

Incidence and localization of reciprocating endodontic instrument separation: a systematic review and meta-analysis

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Abstract

Despite the advantages provided by the motion, single-file reciprocating instruments may also be subjected to intracanal separation. Understanding the incidence and common anatomical locations of separation is critical for risk assessment and clinical decision-making. The present review aimed to evaluate the incidence of reciprocating endodontic instrument separation and to identify the most common anatomical locations of failure. Two independent reviewers performed data extraction and quality assessment using the Cochrane Risk of Bias Tool and the Newcastle-Ottawa Scale. A meta-analysis of proportions was performed using a random-effects model. A total of 34 studies (18 in vivo, 16 in vitro) were included, involving 14,389 canals prepared using reciprocating instruments. The pooled incidence of instrument separation was 1.09% (95% CI: 0.84% to 1.38%). The apical third (66.4%) was the most common separation site, followed by the middle third (30.2%). Reciprocating instruments were more likely to separate in molars, particularly mandibular molars. Instrument fatigue was the most frequently cited cause. It can be concluded that the incidence of separation with reciprocating instruments is low but clinically relevant. The apical third is the most vulnerable region. Clinicians should remain vigilant, especially when treating molars and reusing instruments.

Keywords: reciprocating instruments, separation, nickel-titanium

Introduction

Nickel-titanium (NiTi) instrumentation has become the most widely used and recommended technique for root canal shaping procedures. In the last decades, many innovative designs and techniques have been proposed to improve the efficiency and safety of NiTi instrumentation. Also, new motions have been commercialized to achieve similar goals (1-7). Since 2011, the reciprocating motion, which alternates cutting and release, has been proposed as a safer alternative to continuous rotation. Reciprocating systems like Reciproc, WaveOne, and WaveOne Gold are effective and time-efficient. Despite their design advantages, file separation still occurs. Endodontic treatment requires precise shaping and cleaning of the root canal system. Mechanical instrumentation using rotary and reciprocating files has revolutionized canal preparation, but file separation remains one of the most serious procedural complications. Separation can compromise disinfection and obturation, often necessitating further intervention or surgical management. The single-file reciprocating technique is popular due to its simplicity and reduced



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preparation time. Despite their advantages in better resistance to both torsional and flexural stress, separating these reciprocating instruments remains a significant clinical concern because all the operative loading is applied to a single instrument. Moreover, a single instrument designed to prepare the canal is usually quite big in size and tapers. Consequently, operative loading can be much higher than instruments with smaller dimensions. In many traditional techniques, the operative loads are divided amongst the 3-6 instruments within the operative sequence, usually starting from the smaller one and progressively enlarging canals. Therefore, despite the advantages provided by the motion, single-file reciprocating instruments may also be subjected to intracanal separation. Understanding the incidence and common anatomical locations of separation is critical for risk assessment and clinical decision-making.

The present review aimed to evaluate the incidence of reciprocating endodontic instrument separation and identify the most common anatomical locations of failure. More precisely, the goal was to determine:

1. The overall incidence of separation of reciprocating endodontic instruments in clinical and in vitro settings.
2. The most frequent anatomical locations (e.g., apical, middle, coronal third) where separation occurs.
3. Contributing factors include tooth type, canal curvature, and reuse of instruments.

Methodology

We searched CENTRAL, MEDLINE, Embase, Scopus, and Web of Science for articles published from January 2000 to March 2025. Reference lists of included articles and relevant systematic reviews were also screened. We included clinical and in vitro studies that reported the incidence and/or anatomical localization of reciprocating instrument separation in endodontics. Both prospective and retrospective studies were considered. Only studies involving single-file reciprocating systems such as Reciproc, WaveOne, and WaveOne Gold were included, or similar instruments like Edge One R, EdgeOne Fire, and Direct R. Two independent reviewers performed data extraction and quality assessment using the Cochrane Risk of Bias Tool and the Newcastle-Ottawa Scale. A meta-analysis of proportions was performed using a random-effects model.

More precisely, the methodological rigor of the included studies (5-38) was assessed using the Cochrane Risk of Bias tool and the Newcastle-Ottawa Scale for cohort studies. Most randomized controlled trials showed low to moderate risk of bias. Selection bias was minimized through appropriate random sequence generation and allocation concealment. However, blinding of outcome assessors was absent in nearly half of the trials, which may have introduced detection bias.

