

# Fracture incidence of instruments from a single-file reciprocating system by students in an endodontic graduate programme: a cross-sectional retrospective study

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## Abstract

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**Aim** To assess the fracture incidence of instruments from single-file reciprocating systems when used by students in an endodontic graduate programme.

**Methodology** Dental records and periapical radiographs of patients treated by students on an endodontic graduate programme using reciprocating systems were assessed. Data on tooth type, number of treated root canals, number of fractured instruments, fragment size, angle, radius, arc length and position of root canal curvature where fractures occurred were tabulated for analysis. The risk of fracture was calculated for each group of teeth, root canal and root thirds, whilst the incidence of fractures reported for the reciprocating systems was compared using the chi-squared test at 5% significance level.

**Results** Overall, 2056 root canals (826 teeth) from 810 patients were included. The incidence of fractured files from single-file reciprocating systems in relation to a number of instrumented canals was 0.92%. Fracture rates of 0.84% and 0.93% were found in 830 and 1226 root canals instrumented with WaveOne and Reciproc systems, respectively. No significant differences were observed between the systems. The highest fracture rate was 52.6% in the mesiobuccal root of mandibular molars. The central angle, radius and arc length of the curvature of root canals where the instruments fractured ranged from 58° to 84°, from 1.7 to 7.2 mm and from 2.4 to 7.6 mm, respectively.

**Conclusion** The use of WaveOne and Reciproc single-file reciprocating systems in an endodontic graduate programme was associated with a low incidence of instrument fractures.

**Keywords:** endodontic graduate programme, fracture incidence, Reciproc, reuse, WaveOne.

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## Introduction

Although automated endodontic instruments have great flexibility, they may fracture during root canal

preparation (Sattapan *et al.* 2000, Parashos & Messer 2006), which in turn may influence the outcome of root canal treatment (Spili *et al.* 2005). The fracture of files involves many factors such as the experience of the operator, design and manufacturing process of the instrument, instrumentation technique and root canal configuration (Mandel *et al.* 1999, Parashos *et al.* 2004, Parashos & Messer 2006, Cheung 2009). Several clinical studies have reported a low incidence of fracture in single-file reciprocating systems when

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instrumentation is performed by experienced endodontists (Cunha *et al.* 2014, Plotino *et al.* 2015, Shen *et al.* 2016, Bueno *et al.* 2017). A comparison between experienced endodontists and students of an endodontic graduate programme was conducted by Shen *et al.* (2016), who reported a low risk of fracture in both groups when WaveOne files were used. Considering that there are no studies evaluating the fracture incidence of reused single-file reciprocating systems by students, the purpose of this study was to assess the fracture incidence of single-file reciprocating instruments during clinical root canal treatment performed by students in an endodontic graduate programme.

## Materials and methods

The study was approved by the local research ethics committee (protocol number 1.946.968) and follows the recommendations of the STROBE statement for observational epidemiology studies (Von Elm *et al.* 2008).

This cross-sectional retrospective study used dental records and radiographs of patients treated by 24 students of an endodontic graduate programme within a 24-month period. All the patients approved the use of their dental records for the study, but only those treated with reciprocating systems were selected. All the students included in the study had an initial experience with single-file reciprocating systems, as they received preclinical training that consisted of the instrumentation of four extracted teeth of each tooth type using WaveOne (Dentsply Sirona, Ballaigues, Switzerland) and Reciproc (VDW GmbH, Munich, Germany) systems. All students were trained to access root canals following a straight line to the orifices, and perform an initial glide path using a size 15 K-file. Next, the coronal third of the root canal was prepared using a reciprocating file with three pecking motions and subsequent irrigation with 2.5% sodium hypochlorite. The middle third was prepared in the same manner, and the working length was established 1 mm short of the apical foramen before preparation of the apical third according to the previous steps. After each use, the students checked the instrument at 8× magnification, and in the case of any plastic deformation, the file was discarded. In the absence of alterations, the files were washed with detergent and then submitted to ultrasound before being sterilized in an autoclave for reuse in a maximum of six root canals. Before the reuse of the file, the heat-expanded ring was carefully removed using

a sterile scalpel blade. If the handle was affected during the ring removal, the instrument was discarded.

