

# Early Failures in Root Canal Treatment: A Systematic Review and Meta-Analysis

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## Abstract

**Background:** Root canal treatment is a boon in preserving teeth affected by apical odontitis. This procedure shows a fair success rate with lots of patients reporting alleviation of pain. However, the presence of some factors could be contributors of failure. **Aim and objective:** The primary question that we aimed to answer was: "What are the factors for failure in root canal treatment and how to identify the significant association between the covariates?". **Methods:** The data was retrieved from PubMed and Google Scholar from 2018 to 2024 and 18053 records were identified. After exclusion based on title and abstract, full text screening along with duplicate removal initially, ten studies were considered for the systematic review and meta-analysis finally. **Results:** Males, young adults, molar and under filled tooth showed higher rates of failure in root canal treatment. Pain and sinus came out to be the major factors indicating failure. Missing canal and instrument related factors were some of the major causes for the failure. The C shaped canal usually found in mandibular and second molar leads to failure. **Conclusion:** Peri apical radiolucency can particularly be used as an indicator to assess failure and cone beam computed tomography specially will prove to be beneficial in diagnosis to prevent such failures.

**Keywords:** Root canal treatment, Failure, Meta analyses, Systematic review.

## Introduction

Root canal treatment (RCT) is a well-established, proven modality of choice for the retention of teeth involved in apical odontitis, an infection that is typified by inflammation and infection at the root apex (Gulabivala K, Ng YL, 2023). The main goal of RCT is to preserve a functional tooth in patients, especially in view of the rising life expectancy, requiring the retention of natural dentition for as long as possible (Dobrzański LA *et al.*, 2020). With increasing age, the importance of retaining their teeth assumes a central role, not just for esthetic reasons but also for the preservation of normal oral function and general well-being.

RCT has been shown to alleviate pain and prevent the progression of infection, thereby greatly improving the life of many patients. Large sample prospective cohort studies with good methodology and effective treatment procedures are steps taken to compare the effectiveness of RCT. These studies have also repeatedly shown that RCT can be an economical long-term treatment compared to dental implants, which are likely to require additional procedures and ongoing care in the future. RCT is much better than implant in the long run as far as expenditure is concerned (Zang HL *et al.*, 2023).

However, in spite of its advantage, the success of root canal treatment (RCT) is not guaranteed, and a variety of factors can cause failure. It is important that dental clinicians, who aim to achieve optimal outcomes and improve patient satisfaction, know about these factors. Advances in dental technology over the past decade or so, with the introduction of cone beam computed tomography (CBCT), have changed the way in which practitioners assess and

plan RCT. CBCT allows accurate three-dimensional visualization of the tooth and surrounding anatomy and thereby the identification of complex root canal systems and anatomical anomalies that put the treatment at risk of failure. Additionally, novel procedures, including regenerative endodontics, are becoming more noted as possible future alternatives to the conventional root canal therapy (RCT). These procedures are based on biological pulp tissue regeneration and attempt to revive the tooth's vitality, which is an exciting development for the treatment of the future. In addition, the use of artificial intelligence and machine learning in dental diagnostics will most certainly increase the accuracy of treatment planning and outcome prognosis and, subsequently, increase the success rates of RCT further.

While endodontic science continues to develop, practitioners of dentistry must keep abreast of such updates and implement these in clinical applications. The current systematic review and meta-analysis should be used to evaluate the varied factors of root canal treatment failures early on and provide insights toward improving clinical practice and patient consultation. Through establishing significant associations among these factors and treatment outcomes, we aim to be among those contributing to continued efforts toward producing better root canal treatment methods and making root canal treatment a safe and effective form of tooth preservation in the years to come.

## Methods

This systematic review and meta-analyses followed the Preferred Reporting Item for Systematic Review and Meta-Analyses (PRISMA) guidelines (Moher D *et al.*, 2009).

### Literature search

A comprehensive literature search was done to find out studies published between 2018 to 2024 on root canal treatment failure and various associated factors. Electronic database search was done in PubMed and Google Scholar using the keywords “Root canal treatment” and “Failure”.

