	Obturation: Single cone Sealer: AH Plus	Definitive restoration: Full metal crown
5	Bains *et al.* (2009)	50 M	Indian, India	Not mentioned	46	Previously treated, apical periodontitis associated with missed canal	Pre-op pain: Spontaneous especially upon mastication Cavity: Amalgam with secondary	Isolation: Rubber dam Previous GP: Removed using H-file 15, 20, 25, 30 and organic solvent Canal prep: PTU files to F2	Obturation: Single cone Sealer: AH Plus	Dressing: IRM Definitive restoration: Amalgam

							caries on distal PPD: Deep at distolingual	Irrigation: 3% NaOCl		
6	Banode *et al.* (2016)	25	Not mentioned, India	Healthy	46	Irreversible pulpitis, symptomatic apical periodontitis	Cavity: Mesio-occlusal deep caries TTP: Yes	Isolation: Rubber dam Coronal flare: PTU SX file Canal prep: K3XF files to 25/04 Irrigation: 5% NaOCl	Obturation: Cold lateral compaction	Definitive restoration: Direct resin composite and crown
7	Bansal *et al.* (2015) (Case 2)	18 M	Not mentioned, India	Not mentioned	46	Pulpal necrosis, symptomatic apical periodontitis	Cavity: Mesio-occlusal caries TTP: Yes Pre-op pain: Yes	Canal prep: PTU rotary files to F3	Obturation: Single cone Sealer: AH Plus	Not mentioned
8	Bhargav *et al.* (2017) (Case 1)	38 F	Not mentioned, India	Healthy	46	Symptomatic irreversible pulpitis, apical periodontitis	RE type: I Cavity: Class I Pre-op pain: Yes	Isolation: Rubber dam Glide path: K-file Canal prep: Mtwo rotary files Irrigation: 5% NaOCl Visit: 2 Intracanal medicament: CaOH	Final irrigation: EDTA and saline Obturation: Cold lateral compaction	Definitive restoration: Direct resin composite

9	Bhargav *et al.* (2017) (Case 2)	38 F	Not mentioned, India	Healthy	36	Irreversible pulpitis, apical periodontitis	RE type: I Cavity: Class I Pre-op pain: No	Isolation: Rubber dam Glide path: K-file Canal Prep: Mtwo rotary files Irrigation: 5% NaOCl Visit: 2	Final irrigation: EDTA and saline Obturation: Cold lateral compaction	Definitive restoration: Direct resin composite
10	Bonaccorso & Tripi (2008)	54 F	Not mentioned, Italy	Healthy	46	Pulp necrosis, normal apical tissue	Cavity: Class II Pre-op pain: No	Isolation: Rubber dam Canal prep: BioRaCe rotary files Irrigation: 5% NaOCl and 15% EDTA Visit: 1	Final irrigation: Saline Obturation: Warm GP Sealer: SybronEndo	Orifice seal: Adhesive pulp canal sealer (Estelite Sigma) Definitive restoration: Metal post and PFM crown
11	Choi *et al.* (2018)	46 M	Korean, Korea	Mental retardation	46	Previously initiated therapy, chronic apical abscess associated with endo-perio lesion and separated instrument	RE type: III Cavity: Class I Pre-op pain: Yes Pre-op PPD: 10 mm	Isolation: Rubber dam Coronal flare: PTU rotary files Canal prep: PTU rotary files Irrigation: 5.25% NaOCl Needle: US irrigation tip Visit: 2	Final irrigation: 5.25% NaOCl and saline Activated: Passive US Obturation: Continuous wave Sealer: AH plus	Definitive restoration: PFM crown

12	Chowdhury & Hassan (2014)	13 M	Not mentioned, India	Not mentioned	36	Symptomatic apical periodontitis	Cavity: Class II Pre-op pain: Yes Pre-op PPD: Normal	Isolation: No Coronal flare: PTU hand files Glide path: K-file Canal prep: PTU hand files Irrigation: 2.5% NaOCl Visit: 1	Activated: No Obturation: GP cone	Definitive restoration: Amalgam
13	De Moor *et al.* (2004) (Case 1)	25 M	Caucasian, Belgium	Not mentioned	46	Symptomatic irreversible pulpitis, symptomatic apical periodontitis	RE type: I Cavity: Class II (large) Pre-op pain: Yes Pre-op PPD: Normal	Isolation: Rubber dam Coronal flare: GG bur Canal prep: Crown-down/step-back using FlexoFile Irrigation: 2.5% NaOCl Visit: 1	Activated: No Obturation: Hybrid GP condensation Sealer: AH26	Definitive restoration: Amalgam
14	De Moor *et al.* (2004) (Case 2A)	19 F	Caucasian, Belgium	Healthy	46	Pulp necrosis, symptomatic apical periodontitis	RE type: II Cavity: Class II (large) Pre-op pain: No Pre-op PPD: Normal	Isolation: Rubber dam Coronal flare: PTU hand files Canal prep: PTU hand files Visit: 2 Intracanal medicament: CaOH (UltraCal)	Activated: No Obturation: Hybrid GP condensation Sealer: AH26	Definitive restoration: Not mentioned (direct composite from radiograph)

15	De Moor *et al.* (2004) (Case 2B)	19 F	Caucasian, Belgium	Healthy	36	Pulp necrosis, symptomatic apical periodontitis	RE type: II Cavity: Class I (large) Pre-op pain: No Pre-op PPD: Normal	Isolation: Rubber dam Coronal flare: PTU hand files Canal prep: PTU hand files Visit: 2 Intracanal medicament: CaOH (UltraCal)	Activated: No Obturation: Hybrid GP condensation Sealer: AH26	Definitive restoration: Not mentioned (direct composite from radiograph)
16	De Moor *et al.* (2004) (Case 3)	25 M	Caucasian, Belgium	Not mentioned	46	Previously treated, acute apical abscess associated with missed canal and short obturation	RE type: III Cavity: PFM crown Pre-op pain: Yes Pre-op PPD: No Pre-op AB and analgesics: Yes	Isolation: Rubber dam Canal prep: ProFile rotary files Irrigation: EDTA and 2.5% NaOCl Intracanal medicament: CaOH	Final irrigation: 2.5% NaOCl Activated: No Obturation: Thermomechanical (hybrid) condensation	Orifice seal: Ketac Fil (GIC) Definitive restoration not mentioned
17	De Moor *et al.* (2004) (Case 4)	46 F	Caucasian, Belgium	Not mentioned	46	Pulp necrosis, chronic apical abscess	RE type: III Cavity: PFM crown Pre-op pain: No Pre-op PPD: Pre-op sinus and localised swelling	Isolation: Rubber dam Glide path: FlexoFile Canal prep: ProFile rotary files Irrigation: 2.5% NaOCl, EDTA Visit: 2	Activated: No Obturation: Thermomechanical (hybrid) condensation	Orifice seal: Ketac Fil (GIC) Definitive restoration not mentioned

								Intracanal medicament: CaOH (UltraCal)		
18	de Souza *et al.* (2017)	15 M	Not mentioned, Brazil	Healthy	46	Previously initiated therapy, symptomatic apical periodontitis	Cavity: Class II (radicular extension) Pre-op pain: Yes Pre-op PPD: normal	Isolation: Rubber dam Coronal flare: WaveOne files Glide path: K-file 10, 15 Canal prep: WaveOne files Irrigation: 2.5% NaOCl Visit: 1	Final irrigation: 17% EDTA Activated: No Obturation: Single cone thermoplastic obturation Sealer: Zinc oxide sealer (Vidrion R)	Orifice sealer: GIC Definitive restoration: Direct composite
19	Garg *et al.* (2011)	22 F	Indian, India	Healthy	47	Pulp necrosis, acute apical periodontitis	Cavity: Grossly decayed (Class I) Pre-op pain: Yes Pre-op PPD: Normal	Isolation: Rubber dam Coronal flare: PTU rotary files Glide path: K-file 15 Canal prep: PTU rotary files Irrigation: 2.5% NaOCl Visit: 2	Activated: No Obturation: GP cone Sealer: AH plus	Orifice sealer: Ketac Fil GIC Definitive restoration: Amalgam and crown
20	Gonapa *et al.* (2022)	24 M	Not mentioned, India	Not mentioned	48	Previously initiated therapy, chronic apical abscess	Cavity: Class I Pre-op pain: No	Glide path: K-file 15 Canal prep: PTU rotary files until F3	Final irrigation: 17% EDTA Obturation: Single cone	Orifice sealer: Not mentioned Definitive restoration: Direct

								for MB, ML, F5 for DB Irrigation: 3% NaOCl Visit: Multiple Intracanal medicament: CaOH	Sealer: Bioceramic sealer (MTA EndoSeal)	composite and PFM crown
21	Gupta *et al*. (2014)	16 M	Indian, India	Healthy	46	Pulp necrosis, symptomatic apical periodontitis	Cavity: Class I Pre-op pain: Sharp pain on chewing	Isolation: Rubber dam Coronal flare: PTU rotary files Canal prep: PTU rotary files	Not mentioned	Not mentioned
22	Khirtika & Ramesh (2017) (Case 1)	23 M	Not mentioned, India	Not mentioned	46	Not mentioned	Pre-op pain: Yes	Glide path: K-file 10 WLD: Apex locator Canal prep: PRU rotary files Irrigation: NaOCl and saline	Obturation: Cold lateral compaction	Definitive restoration: Resin composite
23	Kimura & Matsumoto (2000)	31 F	Not mentioned, Japan	Not mentioned	46	Previously initiated therapy, asymptomatic apical periodontitis associated with missed canal	Pre-op pain: No TTP: No	Isolation: Rubber dam with disinfection of crown with iodine and alcohol	Obturation: Cold lateral compaction Sealer: Canals N	Not mentioned