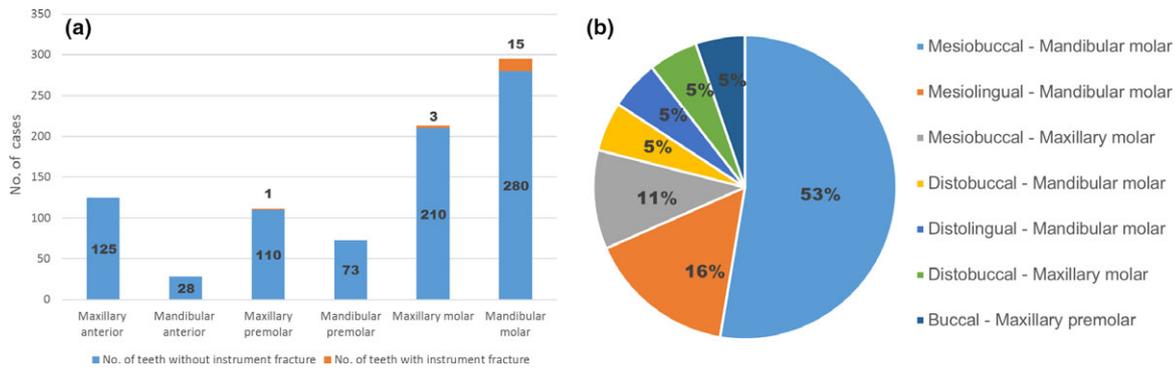
Data on tooth type, number of treated root canals, type of reciprocating single file used and number of fractured files were tabulated for incidence analysis. Periapical radiographs of the root canals with fractured instrument were evaluated for size and localization of the fragment and for determination of the angle and radius of curvature of the root canal according to the method proposed by Pruett *et al.* (1997). Additionally, the arc length and the position of root canal curvature where the instrument fractured were recorded.

The risk of fracture was calculated according to tooth type, root canal and root thirds, whilst the incidence of fracture in the WaveOne and Reciproc systems was compared using chi-squared test at a 5% significance level.

## Results

A total of 966 root canal treatments involving 920 patients were performed during a 24-month period, with 140 teeth being excluded because other conventional rotary systems had been used for their treatment. Therefore, a total of 2056 root canals in 826 teeth (153 anterior teeth, 183 premolars, 490 molars) were instrumented using single-file reciprocating systems. In the study period, no instrument was discarded with plastic deformation or alteration of the handle, but 11 and 8 files fractured in the first and the subsequent 12-month period, respectively. No significant differences were observed between both periods of study ( $\chi^2 = 0.95$ ,  $P = 0.3297$ ).

The fracture incidence of files in relation to the number of root canals was 0.92%, with the mesiobuccal canal of mandibular molars having the greatest incidence (53%). The risk of fracture of files in mandibular molars was five times higher than in maxillary molars ( $\chi^2 = 10.84$ ,  $P = 0.001$ ), whereas this risk was twice more likely to occur in the mesiobuccal root canal than in other root canals of mandibular molars ( $\chi^2 = 7.93$ ,  $P = 0.004$ ) (Fig. 1). As for the localization of the fragment inside the root canal, 74% of the fractures occurred in the apical third and 26% in the middle third. The length of the fractured segments ranged from 2 to 6 mm, with the greatest incidence of 5-mm fragments (47%). The central angle, radius and arc length of the curvature of root canals where the instruments fractured ranged from 58° to 84°, from 1.7 to 7.2 mm and from 2.4 to 7.6 mm, respectively (Table 1).



**Figure 1** Distribution according to tooth type (a) and root canals (b) where instrument fracture from a single-file reciprocating systems occurred.

**Table 1** Fracture instrument data

System	File	Tooth number	Root canal	Fracture location third	Fractured segment length (mm)	Root canal curvature			
						Angle <sup>a</sup> (°)	Radius <sup>a</sup> (mm)	Arc length (mm)	Arc location third
WaveOne	Small	36	ML	Middle	5	83	3.8	5.5	Middle
		14	B	Apical	3	68	2.2	2.6	Apical
	Primary	27	MB	Apical	2	64	1.7	1.9	Apical
		46	ML	Apical	5	62	6.7	7.2	Middle
		38	ML	Apical	5	68	4.4	5.2	Middle
		46	MB	Apical	3	70	2.2	2.7	Apical
Reciproc	R25	46	MB	Apical	3	66	2.4	2.8	Apical
		16	MB	Apical	5	84	2.4	3.5	Apical
		27	DB	Apical	5	68	3.2	3.8	Apical
		46	MB	Apical	5	64	5.4	6	Middle
		47	MB	Middle	5	72	4.7	5.9	Middle
		47	MB	Apical	2	60	2.3	2.4	Apical
		47	MB	Apical	3	80	3.6	5	Apical
	R40	48	MB	Apical	2	58	2.8	3.6	Apical
		36	MB	Middle	6	74	5.9	6.3	Middle
		36	MB	Middle	6	60	7.2	7.6	Middle
		37	MB	Middle	5	62	4.4	4.8	Middle
		46	DB	Apical	3	77	2	2.7	Apical
		46	DL	Apical	5	66	4.3	5	Apical