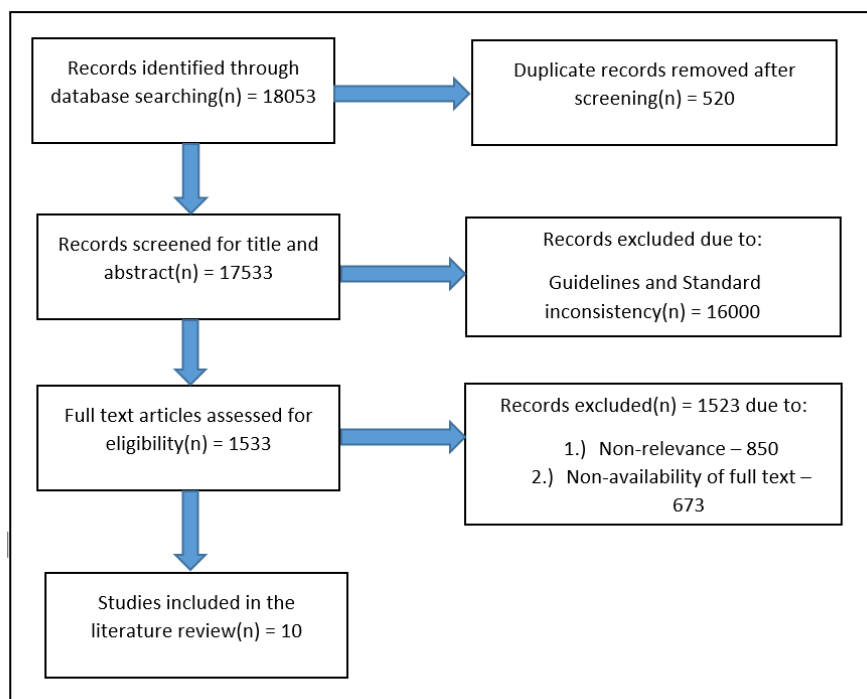
### Inclusion and exclusion criteria

The inclusion criteria were: 1.) Cases available with complete data for root canal treatment failure. 2.) Studies published in English. 3.) Studies done among adults. 4.) Studies cross-sectional, retrospective, prospective, clinical surveys and questionnaire-based studies 5.) Studies that reported early failure for RCT

The exclusion criteria were: - 1.) Case series, reports 2.) Secondary root canal treatment and retreatment 3.) Studies solely based on indications and not reporting outcomes

### Data extraction

The eligibility of the article based on criteria search was completed by 2 authors (P.H.B. and S.P.P.) and the full text of the studies was analysed by using Microsoft Excel 2016. The two authors assessed the methodology and the quality of the articles by using the New Castle Ottawa assessment scale (Wells GA *et al.*, 2000). Finally, a total of 10 studies met the quality of assessment. The studies included were from different parts of the world namely KSA, Spain, Sweden, Finland, India, Pakistan and South Korea. The first author with year of publication, type and period of study, place of study, study characteristics, male, female, maxilla, mandible, young, old, molar and premolar were tabulated (Table 1). Forest graph was plotted for root canal treatment failure in males, females, young and old population (**Figure 2 a and b**).



**Figure 1: Flow chart for systematic review and meta-analyses on RCT failure**

### Statistical analysis

Statistical analysis was performed with SPSS version 28.0 and the data were presented using descriptive statistics such as number and percentage. R Studio was used in the preparation of graphs.

## Results

### Screening flow

According to the search strategy set in advance, a total of 18053 articles were retrieved in the target database (**Figure 1**). Then 520 duplicate articles were removed. Sixteen thousand articles were excluded from 17533 articles during title and abstract screening. Finally, 10 articles were determined to be included in the analysis after excluding 1523 articles from 1533 articles during full text screening (**Figure 1**).

### Funnel's test and egger's test

To assess the risk of publication bias, funnel plot analysis, and Egger's test (Bowden J *et al.*, 2015) were conducted for male, female, young and old (**Figure 3 a and b**). The asymmetry of all funnel plots can be attributed to the relatively small sample sizes and

few studies considered for analysis. The Egger's test for male, female, young and old yielded p values 1, 0.083, 0.267 and <0.001 respectively indicating no evidence of publication bias for male and young individuals while depicting strong evidence of publication bias for old individuals and potential publication bias for females though not statistically significant stressing on interpreting the results cautiously.

Pooled estimates for male, female, young and old were noted as 0.45(95% CI: 0.14-0.75), 0.33(95%CI: 0.15-0.50), 0.40(95% CI: 0.13-0.67), 0.13(95%CI: 0.03-0.23) respectively. Heterogeneity for male, female, young and old were noted as 98.403, 87.814, 97.238 and 78.019 respectively. Different effects of different sub group studies would be a contributor for the high heterogeneity noted in the meta analyses indicating presence of publication bias.

Pearson's Chi Square (Rao CR, 2002), Mann Whitney U (Nachar N, 2008), Kruskal Wallis Test (McKight PE, Najab J., 2010) and Meta Regression Analysis (Stanley TD *et al.*, 2008):

The data for failure percentages for gender, age, tooth type and tooth filling were tabulated based on which the various tests were performed (Table 2).