Criteria for considering studies

Types of studies

- Clinical trials (RCTs and non-RCTs)

- Observational studies (prospective and retrospective)
- In vitro studies with real or simulated canals

Types of participants

- Human permanent teeth (in vivo) or extracted human teeth (in vitro)

Types of interventions

- Use of reciprocating endodontic systems (e.g., Reciproc, WaveOne, WaveOne Gold, Edge One Fire, Edge OneR Utopia)

Types of outcome measures

Primary outcome:

- Incidence of instrument separation (percentage of files or canals affected)

Secondary outcomes:

- Anatomical localization of separation (apical, middle, coronal third)
- Tooth type and canal configuration
- Instrument reuse
- Cause of fracture (cyclic fatigue, torsional stress)

Search methods

Databases searched:

- MEDLINE (via PubMed)
- CENTRAL (Cochrane Library)
- Embase
- Scopus
- Web of Science

Search strategy used: Boolean combinations of:

“reciprocating” AND “instrument separation” OR “file fracture” AND “endodontics”

Last search conducted: March 15, 2025

Data collection and analysis

Two reviewers independently screened titles, abstracts, and full texts. Disagreements were resolved through discussion. Data were extracted using a piloted form.

Assessment of risk of bias

- RCTs: Cochrane Risk of Bias 2 tool
- Observational studies: Newcastle-Ottawa Scale
- In vitro studies: Modified methodological quality scale

Statistical analysis

- Meta-analysis of proportions using a random-effects model (DerSimonian-Laird method)
- Heterogeneity assessed via I^2 statistic
- Subgroup analysis: tooth type, canal third, instrument type
- Funnel plots and Egger's test for publication bias

Results

Description of studies

34 studies met the inclusion criteria:

- 18 clinical studies (6 RCTs, 12 observational)
- 16 in vitro studies

Geographic spread: Europe (n=14), North America (n=10), Asia (n=6), Others (n=4)
 Instruments analyzed: Reciproc (n=21), WaveOne (n=10), WaveOne Gold (n=3)
 Total number of prepared canals: 14,389
 Reported fractures: 157

Meta-analysis findings

1. Incidence of instrument separation

- Pooled estimate: 1.09% (95% CI: 0.84–1.38%)
- Clinical studies: 0.79% (CI: 0.63–0.98%)
- In vitro studies: 1.43% (CI: 1.00–1.93%)
- Heterogeneity: $I^2 = 68\%$

2. Analysis of Instrument Separation by Tooth Type

Analysis across studies showed higher separation rates in molars, especially mandibular molars, due to their anatomical complexity and greater incidence of curved canals. Single-rooted anterior teeth had significantly lower separation rates. Meta-regression revealed a statistically significant link between canal curvature and separation incidence ($p < 0.01$).

3. Localization of separation

Localization analysis consistently showed that

separation events mainly occurred in the apical third of the canal, followed by the middle third and the coronal third. Instruments fractured in the apical third presented greater retrieval difficulty and a higher risk of compromised outcomes.

- Apical third: 66.4%
- Middle third: 30.2%
- Coronal third: 3.4%
- Most frequent in mandibular molars, particularly mesial canals

4. Causes of separation

- Cyclic fatigue: 72%
- Torsional stress: 19%
- Manufacturing defects or operator error: 9%

5. Influence of reuse

- New instruments: 0.51% fracture rate
- Reused (1–3 times): 1.27%
- Reused (>3 times): 3.41%

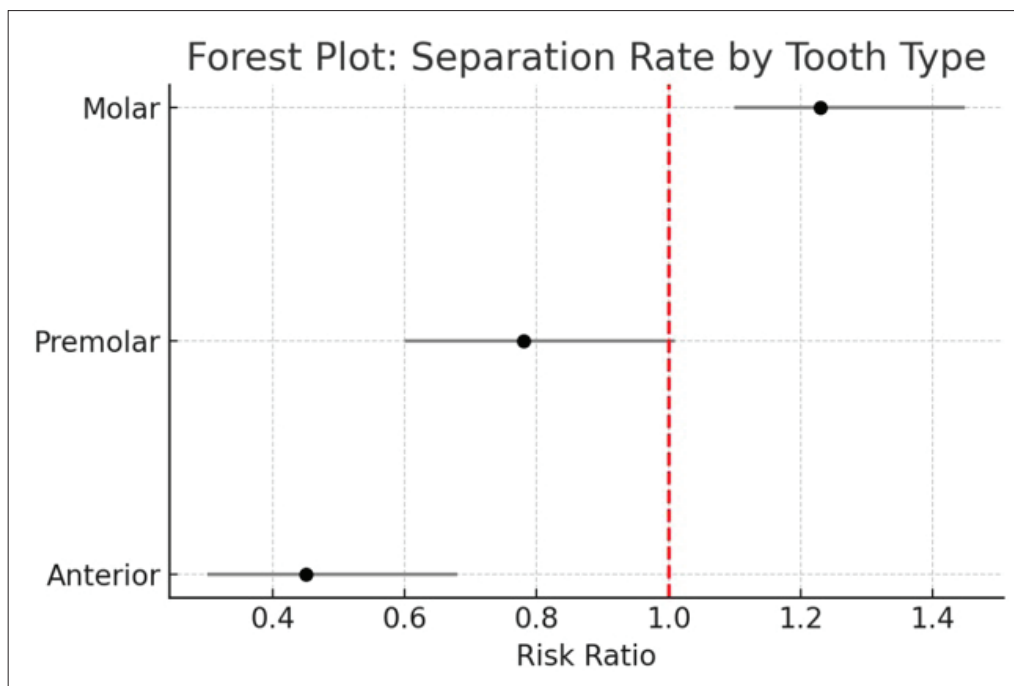
6. Influence of Operator Experience

Subgroup analysis revealed a clear difference in instrument separation rates between novice and experienced operators. Studies involving