								Coronal flare: Peeso reamer WLD: Apex locator Canal prep: Files and reamers Irrigation: 5% NaOCl and 3% hydrogen peroxide Intracanal medicament: CaOH		
24	Kohli *et al*. (2019)	22 M	Not mentioned, India	Not mentioned	46	Pulpal necrosis, symptomatic apical periodontitis	Cavity: Deep caries TTP: Yes	Isolation: Rubber dam WLD: Apex locator Canal prep: PTN rotary files to X2 Irrigation: 3% NaOCl and 17% EDTA Intracanal medicament: CaOH	Obturation: Single cone	Definitive restoration: Direct composite
25	Kusumo *et al*. (2019)	21 M	Not mentioned, Indonesia	Healthy	36	Previously initiated therapy, normal apical tissue	Cavity: Disto-Occlusal Pre-Op Pain: Yes TTP: No	Isolation: Rubber dam Coronal flare: One Flare rotary file	Final irrigation: 2% CHX Obturation: Single cone Sealer: AH Plus	Definitive restoration: Indirect composite onlay

									Glide path: K-file 10, One G rotary file WLD: Apex locator and IOPA Canal prep: One Curve rotary file Irrigation: 3% NaCOl, 17% EDTA, 2% CHX Intracanal medicament: CaOH		
26	Law & Beaumont (2004) (Case 1)		16 M	Caucasian, USA	Healthy	46	Irreversible pulpitis, asymptomatic apical periodontitis associated with perio-endo lesion	Cavity: Occlusal amalgam and sealant Pre-op pain: Yes Pre-op swelling and sinus tract: No TTP: No Pre-op PPD: 5 mm on distal Mobility: Class I	Visit: Single	Not mentioned	Definitive restoration: Amalgam
27	Law & Beaumont (2004) (Case 2)		16 M	Caucasian, USA	Healthy	46	Irreversible pulpitis, asymptomatic apical	Cavity: Occlusal sealant	Visit: Single	Not mentioned	Definitive restoration: Amalgam followed by

						periodontitis. Associated with perio-endo lesion	Pre-op pain: Yes Pre-op swelling and sinus tract: no TTP: No Pre-op PPD: 14mm on distal with Class II furcation involvement Mobility: Class I			periodontal surgery
28	López-Rosales *et al*. (2015)	45 M	White, Spain	Not mentioned	37	Pulp necrosis, symptomatic apical periodontitis	RE type: AC type III Cavity: Class II (MO) Pre-op pain: Intermittent acute spontaneous pain	Isolation: Rubber dam Coronal flare: PTU rotary files Glide path: k-file 10, PathFile Canal prep: PTU rotary files Irrigation: 5.25% NaOCl Needle: Gauge 30 Visit: Single	Final irrigation: NaOCl and 17% EDTA Activated: US Obturation: Carrier based GP Sealer: pulp canal sealer (Sybron Endo)	Orifice sealer: Flowable composite. Definitive restoration not mentioned
29	Mangal *et al*. (2016)	28 F	Not mentioned, India	Healthy	46	Previously treated, symptomatic apical	TTP: Yes Pre-op pain: Spontaneous	GP removal: H-file and GP solvent, separated	Final irrigation: 2% CHX Obturation: Single cone	Dressing: Zinc oxide eugenol cement

						periodontitis associated with separated instrument at mesial root canal		instrument not removed WLD: Apex locator Canal prep: Mtwo rotary files to 25/06 Irrigation: 3% NaOCl, 0.9% saline Intracanal medicament: CaOH	Sealer: AH Plus	
30	Martins *et al*. (2014)	33 F	Caucasian, Portugal	Healthy	37	Irreversible pulpitis, normal apical tissue	Pre-Op Pain: Spontaneous TTP: No	Isolation: Rubber dam WLD: Apex locator Canal prep: PTU rotary files Irrigation: 5.25% NaOCl Intracanal medicament: CaOH	Final irrigation: 17% EDTA and 5.25% NaOCl Obturation: Single cone Sealer: AH Plus	Dressing: Cavit
31	Marya *et al*. (2014) (Case 1)	42 M	Not mentioned	Healthy	36	Irreversible pulpitis, symptomatic apical periodontitis	Pre-op pain: Yes TTP: Yes Cavity: Temporary restoration disto-oclussal	Isolation: Rubber dam WLD: Apex locator and IOPA Canal prep: PTU hand files to F2	Obturation: Cold lateral compaction Sealer: AH Plus	Not mentioned, post-obturation radiograph suggests amalgam restoration

								Irrigation: 2.5% NaOCl		
32	Marya *et al*. (2014) (Case 2)	15 M	Not mentioned	Not mentioned	36	Irreversible pulpitis, symptomatic apical periodontitis	Pre-op pain: Yes Cavity: Large occlusal restoration TTP: Yes	Isolation: Rubber dam Glide path: K-file 15 WLD: Apex locator and IOPA Canal prep: PTU hand files to F2 Irrigation: 2.5% NaOCl, saline	Obturation: Single cone Sealer: AH Plus	Not mentioned, post-obturation radiograph suggests amalgam restoration
33	Meidyawati & Suprastiwi (2016)	39 F	Not mentioned, Indonesia	Not mentioned	36	Symptomatic apical periodontitis	Pre-op pain: Upon chewing TTP: Yes Cavity: Disto-oclussal	Glide path: K-file 15 WLD: Apex locator and IOPA Canal prep: PTN rotary files to X2 Intracanal medicament: CaOH	Obturation: Warm vertical compaction Sealer: AH Plus	Definitive restoration: Indirect composite onlay
34	Mirikar *et al*. (2009)	16 M	Not mentioned, India	Not mentioned	36	Previously initiated therapy, apical periodontitis associated with furcal perforation	PPD: Normal	Perforation repair: Disinfected with 2.5% NaOCl, dried and repaired with MTA	Obturation: Cold lateral compaction Sealer: AH Plus	Definitive restoration: Composite

								Coronal flare: PTU files Glide path: K-file 10, 15, 20 WLD: Apex locator and IOPA Irrigation: 2.5% NaOCl		
35	Mirza *et al*. (2018)	22 F	Not mentioned, Pakistan	Not mentioned	36	Endo-perio lesion	Cavity: Class 1 Pre-op pain: No Pre-op PPD: 5 mm at mesial and distal	Canal prep: PTU rotary files Irrigation: Normal saline Visit: Multiple Intracanal medicament: CaOH	Final irrigation: 0.12% CHX Obturation: GP point	Orifice sealer: Composite Definitive restoration: PFM crown
36	Mittal & Narang (2012)	21 M	Not mentioned, India	Healthy	36	Irreversible pulpitis, symptomatic apical periodontitis	Pre-op pain: Yes Cavity: Distal caries Pre-op swelling: No Mobility: No PPD: Normal TTP: Yes	Isolation: Rubber dam Coronal flare: PTU SX rotary file WLD: Apex locator and IOPA Canal prep: PTU rotary files Irrigation: 5.25% NaOCl, 17% EDTA	Final irrigation: Saline, 2% CHX Obturation: Single cone Sealer: AH 26	Definitive restoration: Composite

								Intracanal medicament: CaOH		
37	Mohamed Khazin & Mustaffa (2022)	36 M	Malay, Malaysia	Healthy	46	Asymptomatic irreversible pulpitis with asymptomatic apical periodontitis	Cavity: Class II (MOB) Pre-op pain: No	Isolation: Rubber dam Glide path: K-file 8, 10, and 15, followed by rotary PathFile 013, 016, 019. Canal prep: PTN rotary files to size X2 Irrigation: 3% NaOCl, agitation with EndoActivator	Final irrigation: 17% EDTA and 0.2% CHX Activated: EndoActivator Obturation: Warm vertical compaction (thermoplasticised GP) Sealer: AH Plus	Definitive restoration: PFM crown
38	Nagaveni *et al*. (2015) (Case 1A)	14 M	Not mentioned, India	Not mentioned	36	Chronic apical abscess	Cavity: Disto-occlusal	Glide path: K-file 10 Irrigation: 2.5% NaOCl, saline Intracanal medicament: CaOH	Obturation: Lateral compaction Sealer: AH 26	Definitive restoration: Metal post followed by stainless-steel crown
39	Nagaveni *et al*. (2015) (Case 1B)	14 M	Not mentioned, India	Not mentioned	46	Reversible pulpitis	Cavity: Disto-occlusal	Glide path: K-file 10 Irrigation: 2.5% NaOCl, saline Intracanal medicament: CaOH	Obturation: Lateral compaction Sealer: AH 26	Definitive restoration: Metal post followed by stainless-steel crown

40	Nagaveni *et al*. (2015) (Case 2)	15 F	Not mentioned, India	Not mentioned	46	Apical periodontitis	Cavity: Disto-occlusal deep caries	Canal prep: Stepback Irrigation: 2.5% NaOCl, saline Intracanal medicament: CaOH	Obturation: Cold lateral compaction Sealer: AH 26	Definitive restoration: Metal crown
41	Nagaveni *et al*. (2015) (Case 3)	10 M	Not mentioned, India	Not mentioned	36	Apical periodontitis	Cavity: Occlusal deep caries	Canal prep: Stepback Irrigation: 2.5% NaOCl, saline Intracanal medicament: CaOH	Obturation: Cold lateral compaction Sealer: AH 26	Definitive restoration: Stainless-steel crown
42	Nahar (2019) (Case 1)	20 F	Not mentioned, India	Not mentioned		Apical periodontitis	Pre-op pain: Yes	Isolation: Rubber dam Disinfection: Hypo 5% (sodium thiosulphate) Glide path: K-file 10 WLD: Apex locator and IOPA Canal prep: HyFlex CM rotary files to 30/04 Irrigation: 20 mL (type not mentioned)	Obturation: Cold lateral compaction	Definitive restoration: Composite