Pearson's Chi Square Test for:

Gender: -  $\chi^2 = 39.38$ ,  $p = 0.0000$

Age: -  $\chi^2 = 39.85$ ,  $p = 0.0000$

Tooth Type: -  $\chi^2 = 35.85$ ,  $p = 8.04 \times 10^{-8}$  (extremely small)

Tooth Filling:  $\chi^2 = 15.32$ ,  $p = 0.0016$

Mann-Whitney U and Kruskal Wallis Test for

Gender:

U=11.00,  $p=0.4857$ , H=0.75,  $p=0.3865$

Age:

U=13.00,  $p=0.2000$ ) and H=2.08,  $p=0.1489$

Tooth Type:

U = 4.00,  $p=1.0000$  and H=0.05,  $p=0.8273$

Filling Type Comparison:

U=4.00,  $p=0.3333$  and H=2.40,  $p=0.1213$

Meta-regression for

a) Age (Young vs Old):

Young trend: slope=-19.72, intercept=69.28,  $R^2=0.8539$

Old trend: slope=5.89, intercept=5.49,  $R^2=0.5686$

b) Gender (Male vs Female)

Male trend: slope=12.86, intercept=27.01,  $R^2=0.3485$

Female trend: slope=11.68, intercept=15.73,  $R^2=0.6974$

**Table 1: Characteristics of Various Studies taken in Systematic Review and Meta-Analyses**

S No	Author, Year	Type and period of study	Place of study	Study characteristics
1	Ali M Almakrami <i>et al.</i> , 2018	clinical survey based on questionnaire, 3 months	Dental Specialist Center, Najran, KSA	
2	Saleh Abdullah Almeshari <i>et al.</i> , 2018	cross sectional	College of Dentistry, University of Hail, Saudi Arabia	
3	Carmen Llena <i>et al.</i> , 2020	retrospective observational study, 6 years	endodontics of the Universitat de València (Valencia, Spain)	The mean age of the included patients was 55.5 $\pm$ 16.43, ranging from 18–81 years old, with a gender distribution of 43.1% male and 56.9% female patients
4	Mohsin <i>et al.</i> , 2020	prospective study, 1 year	Endodontic Department in King Faisal Hospital, Makkah, in the Western region of Saudi Arabia	
5	Emma Wigsten <i>et al.</i> , 2021	questionnaire based study, 2 years 2 months	20 public dental clinics in the county of Västra Götaland, Sweden.	128 (52.7%) women and 115 (47.3%) men, with a mean age of 48.3 years (SD = 16.4).
6	M Mustafa <i>et al.</i> , 2021	retrospective, 6 months	3 different hospitals, Al-Kharj, Saudi Arabia	179 were males and 71 were females
7	Erika Laukkanen <i>et al.</i> , 2021	longitudinal, 2 years	Department of Social Services and Health Care of the City of Helsinki	mean age was 44.2 years (standard deviation [SD] 23.2). Of the 426 patients, 56% were female and 44% male
8	Sneha Rao <i>et al.</i> , 2023	observational cross-sectional, 1 year	Conservative Dentistry and Endodontics department, India	the mean age was 36.29 $\pm$ 12.28 years, ranging from 13 to 88 years. 41.6% of males and 58.4% of females were in the study group
9	Muhammad Ahmad <i>et al.</i> , 2024	cross-sectional, 7 months	Endodontic Department of Multan Medical and Dental College in Pakistan	104 participants, 65.3% (n=68) were identified as male, whereas 34.6% (n=36) were identified as female.
10	Y E Jang <i>et al.</i> , 2024	retrospective, 6 years	Department of Conservative Dentistry, Ewha Womans University Seoul Hospital, Seoul	175 participants, 76 male, 99 females, mean (SD) in yrs 48.75(16.1)

**Table 2: Failure Rates in Different Sub Groups**

S No	Author	Gender		Tooth Type		Age		Tooth Filling	
		Male (n%)	Female (n%)	Molar n (%)	Premolar n (%)	Young (n%)	Old (n%)	Under filling	Over filling
1	Saleh Abdullah Almeshari <i>et al.</i> , 2018							79 (39.5)	3 (1.5)
2	Mohsen <i>et al.</i> , 2020	79 (60.3)	52(39.7)	39 (29.8)	58 (44.3)	103 (78.6)	28 (1.4)	93 (71)	22 (16.8)
3	Carmen Llena <i>et al.</i> , 2020	18 (7.1)	35(11.1)	26 (7.6)	29 (11.3)				
4	M Mustafa <i>et al.</i> , 2021	179 (71.6)	71(28.4)			199 (39.8)	51 (20.4)	36.8	12.8