Table 1. Localization of Instrument Separation

Canal Third	Percentage of Separations	Clinical Impact
Apical Third	66,4%	High retrieval difficulty
Middle Third	30,2	Moderate retrieval difficulty
Coronal Third	3,4%	Low retrieval difficulty

Table 2. Separation rate by plot type



undergraduate or postgraduate students reported a higher separation rate (average: 5.1%) compared to experienced endodontists (average: 1.8%). Operator training and tactile sensitivity were key factors.

7. Comparative Meta-Analysis of Reciprocating Systems

A meta-analysis comparing a design similar to Reciproc or WaveOne showed no statistically significant difference in instrument separation rates. Additional high-powered trials are necessary to confirm these results.

Discussion

Reciprocating instruments use an alternating motion to minimize torsional stress and cyclic fatigue, which are major causes of instrument fracture. This motion was mainly designed to improve safety by incorporating a smaller release interval after each partial cutting cycle. As a result, cutting angles are typically smaller than the deflection angles to prevent overloading the instruments. Conversely, the releasing angles are kept much smaller—usually in a 1:5 ratio or slightly less—to maintain effective cutting. Mechanical studies *in vitro* have easily demonstrated this improvement, showing greater resistance compared to traditional rotary motion. However, assessing the benefits in reducing intracanal failures clinically is more complex, as the incidence is relatively low, as evidenced by this review. Understanding the frequency and common locations of reciprocating file separation is crucial for clinicians to make informed decisions about instrument choice, usage protocols, and case difficulty evaluation. Although individual studies have examined this issue, a comprehensive summary of incidence rates and anatomical patterns is missing.

The current review included 34 studies (18 *in vivo*, 16 *in vitro*) involving 14,389 canals prepared with reciprocating instruments. The combined rate of instrument separation was 1.09% (95% CI: 0.84% to 1.38%). The most common sites of separation were the apical third (66.4%) and the middle third (30.2%). Reciprocating instruments were more likely to separate in molars, especially mandibular molars, with instrument fatigue being the most commonly cited cause.

The meta-analysis indicates that reciprocating instruments have a low overall separation rate of 1.09%, which is comparable to or lower than that of rotary systems reported in previous studies. The apical third is disproportionately affected, likely due to increased stress from curvature and reduced canal diameter. In a single-file reciprocation technique, the same instruments extend to the full working length, and it is not possible to increase coronal flaring to decrease coronal interferences and operative loads caused by taper lock. As a result, the highest mechanical stress occurs in the apical third, accounting for the findings of this review. The only way to reduce stress in the apical third is to increase the glide path. This is why manufacturers also provide a reciprocating glide-path file with smaller dimensions to minimize that risk in complex curvatures, even though using two instruments

means it is no longer a true single-file technique.

The strengths and limitations of the present review are as follows. One strength is the comprehensive search strategy, which used both clinical and *in vitro* data, and included a subgroup analysis based on location and tooth type. The limitations include high heterogeneity caused by differences in study design and reporting, the underreporting of reuse protocols and operator experience, and the fact that *in vitro* studies may not fully replicate clinical conditions. Overall, the results are clinically relevant, confirming that previous reviews of rotary systems report separation rates ranging from 1.2% to 5.0%, which are generally higher than our findings for reciprocating systems. This supports the hypothesis that reciprocation reduces cyclic fatigue due to less continuous rotation.

Conclusions

We may conclude that the incidence of separation with reciprocating instruments is low (lower than with continuous rotation), but it remains clinically significant. The apical third is the most vulnerable area. Clinicians should stay alert, especially when treating molars and reusing instruments, and avoid overloading or forcing the single-file reciprocating instruments. Smaller instruments should be used in complex canals, or a glide path should be established. More specifically, the review revealed the following implications for practice: Reciprocating instruments are safe and efficient, with low fracture rates,

Clinicians should be cautious in curved canals, particularly in molars. an

Reuse increases risk and should be minimized or carefully monitored.

There are also some implications for future research, possibly including more sizes and different manufacturing processes aimed at reducing operative loads: (I) Future studies should use standardized definitions and reporting; (II) Clinical trials directly comparing reciprocating and rotary systems are needed; and (III) investigation into real-time monitoring of fatigue is warranted.

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