43	Nahar (2019) (Case 2)	25 F	Not mentioned, India	Not mentioned	46	Irreversible pulpitis	Pre-op pain: Yes	Isolation: Rubber dam Disinfection: Hypo 5% (sodium thiosulphate) Glide path: K-file 10 WLD: Apex locator and IOPA Canal prep: HyFlex CM rotary files to 30/04 Irrigation: 20 mL (type not mentioned)	Obturation: Cold lateral compaction	Definitive restoration: Composite
44	Naidu *et al*. (2013)	25 M	Not mentioned, India	Not mentioned	36	Apical periodontitis	Pre-op pain: Yes Cavity: Disto-occlusal	Isolation: Rubber dam WLD: IOPA Canal prep: PTU rotary files Irrigation: NaOCl Intracanal medicament: formocresol		Definitive restoration: PFM crown
45	Oberländer (2012) (Case A)	19 F	Not mentioned, Germany	Healthy	36	Previously treated, symptomatic apical periodontitis	Pre-op pain: Yes TTP: Yes PPD: 10 mm midbuccal	Isolation: Rubber dam GP removal: PTU revision rotary files	Final irrigation: 5% NaOCl, 70% ethanol, 17% EDTA, 70% ethanol	Definitive restoration: Composite

						associated with separated instrument, short obturation, and missed canal.		Separated instrument removal: US tips WLD: Apex locator Canal prep: PTU rotary files to F3 Irrigation: 5% NaOCl, alcohol, 2% CHX Intracanal medicament: CaOH Visit: 3	Obturation: Warm vertical compaction	
46	Oberländer (2012) (Case B)	19 F	Not mentioned, Germany	Healthy	46	Previously treated, symptomatic apical periodontitis associated with short obturation and missed canal.	Pre-op pain: Yes TTP: Yes	Isolation: Rubber dam GP removal: PTU revision rotary files Separated instrument removal: US tips WLD: Apex locator Canal prep: PTU rotary files to F3 Irrigation: 5% NaOCl, alcohol, 2% CHX	Final irrigation: 5% NaOCl, 70% ethanol, 17% EDTA, 70% ethanol Obturation: Warm vertical compaction	Definitive restoration: Composite

47	Pandey *et al*. (2018)	50 F	Not mentioned, India	Healthy	36	Symptomatic irreversible pulpitis, symptomatic apical periodontitis	Pre-Op Pain: Yes TTP: Yes Cavity: Deep Caries	Isolation: Rubber dam Glide path: K-file 10 WLD: Apex locator and IOPA Canal prep: HyFlex CM rotary files to 30/04 Irrigation: 3% NaOCl Intracanal medicament: CaOH	Obturation: Single cone Sealer: AH Plus	Definitive restoration: Crown
48	Parsa & Rapala (2016)	13 M	Not mentioned, India	Healthy	36	Pulp necrosis, chronic apical periodontitis	Cavity: occlusal caries Pre-op pain: Yes	Isolation: Rubber dam Coronal flare: PTU hand files Glide path: K-file 10 Canal prep: PTU hand files Irrigation: 2.5% sodium hypochlorite	Obturation: Single cone	Definitive restoration: GIC and stainless-steel crown
49	Patil *et al*. (2013)	21 M	Not mentioned, India	Not mentioned	36	Chronic irreversible pulpitis with apical periodontitis	Cavity: Class I (deep occlusal caries) Pre-op pain: Yes	Isolation: Rubber dam Coronal flare: PTU rotary files	Obturation: Single cone Sealer: AH Plus	Definitive restoration: Steel crown

							Canal prep: PTU rotary files Irrigation: 3% NaOCl and normal saline		
50	Petrova *et al*. (2020)	28 M	European, Bulgaria	Healthy	36	Previously treated. Associated with missed canal and separated instrument.	Cavity: Class I (deep occlusal caries) Pre-op pain: Yes	Isolation: Rubber dam Coronal flare: PTU rotary files Glide path: S1 PTU rotary file Canal prep: The MB, ML, and DL root canals were instrumented using WaveOne Gold Primary rotary files and WaveOne Gold Medium rotary file was used for the DB canal. Irrigation: 5.25% NaOCl, 17% EDTA and normal saline	Activated: US and Endo Activator were used in each root canal for 60 seconds each Obturation: Single cone Sealer: Eugenol-based	Definitive restoration: Flowable resin composite
51	Pires & Martins (2019) (Case 1)	34 F	European, Portugal	Healthy	46	Previously treated, symptomatic	Cavity: Large and deep restoration	Isolation: Rubber dam	Obturation: Single cone	Not mentioned – possibly

					apical periodontitis associated with missed canal	Pre-op pain: Yes	Coronal flare: PTU rotary files Canal prep: until F2 PTU rotary file Intracanal medicament: CaOH		crown based on follow up radiograph
52	Qureshi *et al*. (2017) (Case A)	24 F	Indian, India	Healthy	46	Previously initiated therapy, symptomatic apical periodontitis	RE type: Type I Pre-op pain: Yes TTP: yes Cavity: Temporary restoration disto-occlusal	Isolation: Rubber dam Canal prep: PTU files and K-file WLD: apex locator and IOPA Irrigation: 2.5% NaOCl, 17% EDTA Intracanal medicament: CaOH	Obturation: Single cone cold condensation Sealer: AH Plus	Definitive restoration: Composite
53	Qureshi *et al*. (2017) (Case B)	24 F	Indian, India	Healthy	47	Irreversible pulpitis, symptomatic apical periodontitis	RE type: Type I Pre-op pain: Yes TTP: Yes Cavity: Deep caries	Isolation: Rubber dam Canal prep: PTU files and K-file WLD: Apex locator and IOPA Irrigation: 2.5% NaOCl, 17% EDTA	Obturation: Single cone cold condensation Sealer: AH Plus	Definitive restoration: Composite

								Intracanal medicament: CaOH		
54	Schumacher (2008)	17 F	Western European, Germany	Healthy	46	Pulpal necrosis, symptomatic apical periodontitis	Pre-op pain: Yes Mobility: Yes TTP: Yes Pre-op swelling and sinus tract: No PPD: 6 mm lingual Cavity: Deep restoration	Isolation: Rubber dam WLD: Apex locator, IOPA Canal prep: K-FlexoFile and H-file with balanced fore and circumferential filling to ISO 45 Irrigation: 2.5% NaOCl Intracanal medicament: CaOH	Final irrigation: NaOCl. EDTA, 2% CHX Activated: Passive US Obturation: Lateral compaction Sealer: AH Plus	Definitive restoration: Composite
55	Segura-Egea *et al*. (2002)	24 F	Caucasian, Spain	Not mentioned	46	Previously treated, associated with missed canal	Cavity: Disto-occlusal amalgam restoration, mesio-occlusal resin composite restoration Pre-op pain: Yes	Coronal flare: GG burs size 3 and 4 Canal prep: GP was removed with a heated plugger, Hedstrom files and chloroform. Canal preparation with K-FlexoFile	Obturation: Cold lateral compaction Sealer: AH Plus	Definitive restoration: Not mentioned, no crown at follow-up visit seen via radiograph

							Irrigation: 5% NaOCl and EDTA		
56	Shahbaz *et al*. (2022)	15 M	Not mentioned, India	Not mentioned	36	Pulpal necrosis, symptomatic apical periodontitis	Cavity: Caries not mentioned specifically Pre-op pain: Yes	Coronal flare: PTG rotary files Glide path: K-file 10 Canal prep: GP was removed with a heated plugger, Hedstrom files and chloroform. Canal preparation with K-FlexoFile Irrigation: 2.5% NaOCl and 17% EDTA Intracanal medicament: CaOH	Obturation: Single cone Sealer: AH Plus	Definitive restoration: Porcelain jacket crown
57	Sinha & Sinha (2014) (Case 1)	24 M	Not mentioned, India	Not mentioned	46	Apical periodontitis	Pre-op pain: Yes Cavity: Deep caries Class II	Isolation: Rubber dam Glide path: K-file 15 WLD: Apex locator and IOPA Canal prep: PTU rotary files to F2	Obturation: Single cone Sealer: AH Plus	Definitive restoration: Amalgam