5	Erika Laukkanen <i>et al.</i> , 2021			63 (44.4)	43 (30.3)				
6	Sneha Rao <i>et al.</i> , 2023			67.6	14			17.8	1.5
7	Y E Jang <i>et al.</i> , 2024	30 (46.2)	35 (53.8)			33 (19)	42 (24)		
8	Muhammad Ahmad <i>et al.</i> , 2024					67 (21.36)			

**Table 3: Causes Related to RCT Failure Rates**

S No	Author	Missing canal	Instrument related	Coronal leakage/inadequate coronal restoration	Anatomic	Iatrogenic	Perforation
1	Ali M Almakrami <i>et al.</i> , 2018	10 (20%)	3 (6%)				2 (4%)
2	Saleh Abdullah Almeshari <i>et al.</i> , 2018	17 (8.5%)	2 (1%)	30 (15%)			7(1.75)
3	Mohsen <i>et al.</i> , 2020	21(16)		56(42.7)	2(3.1)	8(6.1)	
4	M Mustafa <i>et al.</i> , 2021	14.4	8.8				
5	Muhammad Ahmad <i>et al.</i> , 2024	4(1.9)	20(6.7)				
6	YE Jang <i>et al.</i> , 2024	OR-6.210 (1.836-21.007)	6 (9.2)		1.457		
7	Sneha Rao <i>et al.</i> , 2023			16.8			

**Table 4: Clinical Criteria Associated with Post RCT Failure**

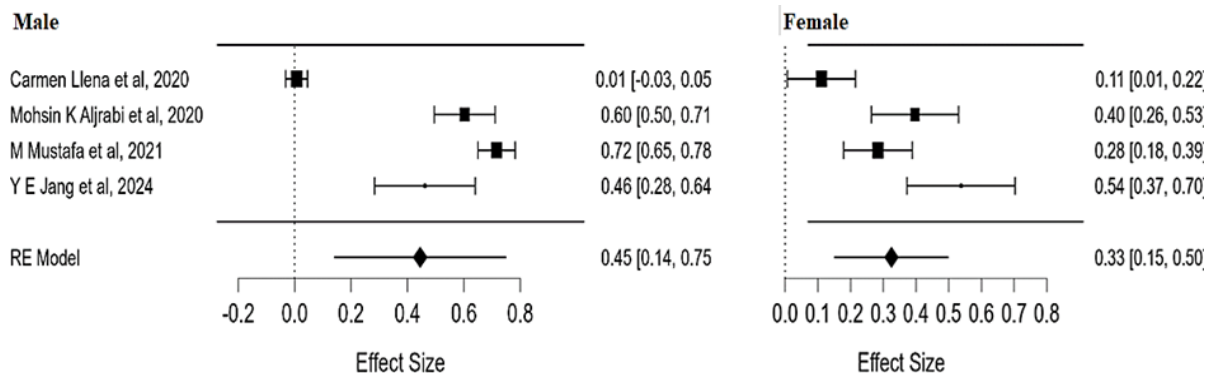
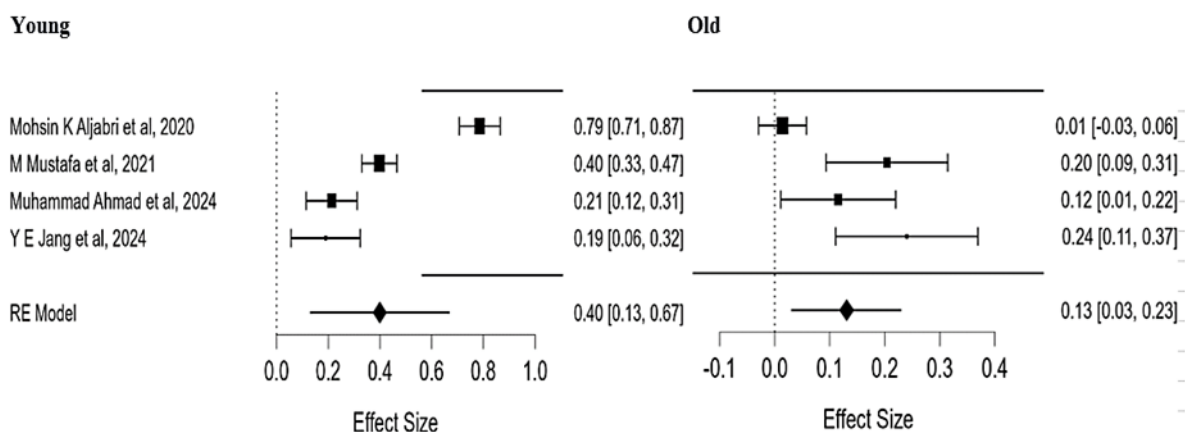
S No	Author	Pain	Pain with percussion	Swelling	Pain+ Swelling	Sinus	Swelling+ Sinus
1	Ali M Almakrami <i>et al.</i> , 2018	27 (54%)		0 (0%)	17 (34%)	6 (12%)	0 (0%)
2	Carmen Llena <i>et al.</i> , 2020	463 (92.8%)	17 (3%)			3 (0.5%)	
3	Emma Wigsten <i>et al.</i> , 2021	65.6					
4	Erika Laukkanen <i>et al.</i> , 2021	5 (4.2%)					
5	Muhammad Ahmad <i>et al.</i> , 2024	75 (70)		8(7.7)		7(6.7)	
6	Sneha Rao <i>et al.</i> , 2023	25 (10)	28 (11.2)		1(0.4)	1(0.4)	1(0.4)