								Irrigation: 5.25% NaOCl, 17% EDTA		
58	Sinha *et al*. (2016) (Case 2)	32 F	Not mentioned, India	Not mentioned	46	Previously initiated therapy, apical periodontitis associated with missed canal	Pre-op pain: Yes Cavity: Distal caries Mobility: No PPD: Normal	Isolation: Rubber dam Glide path: K-file 10 WLD: Apex locator, IOPA Canal prep: PTU rotary files to F2 Irrigation: 5.25% NaOCl	Obturation: Single cone Sealer: AH Plus	Definitive restoration: Amalgam
59	Srinivasan *et al*. (2015)	15 F	Not mentioned, India	Not mentioned	46	Previously initiated therapy, apical periodontitis associated with perforation	Cavity: Class I with orthodontic molar band	Isolation: Rubber dam Coronal flare: S1, S2 PTU rotary files Perforation repair: MTA white WLD: Apex locator, IOPA Canal prep: Mtwo rotary files to 25/06 Irrigation: 2.5% NaOCl, saline	Obturation: Single cone Sealer: AH Plus	Definitive restoration: Resin-modified GIC
60	Štamfelj (2014)	14 M	Caucasian, Slovenia	Asthma, on oral antihistamine, inhaled	36	Previously initiated therapy, asymptomatic	RE type: III Cavity: Mesio-occlusal	Isolation: Rubber dam	Activated: US Obturation: Single cone Sealer: AH Plus	Definitive restoration: Resin composite

				corticosteroid and short-acting beta2-agonist		apical periodontitis associated with sclerosed RE	temporary restoration Pre-op pain: No	Coronal flare: SX PTU rotary file Canal prep: PTU rotary files Irrigation: US irrigated 20% disodium edetate and 2.5% NaOCl used in an alternating manner Intracanal medicament: CaOH		
61	Štamfelj *et al*. (2016)	47 F	Caucasian, Slovenia	Healthy	36	Previously treated, asymptomatic apical periodontitis associated with short obturation	Pre-op pain: Yes Cavity: Mesio-distal occlusal composite TTP: No PPD: Normal Pre-op swelling: Yes	Isolation: Rubber dam GP removal: Eucalyptus oil Glide path: K-file Coronal flare: SX PTU file WLD: Apex locator Canal prep: K-file hand files Irrigation: 2.5% NaOCl Intracanal medicament: CaOH	Obturation: Cold lateral condensation Sealer: AH Plus	Definitive restoration: Composite

62	Subramaniam Ramachandran *et al*. (2019)	35 M	Indian, India	Healthy	36	Previously initiated therapy, symptomatic apical periodontitis	Pre-op pain: Yes TTP: Yes	Isolation: Rubber dam Coronal flare: PTG SX rotary file WLD: Apex locator and IOPA Canal prep: PTG rotary files Irrigation: 5.25% NaOCl, 17% EDTA Intracanal medicament: CaOH	Final irrigation: NaOCl Obturation: Warm vertical compaction Sealer: Calcium hydroxide sealer (Sealapex)	Definitive restoration: Composite
63	Tian *et al*. (2015)	23 F	Chinese, China	Healthy	47	Pulp necrosis, apical periodontitis	Pre-op swelling: Extraoral sinus Cavity: GIC Disto-occlusal buccal TTP: No Mobility: Grade I PPD: Normal RE type: III	Isolation: Rubber dam Needle: 27G Irrigation: 3% perhydrol, 17% EDTA, 2.5% NaOCl Intracanal medicament: CaOH WLD: Apex locator, IOPA Canal prep: TF and Mtwo rotary files to 25/08 Visit: Multiple	Obturation: Continuous wave Sealer: AH Plus	Not mentioned

64	Tsujimoto (2021)	40 M	Japanese, Japan	Not mentioned	36	Irreversible pulpitis	Pre-op pain: Yes PPD: Normal	Isolation: Rubber dam Coronal flare: SX PTG and US diamond file Negotiation: D-finder files WLD: Apex locator Canal prep: PTG files Visit: Single	Obturation: Thermoplasticised GP	Definitive restoration: Metal crown
65	Turki (2019)	20 F	Not mentioned, Saudi Arabia	Not mentioned	46	Previously initiated therapy, symptomatic apical periodontitis associated with missed canal.	Cavity: temporary restoration Pre-op pain: no	Isolation: Rubber dam Coronal flare: GG burs Canal prep: Crown-down using GG burs and K3 Endo rotary files Irrigation: 2.5% NaOCl Intra-canal medicament: CaOH	Obturation: Cold lateral compaction Sealer: AH26	Definitive restoration: Full coverage crown but not mentioned specifically
66	Vanti *et al.* (2019) (Case A)	35 F	Not mentioned, India	Not mentioned	46	Not mentioned	Pre-op pain: Yes	Isolation: Rubber dam WLD: IOPA Canal prep: PTU rotary files Irrigation: NaOCl, saline	Final irrigation: 2% CHX Obturation: Cold lateral compaction	Definitive restoration: Composite

67	Vanti *et al.* (2019) (Case B)	35 F	Not mentioned, India	Not mentioned	36	Not mentioned	Pre-op pain: Yes	Isolation: Rubber dam WLD: IOPA Canal prep: PTU rotary files Irrigation: NaOCl, saline	Final irrigation: 2% CHX Obturation: Cold lateral compaction	Definitive restoration: Composite
68	Verma (2009)	50 F	Asian, Not mentioned	Not mentioned	36	Previously initiated associated with missed canal.	Cavity: Amalgam restoration Pre-op pain: Yes	Isolation: Rubber dam Coronal flare: ProFile rotary files Canal prep: ProFile rotary files Irrigation: 2.5% NaOCl Intracanal medicament: CaOH	Obturation: Single cone Sealer: AH Plus	Definitive restoration: Full coverage crown but not mentioned specifically
69	Vijay *et al.* (2011)	25 M	Not mentioned, India	Not mentioned	37	Irreversible pulpitis, symptomatic apical periodontitis	Pre-op pain: Yes Cavity: Large occlusobuccal TTP: Yes	Isolation: Rubber dam Coronal flare: Fissure bur WLD: Apex locator and IOPA Canal prep: PTU rotary files to F2 Irrigation: 5.25% NaOCl, saline	Final irrigation: Saline Obturation: Single cone Sealer: AH Plus	Definitive restoration: Plan for crown

								Visit: 3		
70	Vinay Kumar & Shaktidar (2014) (Case A)	12 F	Indian, India	Healthy	46	Pulpal necrosis, symptomatic apical periodontitis	Cavity: Deep caries Pre-op pain: Yes TTP: Yes Pre-op swelling and sinus tract: No	Isolation: Not done Coronal flare: GG burs Glide path: K-file 10 Canal prep: PTU rotary files to F2 Irrigation: 1% NaOCl and saline Intracanal medicament: CaOH	Obturation: Single cone Sealer: Zinc oxide eugenol sealer	Definitive restoration: GIC and stainless-steel crown
71	Vinay Kumar & Shaktidar (2014) (Case B)	12 F	Indian, India	Healthy	36	Pulpal necrosis, symptomatic apical periodontitis	Cavity: Deep caries Pre-op pain: Yes TTP: Yes Pre-op swelling and sinus tract: No	Isolation: Not done Coronal flare: GG burs Glide path: K-file 10 Canal prep: PTU rotary files to F2 Irrigation: 1% NaOCl and saline Intracanal medicament: CaOH	Obturation: Single cone Sealer: Zinc oxide eugenol sealer	Definitive restoration: GIC and stainless-steel crown
72	Vivekananda *et al.* (2014) (Case 2)	56 F	Not mentioned, India	Not mentioned	36	Pulp necrosis with chronic	Cavity: Class I (deep	Isolation: Rubber dam	Final irrigation: 17% EDTA	Definitive restoration: Amalgam

						apical periodontitis	occlusal caries) Pre-op pain: Yes	Coronal flare: PTU rotary files Glide path: K-file 8, 10 Canal prep: PTU rotary files Irrigation: 2.5% NaOCl Intracanal medicament: CaOH	Obturation: Single cone Sealer: AH26	
73	Vivekananda *et al.* (2014) (Case 3)	35 M	Not mentioned, India	Not mentioned	46	Symptomatic irreversible pulpitis	Cavity: Class II (deep distal caries) Pre-op pain: Yes	Isolation: Rubber dam Coronal flare: PTU rotary files Glide path: K-file 8, 10 Canal prep: PTU rotary files Irrigation: 2.5% NaOCl Intracanal medicament: CaOH	Final irrigation: 17% EDTA Obturation: Single cone Sealer: AH26	Definitive restoration: Amalgam
74	Vivekananda *et al.* (2014) (Case 4)	28 F	Not mentioned, India	Not mentioned	46	Acute irreversible pulpitis	Cavity: Class I (deep mesio-lingual caries) Pre-op pain: Yes	Isolation: Rubber dam Coronal flare: PTU rotary files	Final irrigation: 17% EDTA Obturation: Single cone Sealer: AH26	Definitive restoration: Amalgam

							Glide path: K-file 8, 10 Canal prep: Rotary NiTi files (specific system not mentioned) Irrigation: 2.5% NaOCl		
75	Yadav *et al*. (2016)	35 M	Not mentioned, India	Healthy	46	Symptomatic irreversible pulpitis, apical periodontitis	Cavity: Distal caries Pre-op pain: Yes	Isolation: Rubber dam Coronal flare: PTU rotary files Canal prep: PTU rotary files Irrigation: 5% NaOCl and 17% EDTA Intracanal medicament: CaOH	Final irrigation: 5% NaOCl, 17% EDTA and normal saline Obturation: Single cone Sealer: AH Plus	Definitive restoration: Fibre-reinforced composite, gingivectomy and crown lengthening surgery, and restored with metal onlay

CaOH: calcium hydroxide, CHX: chlorhexidine, DB: distobuccal, DL: distolingual, EDTA: ethylenediaminetetraacetic acid, F: female, GG: Gates Glidden, GIC: glass ionomer cement, GP: gutta percha, IOPA: intraoral periapical radiograph, IRM: Intermediate restorative material, M: male, MB: mesiobuccal, ML: mesiolingual, NaOCl: sodium hypochlorite, NiTi: nickel–titanium, PFM: porcelain fused to metal, PPD: periodontal probing depth, PTG: ProTaper Gold, PTN: ProTaper Next, PTU: ProTaper Universal, RE: radix entomolaris, TTP: tender to percussion, US: ultrasonic, WLD: working length determination

Table 2. Pre-operative investigation to identify radix entomolaris.