**Table 5: Important Findings Suggested by Authors of Various Studies**

S No	Author	Important Findings
1	Ali M Almakrami <i>et al.</i> , 2018	Endodontic failures depend on the skill of the person who performed RCT
2	Saleh Abdullah Almeshari <i>et al.</i> , 2018	posterior teeth had more failure rates than anterior due to underfilling, Ni-Ti rotary instrument is better in RCT treatment and less iatrogenic
3	Mustafa <i>et al.</i> 2019	First molars were the most commonly affected tooth in the failure of endodontic treatment. Poor adjunctive treatment and inadequate filling of the root canals were the most common causes of endodontic failure, more commonly seen in male than female patients. Most of the failure cases were found in the age group of 26–45 years
4	Carmen <i>et al.</i> , 2020	The maximum period between RCTs and the placement of coronal restorations was 2 weeks, the instrumentation technique used in RCT, whether manual or rotary, may also influence its outcome, It is generally considered as “adequate” if the gutta percha filling extends 0–2 mm from the radiographic apex, teeth with a favourable coronal restoration have a 1.82 times higher probability of success than an unfavourable restoration. A greater periapical lesion size was also negatively associated with healing,
5	Mohsen <i>et al.</i> , 2020	endodontic treatment failures mostly occurred in under filled root canals, followed in number by coronal leakage. Premolars had a higher failure rate than did anterior and molar teeth
6	Erika Laukkanen <i>et al.</i> , 2021	RCTs were more likely to succeed in non-molars , in teeth with optimal root fillings and in teeth without apical periodontitis. Improvement is needed in quality of RCTs by GDPs.
7	Emma <i>et al.</i> , 2021	The main diagnoses were pulpal necrosis with apical periodontitis (n = 90, 38.1%) or pulpitis (n = 89, 37.7%). Molar teeth predominated (n = 116, 47.7%).
8	Sneha Rao <i>et al.</i> , 2023	Maximum primary root canal treatment failure was noted in molars, quality of obturation is a prognostic factor determining endodontic treatment outcome, endodontic treatment failures mostly occurred in under filled root canals and poorly sealed post-endodontic coronal restoration, along with association with peri-apical radiolucency
9	Muhammad Ahmad <i>et al.</i> , 2024	The mandibular first molar had the greatest endodontic treatment failure rate. Poor coronal seal and under filled root canal caused most root canal failures.
10	Y E Jang <i>et al.</i> , 2024	The presence of untreated additional canals was a predictor of endodontic failure within 5 years following initial root canal treatment

**Table 6: Strengths and Gaps of Various Studies Author Wise**

S No	Author	Limitations	Strengths
1	Ali M Almakrami <i>et al.</i> , 2018	Low sample size	The relationship between skills of the practitioner, canal obturation technique and endodontic failure has been highly stressed upon
2	Saleh Abdullah Almeshari <i>et al.</i> , 2018	Electronic apex locator and rotatory nickel titanium instruments were not used	Strong association between posterior underfilling and endodontic failure was established
3	M Mustafa <i>et al.</i> , 2019	Retrospective nature might lead to missing data	stress was laid upon improvement of endodontic treatment skill, also first molar was found to be associated with RCT failure most often
4	Carmen Llana <i>et al.</i> , 2020	Retrospective study might lead to missing data	Lots of associations and key findings were presented in the study
5	Mohsen <i>et al.</i> , 2020	The accuracy of the prognostic aspects for tooth survival was quite feeble. Thus, the need was emphasized for long-term prospective research and studies with thorough and in-depth data to delve more into factors for RCT development.	Correlation between premolars and endodontic treatment failure was established
6	Erika Laukkanen <i>et al.</i> , 2021	Variation in the clinical experience of the GDPs may lead to variable findings	longitudinal study
7	Emma <i>et al.</i> , 2021	Small sample size	The results emphasized on further clinical observational studies of RCTs with special reference to patient- centred outcomes.
8	Sneha Rao <i>et al.</i> , 2023	Cross sectional nature of study	Strong correlation between periapical radiolucency and under filled canal with RCT failure was depicted
9	Muhammad Ahmad <i>et al.</i> , 2024	Cross-sectional study	Positive correlation between mandibular first molar and endodontic failure was established
10	Y E Jang <i>et al.</i> , 2024	The retrospective nature and clinical heterogeneity of our data and limited potential causative factors	missed canal is predictive of early endodontic failure (i.e., within 5 years)