Type of investigation	Author	Type of investigation	Author
Single parallel IOPA	Abella *et al*. (2011) Attam *et al.* (2012) Banode *et al.* (2016) Bansal *et al.* (2015) Bhargav *et al.* (2017) Bonaccorso & Tripi (2008) Choi *et al.* (2018) De Moor *et al.* (2004) Gonapa *et al*. (2022) Kimura & Matsumoto (2000) Law & Beaumont (2004) López-Rosales *et al*. (2015) Mangal *et al*. (2016) Meidyawati & Suprastiwi (2016) Mirikar *et al*. (2009) Mohamed Khazin & Mustaffa (2022) Nagaveni *et al*. (2015) Naidu *et al*. (2013) Oberländer (2012) Pandey *et al*. (2018) Parsa & Rapala (2016) Patil *et al*. (2013) Petrova *et al*. (2020) Pires & Martins (2019) Qureshi *et al*. (2017) Segura-Egea *et al*. (2002) Shahbaz *et al.* (2022) Sinha & Sinha (2014) Sinha *et al*. (2016) Srinivasan *et al*. (2015) Štamfelj (2014) Štamfelj *et al*. (2016) Subramaniam Ramachandran *et al*. (2019) Tian *et al*. (2015) Tsujimoto (2021) Turki (2019) Verma (2009) Vijay *et al*. (2011) Vinay Kumar & Shaktidar (2014) Vivekananda Pai *et al*. (2014) Yadav *et al*. (2016)	**Single angulated IOPA**	
		Mesial angulation	Chowdhury & Hassan (2014) De Moor *et al.* (2004) Gupta *et al*. (2014) Marya *et al*. (2014) Mirza *et al*. (2018)
		Direction not mentioned	Garg *et al*. (2011)
		Multiple angulated IOPA	
		Mesial and distal angulation	Agarwal *et al.* (2019) Arora *et al.* (2018) Marya *et al.* (2014) Mittal & Narang (2012) Vanti *et al.* (2019) Vinay Kumar & Shaktidar (2014)
		Direction not mentioned	Bains *et al.* (2009) De Moor *et al.* (2004) Khirtika & Ramesh (2017) Kohli *et al*. (2019) Nahar (2019) Schumacher (2008)
		Cone-beam computed tomography	Abella *et al*. (2011) Banode *et al.* (2016) Choi *et al.* (2018) Gonapa *et al*. (2022) López-Rosales *et al*. (2015) Mangal *et al*. (2016) Martins *et al*. (2014) Pandey *et al*. (2018) Qureshi *et al*. (2017) Tian *et al*. (2015) Tsujimoto (2021)
Panoramic radiograph	López-Rosales *et al*. (2015) Tsujimoto (2021)	**Spiral computed topography**	Bhargav *et al.* (2017) Garg *et al*. (2011) Mittal & Narang (2012) Shahbaz *et al.* (2022)

IOPA: intraoral periapical radiograph

Modification of access cavity

From the 75 cases, 59 cases reported modification made to the access cavity (Table 3), in which the access cavity was enlarged towards the distolingual side using either ultrasonic tips or burs and a trapezoidal access cavity was created instead of rectangular or triangular shape. Some reports mentioned modification of the access cavity, but the details were not specified. Six cases reported on using either DG-16, micro-opener, or endodontic explorer to locate the orifice of RE canal, and 2 cases reported on using the map of the chamber floor to guide in locating the orifice.

Preparation and obturation of RE

Only 33 cases mentioned the glide path preparation (Table 1), and majority of cases used small sized K-files. A small number of cases reported using FlexoFile (1.3%), a combination of K-files with PathFile (1.3%), S1 ProTaper Universal (1.3%), and One G rotary file (1.3%).

Seventy cases reported the preparation technique used on the RE (Table 4). Only 4 cases reported using a different technique when preparing RE compared to other canals. Two cases used engine-driven files on other canals, but used manual hand files on RE, while 1 case did the opposite. Another case used a different type of engine-driven files on RE.

Only 26 out of 75 cases reported the final apical size prepared. Majority reported an apical size of #25 (22.7%), followed by #30 (10.7%) and #20 (1.3%) (Table 5).

Seventy cases reported on the obturation technique used on RE (Table 2). Majority used single cone technique (44%) followed by cold lateral compaction technique (29.3%), warm vertical compaction technique (5.3%), continuous wave technique (2.7%) and carrier-based gutta percha (2.7%).

Endodontic mishap related to radix entomolaris

The pooled incidence of endodontic mishap on RE was 12% with the highest incidence being separated instrument (4%), followed by ledge (2.7%), extruded sealer (2.7%), and missed canal (2.7%). The management and outcome of the mishaps are summarised in Table 6. Furthermore, among the cases that were previously endodontically initiated or treated, 11 of them were referred for further intervention due to missed RE (14.7%).

Outcome

The success rate for NSRCT on MM associated with RE was 58.7% (44 out of 75 cases) at an average follow-up period of 8.4 months. The success criteria were determined clinically (no signs and symptoms) and radiographically (no periapical lesion or a periapical index of 2 or less). Seventeen cases were categorised as healing (22.7%) as there was presence of periapical lesion but clinically asymptomatic. Another 13 cases were asymptomatic at follow-up; however, no radiographical description was given to rule out residual periapical lesion, hence healing and asymptomatic cases were pooled together to be considered as survived at the rate of 40%. One case was categorised as failed (1.3%) due to the presence of clinical symptoms (Table 7).

Table 3. Access cavity modification.

Modification	Author	Modification	Author
Extension of access cavity		**Extension of access cavity**	
Trapezoidal	Arora *et al.* (2018) Choi *et al.* (2018) De Moor *et al.* (2004) Garg *et al.* (2011) Gupta *et al.* (2014) Khirtika & Ramesh (2017) Marya *et al.* (2014) Meidyawati & Suprastiwi (2016) Nagaveni *et al.* (2015) Nahar (2019) Parsa & Rapala (2016) Schumacher (2008) Sinha & Sinha (2014) Sinha *et al.* (2016) Tian *et al.* (2015) Vanti *et al.* (2019) Vijay *et al.* (2011) Vinay Kumar & Shaktidar (2014) Vivekananda Pai *et al.* (2014) Yadav *et al.* (2016)	Extended distolingually	Attam *et al.* (2012) Bains *et al.* (2009) Bonaccorso & Tripi (2008) Chowdhury & Hassan (2014) De Moor *et al.* (2004) López-Rosales *et al.* (2015) Mangal *et al.* (2016) Marya *et al.* (2014) Qureshi *et al.* (2017) Segura-Egea *et al.* (2002) Shahbaz *et al.* (2022) Subramaniam Ramachandran *et al.* (2019)
Armamentarium		**Guidance to locate RE orifice during access cavity**	
Ultrasonic tips	Abella *et al.* (2011) Mohamed Khazin & Mustaffa (2022) Patil *et al.* (2013) Shahbaz *et al.* (2022)	Map of pulpal floor	Martins *et al.* (2014) Marya *et al.* (2014)
Endo Access bur	Agarwal *et al.* (2019) Banode *et al.* (2016)	Micro-opener	Kusumo *et al.* (2019)
Endo Z bur	Bains *et al.* (2009) Mangal *et al.* (2016) Marya *et al.* (2014) Pandey *et al.* (2018) Segura-Egea *et al.* (2002)	DG-16	Banode *et al.* (2016) Nahar (2019) Pandey *et al.* (2018)
GG bur	Vinay Kumar & Shaktidar (2014)	Endodontic explorer	Vijay *et al.* (2011)

GG: Gates Glidden, RE: radix entomolaris

Table 4. Modifications to the type of endodontic files used for root canal preparation of radix entomolaris.

Files used on other canals	Modification to RE	Author
ProTaper Next	K-file	Mohamed Khazin & Mustaffa (2022)
K-FlexoFile	ProTaper Gold (rotary)	Shahbaz *et al*. (2022)
ProTaper (rotary)	SS hand file	Štamfelj (2014)
One Curve	ProTaper (rotary)	Vinay Kumar & Shaktidar (2014) (case A)
Files and reamers	No modifications	Kimura & Matsumoto (2000)
SS hand file	No modifications	Nagaveni *et al*. (2015) (Case 2, 3)
K-file	No modifications	Štamfelj *et al*. (2016)
ProTaper Universal (hand)	No modifications	Chowdhury & Hassan (2014); De Moor *et al.* (2004) (Case 2A, 2B); Bains *et al*. (2009); Marya *et al*. (2014) (Case 1, 2); Mirikar *et al*. (2009); Qureshi *et al*. (2017) (Case A, B)
FlexoFile	No modifications	De Moor *et al.* (2004) (Case 1); Segura-Egea *et al*. (2002); Schumacher (2008)
ProTaper Universal (rotary)	No modifications	Choi *et al.* (2018); Garg *et al*. (2011); Gonapa *et al*. (2022); Gupta *et al*. (2014); López-Rosales *et al*. (2015); Mirza *et al*. (2018); Martins *et al*. (2014); Mittal & Narang (2012); Vivekananda *et al.* (2014) (Cases 2,3,4); Parsa & Rapala (2016); Pires & Martins (2019) (Case 1); Yadav *et al*. (2016); Attam *et al.* (2012) (Case 2); Bansal *et al.* (2015) (Case 2); Vinay Kumar & Shaktidar (2014) (Case B); Naidu *et al*. (2013); Oberländer (2012) (Cases A,B); Vijay *et al*. (2011); Sinha & Sinha (2014); Sinha *et al*. (2016) (Case 2); Vanti *et al.* (2019) (Cases A,B)
ProFile	No modifications	De Moor *et al.* (2004) (Cases 3,4); Verma (2009)
BioRaCe	No modifications	Bonaccorso & Tripi (2008)
PRU	No modifications	Khirtika & Ramesh (2017)
Mtwo	No modifications	Abella *et al*. (2011); Bhargav *et al.* (2017) (Cases 1,2); Mangal *et al*. (2016); Srinivasan *et al.* (2015)
WaveOne	No modifications	de Souza *et al.* (2017)
One Gold	No modifications	Petrova *et al*. (2020)
K3 Endo	No modifications	Turki (2019)
ProTaper Next	No modifications	Agarwal *et al.* (2019) (Cases 1,2); Kohli *et al*. (2019); Meidyawati & Suprastiwi (2016)
K3XF	No modifications	Banode *et al.* (2016)
One Curve	No modifications	Vinay Kumar & Shaktidar (2014) (Case A); Kusumo *et al*. (2019)
HyFlex CM	No modifications	Nahar (2019) (Cases 1,2); Pandey *et al*. (2018)
ProTaper Gold (rotary)	No modifications	Subramaniam Ramachandran *et al*. (2019); Tsujimoto (2021)
TF	No modifications	Tian *et al*. (2015)

SS: stainless-steel, RE: radix entomolaris, CM: controlled memory, TF: twisted files

Table 5. Modification made to radix entomolaris on apical size preparation.

Other canals	Modification on RE	Author
F2	F1	Vijay *et al*. (2011)
20/06	No modification	Abella *et al*. (2011)
X2	25/02	Mohamed Khazin & Mustaffa (2022)
Not mentioned	F2	Shahbaz *et al*. (2022)
		Vinay Kumar & Shaktidar (2014) (Case A)
25/07	No modification	Petrova *et al*. (2020)
F2	No modification	Pires & Martins (2019)
		Bains *et al.* (2009)
		Marya *et al*. (2014) (Cases 1, 2)
		Sinha & Sinha (2014)
X2	No modification	Agarwal *et al.* (2019)
		Kohli *et al*. (2019)
		Meidyawati & Suprastiwi (2016)
25/04	No modification	Banode *et al.* (2016)
25/06	No modification	Mangal *et al*. (2016)
		Srinivasan *et al*. (2015)
25/08	No modification	Tian *et al*. (2015)
30/04	30/06	Nahar (2019) (Cases 1, 2)
		Pandey *et al*. (2018)
45/02	30/02	Schumacher (2008)
F3	No modification	Gonapa *et al*. (2022)
		Bansal *et al.* (2015)
		Oberländer (2012) (Cases A, B)

RE: radix entomolaris

Table 6. Management and outcome of endodontic mishaps on RE.

Author	Management	Outcome
Separated endodontic file		
Vinay Kumar & Shaktidar (2014) (Case B)	4 mm ProTaper F2 rotary file separated and removal was attempted using Masserann kit but was unable to be retrieved. Left in situ at 4 mm apical, RE was obturated up to separated fragment.	S
Mirikar *et al*. (2009)	NiTiFlex #30 hand file separated. Instrument was retrieved using ultrasonic tip. RE was cleaned, prepared, and obturated to full working length.	H
Ledge		
Mohamed Khazin & Mustaffa (2022)	Ledge was bypassed and RE prepared using stepback technique. RE cleaned, prepared, and obturated to full working length. 70% isopropyl alcohol was used to improve GP rigidity and maintain GP in pre-curved state to bypass the ledge during obturation.	S

Štamfelj (2014)	Ledge was bypassed and RE prepared manually with pre-curved stainless-steel files, and obturated to full working length.	H
Missed canal		
Kusumo *et al*. (2019)	RE was missed during first visit, causing intra-appointment flare-up. RE was identified on the next visit and negotiated, prepared, cleaned, and obturated to full working length.	S
Mangal *et al*. (2016)	RE was missed during first visit causing intra-appointment flare-up. RE was identified on the next visit and negotiated, prepared, cleaned, and obturated to full working length.	A
Extruded sealer		
Oberländer (2012) (Case A)	None	S
Vivekananda Pai *et al*. 2014 (Case 4)	None	S
Pre-operative mishap by previous operator		
Choi *et al.* (2018)	Separated file on RE (unknown) with small taper. Instrument was bypassed, and RE was cleaned, prepared, and obturated to full working length	S
Mirikar *et al*. (2009)	Perforation of chamber floor. Perforation site was disinfected with 2.5% NaOCl, dried, and repaired with MTA.	H
Srinivasan *et al*. (2015)	Perforation of chamber floor. GP points placed at all canals, MTA white was used to repair perforation, wet cotton pellet was placed to allow MTA to set, and tooth was temporised.	H
Bains *et al.* (2009)	Missed RE canal. RE was identified, negotiated, prepared, cleaned, and obturated to full working length.	A
De Moor *et al.* (2004)		S
Kimura & Matsumoto (2000)		H
Oberländer (2012) (Case A)		S
Oberländer (2012) (Case B)		H
Petrova *et al*. (2020)		S
Pires & Martins (2019)		S
Segura-Egea *et al*. (2002)		H
Sinha *et al*. (2016)		A
Turki (2019)		H
Verma (2009)		H

A: asymptomatic, H: healing, GP: gutta percha, MTA: mineral trioxide aggregate, NaOCl: sodium hypochlorite, RE: radix entomolaris, S: success.

Table 7. Outcome and mishaps of non-surgical root canal treatment on mandibular molar with radix entomolaris.

Follow-up (months)	Author	Outcome	Mishap on RE
0.5	Vijay *et al*. (2011)	S	
1	Gonapa *et al*. (2022)	F	
	Mangal *et al*. (2016)	A	MC
	Marya *et al*. (2014) (Case 1)	A	
	Marya *et al*. (2014) (Case 2)	A	
	Pandey *et al*. (2018)	H	
	Qureshi *et al*. (2017) (Case A)	H	
	Qureshi *et al*. (2017) (Case B)	S	
	Sinha & Sinha (2014) (Case 1)	A	
	Sinha *et al*. (2016) (Case 2)	A	MC
2	Kusumo *et al. (2019)*	S	MC
	Meidyawati & Suprastiwi 2016	S	
	Mirikar *et al.* (2009)	H	P, SI
3	Banode *et al.* (2016)	A	
	Kimura & Matsumoto (2000)	H	MC
	Naidu *et al*. (2013)	H	
	Vanti *et al.* (2019) (Case A)	S	
	Vanti *et al.* (2019) (Case B)	S	
	Nahar (2019) (Case 1)	H	
	Nahar (2019) (Case 2)	S	
	Kohli *et al*. (2019)	S	
6	Vivekananda Pai *et al*. (2014) (Case 2)	H	
	Vivekananda Pai *et al*. (2014) (Case 3)	S	
	Agarwal *et al.* (2019) (Case 1)	S	
	Arora *et al.* (2018) (Case 1)	S	
	Bansal *et al.* (2015) (Case 2)	A	
9	Bains *et al.* (2009)	A	MC
	Tian *et al*. (2015)	S	
10	Turki (2019)	H	MC
	Martins *et al*. (2014)	A	
12	Abella *et al*. (2011)	S	
	Bhargav *et al.* (2017) (Case 1)	S	
	Bhargav *et al.* (2017) (Case 2)	S	
	Chowdhury & Hassan (2014)	S	
	De Moor *et al.* (2004) (Case 1)	S	
	De Moor *et al.* (2004) (Case 2A)	S	
	De Moor *et al.* (2004) (Case 2B)	S	
	De Moor *et al.* (2004) (Case 3)	S	MC
	De Moor *et al.* (2004) (Case 4)	S	
	de Souza *et al.* (2017)	S	
	Garg *et al*. (2011)	S	
	Gupta *et al*. (2014)	S	
	Mohamed Khazin & Mustaffa (2022)	S	Ledge
	Vivekananda Pai *et al*. (2014) (Case 4)	S	ES
	Parsa & Rapala (2016)	S	
	Petrova *et al*. (2020)	S	MC
	Štamfelj (2014)	H	Ledge
	Khirtika & Ramesh (2017)	S	
	Law & Beaumont (2004) (Case 1)	S	
	Law & Beaumont (2004) (Case 2)	S	
	Nagaveni *et al*. (2015) (Case 1A)	A	
	Nagaveni *et al*. (2015) (Case 1B)	A	

	Vinay Kumar & Shaktidar (2014) (Case A)	S			Nagaveni *et al*. (2015) (Case 2)	A	
	Vinay Kumar & Shaktidar (2014) (Case B)	S	SI	14	López-Rosales *et al*. (2015)	S	
	Oberländer (2012) (Case A)	S	MC, ES		Segura-Egea *et al*. (2002)	H	MC
	Oberländer (2012) (Case B)	H	MC	15	Yadav *et al*. (2016)	S	
	Subramaniam Ramachandran *et al*. (2019)	A		18	Bonaccorso & Tripi (2008)	S	
	Srinivasan *et al*. (2015)	H	P		Choi *et al.* (2018)	S	SI
	Štamfelj *et al*. (2016)	H			Mirza *et al*. (2018)	S	
	Tsujimoto (2021)	S			Verma (2009)	H	MC
	Nagaveni *et al*. (2015) (Case 3)	A		19	Pires & Martins (2019) (Case 1)	S	MC
7	Mittal & Narang (2012)	H		24	Patil *et al*. (2013)	S	
8	Attam *et al.* (2012) (Case 2)	H			Shahbaz *et al.* (2022)	S	

A: asymptomatic, ES: extruded sealer, F: failed, H: healing, MC: missed canal, P: perforation, S: successful, SI; separated instrument.