**Figure 2 a). Forest plot for RCT failure in male vs female****Figure 2 b): Forest plot for RCT failure in young vs old**

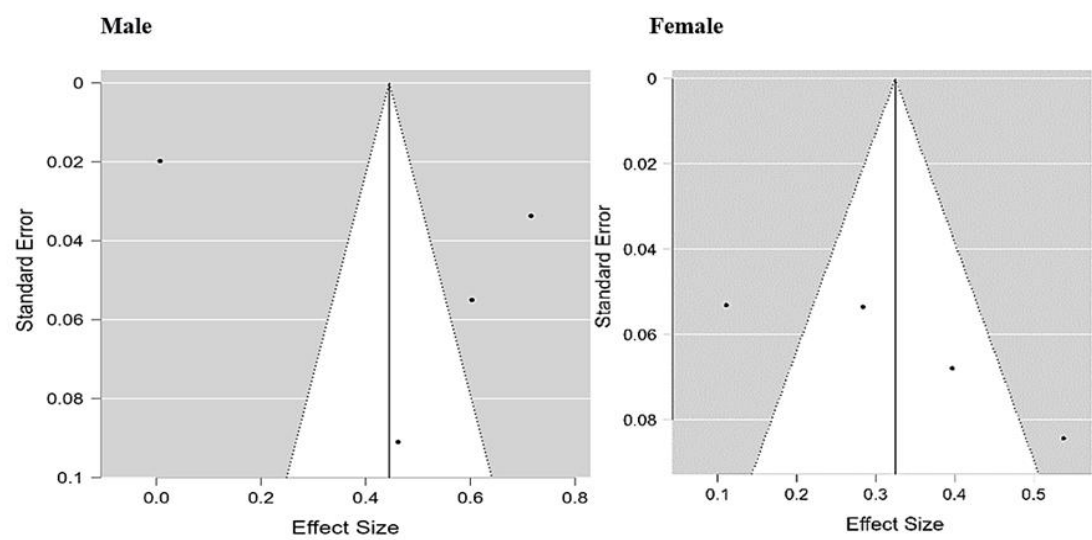


Figure 3 a): Funnel plot for RCT failure in male vs female

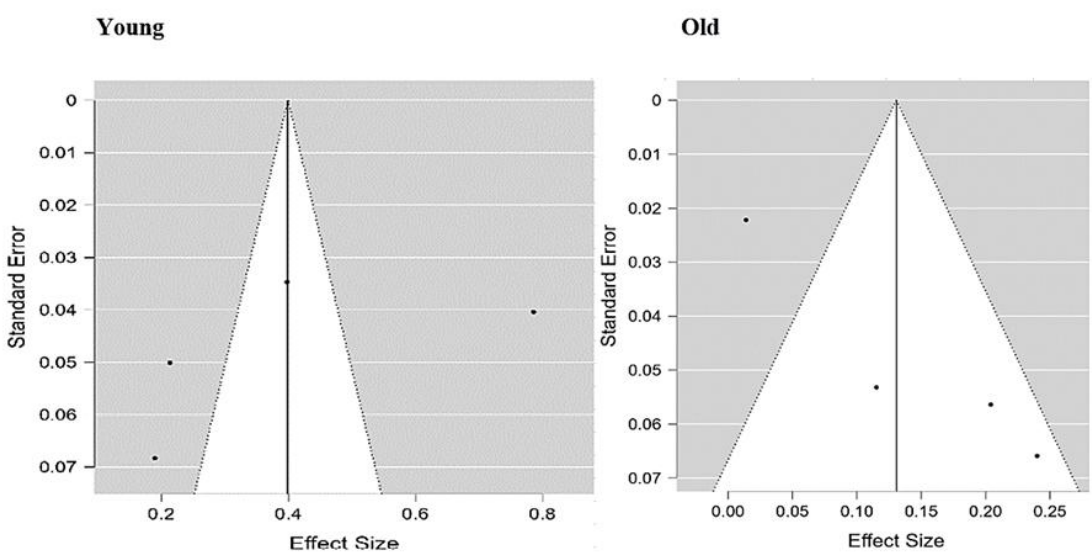


Figure 3 b) Funnel plot for RCT failure in young vs old

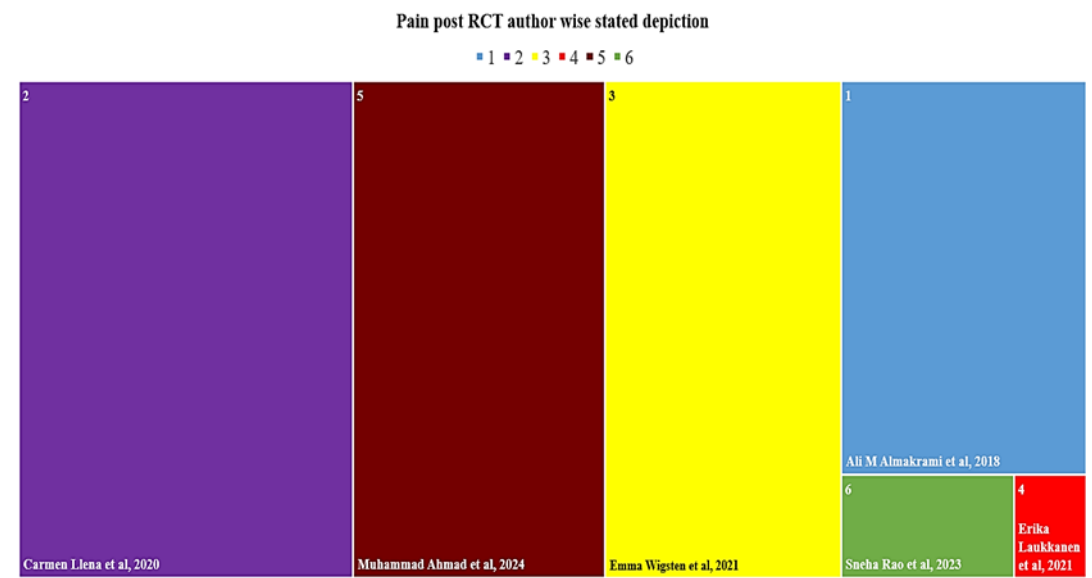


Figure 4: Treemap for pain post RCT depicted author wise



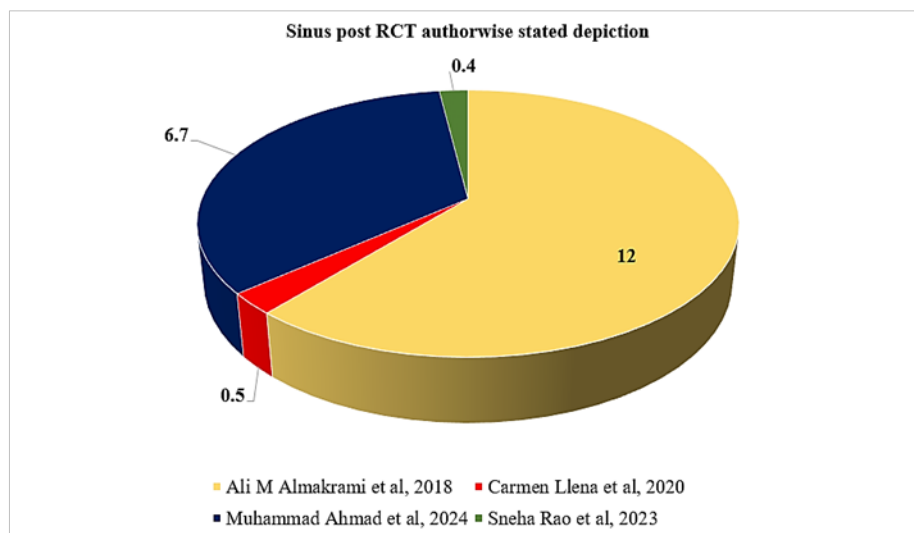


Figure 5: Post RCT sinus author wise report

## Discussion

We have analysed the influence of age on RCT treatment failure. The young patients showed higher failure than the elderly with a weighted average of 44.96% in young and 15.94% in old. However, this was contradicted by a study (Chatzopolous GS *et al.*, 2018). Both Mann Whitney U Test and Kruskal Wallis Test showed no difference in the failure rate between age groups.