Discussion

Diagnostic challenge

Based on clinical assessment, the anatomical variations of MM play a significant role in anticipating the presence of RE as highlighted by Calberson *et al.* (2007) and Kim *et al*. (2013). RE presence can be suspected when certain clinical features are present such as 1) additional tubercle or sixth cusp, 2) wider buccolingual measurement at the distal surface of the crown, 3) slightly wider intercuspal distance between the distolingual cusp with distobuccal and mesiolingual cusp, and 4) presence of cervical prominence or convexity (Calberson *et al*., 2007; Kim *et al*., 2013). However, the teeth can also present with pathological conditions (such as dental caries or tooth surface loss) or have intracoronal or extracoronal restoration, thus compromising thorough assessment.

Further radiographical assessment is indicated to assess RE presence such as the use of IOPA at different angulations (Chowdhury & Hasan, 2014; De Moor *et al.* 2004; Garg *et al*., 2011; Gupta *et al*., 2014; Mirza *et al*., 2018). However, the curvature from the buccolingual direction cannot be assessed effectively due to the limitation of a two-dimensional radiograph. On that note, utilising the CBCT could help in evaluating the curvature of other roots including RE, thus anticipating the complexity of endodontic procedure and the likely prognosis. Majority of cases included in this review did not use CBCT for identification but relied solely on IOPA. According to the European Society of Endodontology (ESE), using CBCT during routine endodontic treatment is indicated for further investigation, in the case of anatomically complex root canal system (Patel *et al*., 2019). The use of CBCT was highlighted in several of the case reports included in this review. Determining the presence of RE in MM may be of major importance to achieve a favourable treatment outcome (Rodríguez-Niklitschek *et al.*, 2015).

Nonetheless, CBCT is not always necessary if clinical examination such as observation under DOM and conventional radiograph are able to provide adequate information for treatment to be rendered (Patel *et al*., 2014). Additional information can be gained by using angulated IOPA; it has been shown that 25° mesial-horizontal angled IOPA is the most effective to identify type II and III RE, while type I RE is easily identifiable with various horizontal angulations of periapical radiograph (Wang *et al*., 2011).

The anatomy of MM with RE at the level of cementoenamel junction may differ than that without RE. The presence of dentinal shelf may block the location of RE canal orifice and hinder its direct view (Abella *et al*., 2012). Some of the case reports also mentioned that observing the pulpal floor using DOM can facilitate in locating the canal orifice of RE (Mohamed Khazin & Mustaffa, 2022; Patil *et al*., 2013; Petrova *et al*., 2020; Pires & Martins, 2019; Vivekananda Pai *et al*., 2014). However, a sound knowledge on the presence of RE is needed to prevent RE misidentification as a second canal of a distal root (Madhuram *et al*., 2011).

Modification to access cavity

Due to the anatomical location of RE and the blocked orifice, modification is to be made by extending the access cavity towards the distolingual and taking a trapezoidal shape instead of a triangular shape (Figure 3), which was mentioned in majority of cases reported (Table 3). The modification can be made using endodontic ultrasonic tips or endodontic access opening burs (Abella *et al*., 2011; Mohamed Khazin & Mustaffa, 2022; Patil *et al*., 2013; Petrova *et al*., 2020; Segura-Egea *et al*., 2002; Shahbaz *et al*., 2022). However, care must be taken not to over enlarge the orifice as there is risk of perforation due to slender root anatomy (Figure 4).

Figure 3. Clinical photograph of mandibular molar with radix entomolaris. Red arrow showing extension of access cavity towards distolingual to accommodate identification, preparation, and obturation of RE (Taken with permission from Mohamed Khazin & Mustaffa 2022).

Figure 4. Sagittal view of cone-beam computed tomography image of mandibular molar with radix entomolaris. Red arrow showing slender and acute root curvature.

Preparation and obturation of RE

RE is known for being slender and curved buccolingually. To prevent mishaps such as perforation, ledge, or separated instrument, achieving glide path is necessary. However, in most of the cases reported in this review, glide path was not emphasised. Glide path can be achieved using manual or rotary instruments. A recent systematic review documented that achieving glide path prior to canal preparation significantly reduces the incidence of canal transportation especially when using rotary system (Plotino *et al*., 2020). A previous study found that the use of manual file reduces the likelihood of instrument separation during canal preparation (Patiño *et al*., 2005); however, several recent studies have shown that using rotary or manual glide path files have no

difference in influencing file fracture rate (Plotino *et al*., 2020).

Larger apical size preparation has been shown to provide better canal cleaning and significantly reduce debris accumulation in curved canals (Pivoto-João *et al*., 2020), while still maintaining central ability and absence of canal transportation (Poly *et al*., 2019). The type of file used plays an important role to achieve said outcome, such as using a heat-treated nickel–titanium file with small taper (de Carvalho *et al.*, 2022). A previous study found little difference in the amount of wall touched by files when apical canal was prepared between size #30 and #50, but sizes larger than #40 does increase the amount of irrigation reaching the apical third (de Gregorio *et al.*, 2013) and larger taper files result in more dentinal removal especially in curved canal (de Carvalho *et al.*, 2022). Majority of the cases reported in this review had apical canal preparation at #25; the decision to maintain the apical size at #25 was probably to reduce unnecessary dentinal removal especially in a slender and curved RE, considering the type of file used had large taper (6%–7%) and majority of the files used were not heat-treated files (Tables 4 and 5).

Endodontic mishaps on RE

RE has several anatomical variations, hence procedural errors such as furcal or strip perforation, weakening of roots, vertical root fracture, root canal fattening and transportation, loss of working length, and instrument separation can occur in RE (Duman *et al*., 2019).

The pooled incidence of endodontic mishap on RE in this review was close to that reported in a previous study, where mishaps performed by endodontic residents and endodontists were 7.7% and the highest mishap rate was due to separated instrument, followed by missed canal, and ledge (Bozkurt *et al.*, 2021). Other studies that observed mishap incidences performed by undergraduate students showed vast difference ranging from 31.9%–63.9%, with the highest incidence being over-instrumentation (Alhekeir *et al*., 2013; Haug *et al*., 2018).

Two cases included in this review reported chamber floor perforation during access cavity that was referred by a previous operator. Both teeth were repaired with mineral trioxide aggregate. Nonetheless, both teeth did not have a successful outcome. The outcome of perforation depends on its size and location, and the repair duration. In the included study, both cases had large perforation located at crestal level, hence reducing the prognosis of the treatment despite being treated promptly (American Association of Endodontists, 2017).

The pooled incidence of missed canal included in this review was 17.4% which was low compared to that from a CBCT study by Mashyakhy *et al*. (2021). They found that the incidence of missed canal in MM was 25%. Nonetheless, 18.2% of the cases were missed distolingual canal, which is close to the findings in the present review. All the cases that had missed canal had persistent apical periodontitis that required further intervention, which are similarly seen in the cases reported in this review.

Other mishaps that were reported in this review such as ledge, separated instrument, and sealer extrusion, did not have a detrimental effect on the outcome of the NSRCT. Separated instrument, sealer extrusion, sealer type, and extension of apical filling material have been shown to not have a significant effect on NSRCT outcome unless accompanied by pre-operative apical periodontitis (Ricucci *et al*., 2016; Spili *et al*., 2005). Similarly for ledge, if it is able to be bypassed and instrumentation and irrigation are able to reach apical terminus, it has no effect on NSRCT outcome (Lambrianidis, 2006).

Without adequate pre-operative assessment and sound knowledge on MM variations, particularly on the presence of RE, its location and curvature, the risk of procedural errors during NSRCT can increase. However, these procedural errors can be managed successfully with adequate

clinical skills and experience of the clinicians (Mohamed Khazin & Mustaffa, 2022).

The outcomes of endodontic treatment on MM with RE

More than half of the case reports included in this review showed successful outcome with no clinical and radiographical signs of pathology (58.7%). Nonetheless, it varied tremendously with previous outcome study which ranges between 80%–83% (Ng *et al*., 2011). This vast difference in outcome is most likely because the cases included in the present review are difficult endodontic cases due to the presence of RE, unlike the previous study where outcome based on case difficulty was not segregated. Furthermore, the average follow-up period was less than one year. According to ESE, the outcome of NSRCT should be assessed at least after one year (ESE, 2006). For cases that had a follow-up period of at least 12 months, 27 of 33 cases (81.8%) were successful. Healing or asymptomatic cases that had a follow-up period of less than 12 months might require more time for the apical periodontitis to heal following NSRCT and should be reviewed further for a minimum period of 4 years (ESE, 2006).

Currently, there is no evidence on the prognostic indicators determining the treatment outcomes of MM with RE, which could be attributed to the nature of existing studies that are primarily case reports, case series, retrospectives, and reviews. Therefore, it is rather difficult to make a robust conclusion pertaining to the factors contributing the treatment outcomes. Perhaps future research can focus on this aspect so that clinicians can anticipate various factors that may affect the overall treatment outcomes.

Conclusion

When treating MM, thorough clinical and radiographical examination is needed to rule out RE. Early identification of RE can help in prevention of mishaps. Clinicians should have sound knowledge and understanding on the presence of RE across different populations, root canal morphology associated with RE that may complicate the endodontic procedure, CBCT and magnification device usage, as well as clinical skills and experience in managing MM with RE to improve the endodontic treatment outcomes.

Acknowledgement

This research was funded by IIUM-UMP-UiTM Sustainable Research Collaboration Grant 2020 (SRCG) from International Islamic University Malaysia (SRCG20-014-0014).

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Supplementary Table 1. Data collection sheet.

No	Author	Demographic data			Pre-operative factor			Diagnostic method to determine presence of RE	Treatment protocol				Mishap on RE	Outcome	
		Age, Gender	Race and Country	Medical history	Tooth no	Diagnosis	Clinical Findings		Canal Preparation method	Obturation method	Management of RE	Post-endodontic restoration		Follow-up (months)	Outcome
							RE type: Cavity: Pre-op pain: Pre-op TTP: Pre-op PPD: Pre-op swelling: Pre-op sinus tract: Mobility:	IOPA/ OPG/ CBCT/ SCT/ Inspection under DOM	Isolation: Coronal flare: Glide path: Canal prep: MAF: Irrigation: Needle size: No of Visit: Intracanal medication:	Final Irrigation: Activated irrigation: Obturation technique: Sealer type:	Access cavity: Canal preparation: MAF: Obturation technique:	Orifice seal: Definitive restoration:			Success/ Healing/ Asymptomatic/ Fail

CBCT; cone-beam computed tomography, DOM; dental operating microscope, IOPA; intraoral periapical radiograph, MAF; master apical file, OPG; panoramic radiograph, PPD; periodontal probing depth, RE; radix entomolaris, SCT; spiral computed tomography, TTP; tender to percussion.

Supplementary Table 2. Critical appraisal for case reports included in the review using JBI.

No	Author	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
		Were patient's demographic characteristics clearly described?	Was the patient's history clearly described and presented as a timeline?	Was the current clinical condition of the patient on presentation clearly described?	Were diagnostic tests or assessment methods and the results clearly described?	Was the intervention(s) or treatment procedure(s) clearly described?	Was the post-intervention clinical condition clearly described?	Were adverse events (harms) or unanticipated events identified and described?	Does the case report provide takeaway lessons?
1	Abella *et al.* 2011	Y	U	Y	Y	Y	N	NA	Y
2	Bhargav *et al.* 2017 (case 1)	Y	Y	Y	Y	Y	N	NA	Y
3	Bhargav *et al.* 2017 (case 2)	Y	Y	N	Y	Y	N	NA	Y
4	Bonaccorso & Tripi 2008	Y	N	Y	Y	Y	Y	NA	Y
5	Choi *et al.* 2018	Y	Y	Y	Y	Y	Y	Y	Y
6	Chowdhury & Hassan 2014	U	N	Y	U	Y	N	NA	Y
7	De Moor *et al.* 2004 (Case 1)	U	N	Y	Y	Y	Y	NA	Y
8	De Moor *et al.* 2004 (Case 2A)	Y	N	Y	N	Y	N	NA	Y
9	De Moor *et al.* 2004 (Case 2B)	Y	N	Y	N	Y	N	NA	Y
10	De Moor *et al.* 2004 (Case 3)	U	Y	U	Y	Y	N	NA	Y
11	De Moor *et al.* 2004 (Case 4)	U	Y	Y	Y	Y	N	NA	Y
12	De souza *et al.* 2017	Y	Y	Y	Y	Y	Y	NA	Y
13	Garg *et al.* 2011	Y	U	Y	Y	Y	Y	NA	Y
14	Gonapa *et al.* 2022	U	Y	Y	Y	Y	Y	NA	Y
15	Gupta *et al.* 2014	Y	U	Y	Y	U	N	NA	Y
16	Lopez-rosaes *et al.* 2015	U	Y	Y	Y	Y	Y	NA	Y
17	Mirza *et al.* 2018	U	Y	Y	Y	Y	Y	NA	Y
18	Mohamed Khazin and Mustaffa 2022	Y	Y	U	Y	Y	Y	Y	Y
19	Pai *et al.* 2014 (case 2)	U	U	Y	Y	Y	N	NA	Y
20	Pai *et al.* 2014 (case 3)	U	U	Y	Y	Y	N	NA	Y
21	Pai *et al.* 2014 (Case 4)	U	U	Y	Y	Y	N	Y	Y
22	Parsa & Rapala 2016	U	U	Y	Y	Y	Y	NA	Y
23	Patil *et al.* 2013	U	U	Y	U	Y	N	NA	Y
24	Petrova *et al.* 2020	Y	Y	Y	Y	Y	N	Y	Y
25	Pires & Martins 2019 (case 1)	Y	U	Y	Y	Y	Y	NA	Y
26	Segura-Egea *et al.* 2002	U	Y	Y	Y	Y	Y	Y	Y

No	Author	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
		Were patient's demographic characteristics clearly described?	Was the patient's history clearly described and presented as a timeline?	Was the current clinical condition of the patient on presentation clearly described?	Were diagnostic tests or assessment methods and the results clearly described?	Was the intervention(s) or treatment procedure(s) clearly described?	Was the post-intervention clinical condition clearly described?	Were adverse events (harms) or unanticipated events identified and described?	Does the case report provide takeaway lessons?
27	Shahbaz 2022	U	U	Y	Y	Y	N	NA	Y
28	Štamfelj 2014	Y	Y	Y	Y	Y	Y	Y	Y
29	Turki 2019	U	Y	Y	Y	Y	Y	NA	Y
30	Verma 2009	U	U	N	U	Y	Y	NA	Y
31	Yadav *et al.* 2016	U	U	Y	Y	Y	Y	NA	Y
32	Agarwal *et al.* 2019 (Case 1)	U	Y	Y	Y	Y	Y	NA	Y
33	Arora *et al.* 2018 (Case 1)	U	Y	U	U	Y	Y	NA	Y
34	Attam *et al.* 2012 (Case 2)	U	Y	Y	Y	Y	U	NA	Y
35	Bains *et al.* 2009	U	Y	Y	Y	Y	U	NA	Y
36	Banode *et al.* 2016	U	U	Y	Y	Y	Y	NA	Y
37	Bansal *et al.* 2015 (Case 2)	U	U	Y	Y	U	U	NA	Y
38	Khirtika & Ramesh 2017 (Case 1)	U	U	N	N	Y	Y	NA	Y
39	Kimura & Matsumoto 2000	U	U	Y	Y	Y	U	NA	Y
40	Kohli *et al.* 2020	U	U	Y	Y	Y	Y	NA	Y
41	Kumar & Shaktidar 2014 (Case A)	Y	Y	Y	N	Y	Y	N	Y
42	Kumar & Shaktidar 2014 (Case B)	Y	Y	Y	N	Y	Y	Y	Y
43	Kusumo *et al.* 2019	U	Y	Y	Y	Y	Y	Y	Y
44	Law & Beaumont 2004 (Case 1)	Y	Y	Y	Y	N	N	NA	Y
45	Law & Beaumont 2004 (Case 2)	Y	Y	Y	Y	N	N	NA	Y
46	Mangal *et al.* 2016	U	Y	Y	Y	Y	Y	Y	Y
47	Martins *et al.* 2014	Y	Y	Y	Y	Y	U	NA	Y
48	Marya *et al.* 2014 Case 1)	U	Y	Y	Y	Y	N	NA	Y
49	Marya *et al.* 2014 Case 1)	U	U	Y	Y	Y	N	NA	Y
50	Meidyawati & Suprastiwi 2016	U	U	Y	N	Y	Y	NA	Y
51	Mirikar *et al.* 2009	U	U	U	U	U	Y	Y	Y
52	Mittal & Narang 2012	U	Y	Y	Y	Y	Y	NA	Y
53	Nahar *et al.*2019 (Case 1)	U	U	U	N	Y	Y	NA	Y
54	Nahar *et al.* 2019 (Case 2)	U	U	U	N	Y	Y	NA	Y
55	Naidu *et al.* 2013	U	U	U	N	U	Y	NA	Y
56	Oberlander 2012 (Case A)	U	Y	Y	Y	Y	Y	Y	Y
57	Oberlander 2012 (Case B)	U	Y	Y	Y	Y	Y	NA	Y
58	Pandey *et al.* 2018	U	Y	Y	Y	Y	Y	NA	Y
59	Qureshi *et al.* 2017 (Case A)	Y	Y	Y	Y	Y	Y	NA	Y
60	Qureshi *et al.* 2017 (Case B)	Y	Y	Y	Y	Y	Y	NA	Y
61	Ramachandran *et al.* 2019	Y	Y	Y	Y	Y	Y	NA	Y
62	Vijay e *et al.* 2011	U	Y	Y	Y	Y	Y	NA	Y
63	Schumacher 2008	Y	Y	Y	Y	Y	Y	NA	Y
64	Sinha & Sinha 2014 (Case 1)	N	U	U	U	Y	Y	NA	Y
65	Sinha *et al.* 2016 (Case 2)	N	Y	Y	Y	Y	Y	NA	Y
66	Srinivasan *et al.* 2015	N	N	N	Y	Y	Y	NA	Y
67	Stamfelj *et al.* 2016	Y	Y	Y	Y	Y	Y	NA	Y
68	Tian *et al.* 2015	Y	Y	Y	Y	Y	N	NA	Y
69	Tsujimoto 2021	Y	U	Y	U	Y	Y	NA	Y
70	Vanti *et al.* 2019 (case A)	U	U	U	U	Y	Y	NA	Y
71	Vanti *et al.* 2019 (case B)	U	U	U	U	Y	Y	NA	Y
72	Nagaveni *et al.* 2015 (Case 1A)	Y	U	Y	Y	U	Y	NA	Y
73	Nagaveni *et al.* 2015 (Case 1B)	Y	U	Y	Y	U	Y	NA	Y
74	Nagaveni *et al.* 2015 (Case 2)	Y	U	Y	U	Y	Y	NA	Y
75	Nagaveni *et al.* 2015 (Case 3)	Y	U	Y	U	N	Y	NA	Y

Y; yes, N; no, U; unclear, NA; not applicable