The data suggested notable difference in gender with males showing higher failure rate than females with an average of 62.4% for males vs 32.91% for females. This is depicted in another study (Thyvalikakath T *et al.*, 2022). Mann Whitney U Test ( $p = 0.4857$ ) and Kruskal Wallis Test ( $p = 0.3865$ ) showed  $p$  value greater than 0.5 indicating no significant difference. Overall result of meta regression analysis depicted no significant difference in failure rate across subgroups (gender, age, tooth filling and tooth type).

The  $p$  value for Pearson Chi Square Test was much lower than 0.05 showing significant correlation. Molar depicted higher odds of failure with an OR of 0.93 in comparison to premolar. Contradictory statement was reported by a study (Wang FM *et al.*, 2023). Mann Whitney U Test ( $p = 1$ ) and Kruskal Wallis Test ( $p = 0.8273$ ) showed very similar failure distribution.

Both Mann Whitney U Test ( $p = 0.7$ ) and Kruskal Wallis Test ( $p = 0.513$ ) showed no significant difference for maxilla vs mandible supported by Chi Square Test ( $p = 0.262$ ). Maxilla had higher failure rate with an OR of 1.124 in comparison to mandible. Another author corroborated on this observation (Katie E *et al.*, 2024).

The  $p$  value 0.0016 for filling type was less than 0.05 indicating positive correlation between filling type and failure rate. Under filling showed a very high odds ratio of failure with an OR of 12.26 when compared to overfilling. The contradiction was elucidated upon by another author (Zargar N *et al.*, 2024). While, Mann Whitney U Test ( $p = 0.3333$ ) and Kruskal Wallis Test ( $p = 0.1213$ ) showed no significant difference. However, the trend suggested higher failure in under filling.

The failure due to anatomical causes was noted in two of our studies (Aljabri MK *et al.*, 2020; Jang YE *et al.*, 2024) (Table 3). Similar observation was noted in another study (Versiani MA *et al.*, 2023). The iatrogenic failure was also noted in a study (Aljabri MK *et al.*, 2020). Another author observed similar findings with iatrogenic factor as the main cause (Al Yahya RS *et al.*, 2023). Tooth fracture was also noted in a study. Coronal leakage was also reported as a failure by three studies (Main Ri, 2018; Aljabri MK *et al.*, 2020; Rao S *et al.*, 2023). This was stressed upon in another study (Usri K

*et al.*, 2023). The potential causes for endodontic failure were obturation quality, inadequate coronal status, missed canal and anatomical delta. Missing canal with an average of 12.6% and instrument related causes with an average of 6.3% were noted in our review. The C shaped canal usually found in mandibular and second molar leads to failure. Further now days CBCT (cone beam computed tomography) conducted for determining RCT failure is trending and most commonly adopted (Mirza MB *et al.*, 2022). Periapical radiolucency was found to be an indicator of failure for RCT as majorly reported by a study (Almakrami AM *et al.*, 2018). This was reported by another study (Barati S *et al.*, 2023). Pain was noted in post RCT as an indicator for failure with an average of 49.4% (Figure 4). We observed an average of 4.9% for sinus as post RCT failure cause (Figure 5 and Table 5).

The important findings as well as strengths and gaps of various studies taken in our systematic review and meta-analyses were tabulated (Table 6 and 7).

## Conclusion

This study aims to evaluate various factors among the few patients who are majorly affected by the failure and to prevent failure among these patients who have no other method for tooth preservation. In dentistry, machine learning has been used for detecting apical periodontitis, proximal caries even alveolar bone loss on radiographs for diagnosis, and treatment, this unique feature may bring a solution to this problem in future, RCT is a non-surgical conservative, non-expensive, affordable mode of treatment which is offered to a common man to preserve the functional tooth throughout his life time. It is an acceptable mode of treatment. In future further research may open up new additional methods to reduce the failure rate, thanks to AI new innovative techniques may be developed to make a difference with life style of a common man. Finally, the RCT can be considered as a reliable, popular long term choice for preservation of the tooth. Further there must be specific skills, required to do RCT and proper training should be provided to trainees in the instrumentation to avoid common errors in procedures like manual and rotatory instrumentation in molar RCT treatment requires intensive training and supervision.

## Strength and limitations

Multifactorial analysis was done for RCT treatment failure and establishing relationships with various statistical tests and techniques for meta-analyses. However, the study had its own

limitations. The period for review was short with a time span of seven years and the sample size was considerably small. High heterogeneity was also observed.

## Declaration

## Acknowledgments

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## Conflicts of interest

The authors report no conflict of interest.

## Ethical approval

Not Required since the study was a systematic review and meta-analysis

## Consent to publication

Not applicable

## Availability of supporting data

Not applicable as the study is a systematic review and meta-analyses.

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