ML, mesiolingual; MB, mesiobuccal; DL, distolingual; DB, distobuccal; B, buccal; mm, millimetre; °, degrees.

<sup>a</sup>Measurement results of root curvature according to Pruett *et al.* (1997).

A total of 132 WaveOne files and 196 Reciproc files were used for preparation of up to six root canals without fracture failure. Therefore, 837 and 1238 roots canals were instrumented with WaveOne and Reciproc files, respectively. Fractures occurred in seven (0.84%) WaveOne and 12 (0.93%) Reciproc files, but there was no significant difference between the systems ( $X^2 = 0.1$ ,  $P = 0.7518$ ). The range and mean use of the fractured instruments was 2–6 and 4.6 root canals, respectively.

As for the WaveOne system, the fracture incidence was the greatest for the primary file (71%), followed

by the small file (29%), and no fracture was detected in the large file. As for the Reciproc system, the fracture incidence was the greatest for the R25 file (83%), followed by the R40 file (17%), and no fracture was detected in the R50 file.

### Discussion

The alloy for endodontic instruments, as well as their design and instrumentation technique, have been modified in order to make them more resistant to fracture (Glossen *et al.* 1995, De-Deus *et al.* 2010,

Shen *et al.* 2013, Kiefner *et al.* 2014). However, the fracture of automated Ni-Ti instruments might occur during root canal preparation unexpectedly (Parashos *et al.* 2004, Spanaki-Voreadi *et al.* 2006, Cunha *et al.* 2014, Plotino *et al.* 2015, Shen *et al.* 2016, Bueno *et al.* 2017). The results of the present cross-sectional retrospective study have shown a low number of fractured instruments in two single-file reciprocating systems when used by students of an endodontic graduate programme in up to six root canals.

Root canal preparation using a single Ni-Ti instrument simplifies the treatment (De-Deus *et al.* 2010). Initially, the students had no experience with reciprocating systems, and for this reason, they undertook preclinical training using this technique for 128 h on extracted teeth. Nevertheless, no significant differences were observed in fracture incidence of files in treatments performed by the first cohort and the second cohort.

The fracture incidences of files for root canals and teeth treated were 0.92% and 2.3%, respectively. The number of root canals varies according to tooth type, and for this reason, the fracture incidence should consider the number of root canals as it is more accurate than considering the number of teeth treated (Wu *et al.* 2011). Studies show fracture incidences of rotary files in an endodontic graduate programme based on the number of root canals, ranging from 0.82% (Di Fiore *et al.* 2006) to 1.33% (Tzanetakis *et al.* 2008). This incidence is in accordance with the present study. Only one study evaluated the risk of fracture of WaveOne files during instrumentation by postgraduate students, reporting a low (0.5%) fracture incidence (Shen *et al.* 2016). However, these authors evaluated the number of WaveOne files fractured after single use without considering the number of teeth or root canals treated, thus making it difficult to compare their results with those of the present study.

The fracture incidence of single-file reciprocating systems when used by endodontists ranges from 0.13% to 0.21% (Cunha *et al.* 2014, Plotino *et al.* 2015) when used only once, and up to 0.26% when reused (Bueno *et al.* 2017). A greatest fracture incidence in the present study may be explained by the clinician's skill level, and some findings have demonstrated that clinical experience is a factor that can influence the incidence of fractured instruments (Mandel *et al.* 1999, Parashos *et al.* 2004).

Several laboratory studies have been conducted to assess the fracture resistance of WaveOne and Reciproc systems (Kim *et al.* 2012, Plotino *et al.* 2012, Ha

*et al.* 2015, Silva *et al.* 2016). These studies are important to determine factors that can influence this resistance, but clinical observations have led to more valid interpretations. In the present analysis, variables such as the tooth type, angle and radius curvature, length and diameter of root canal were not standardized for determining the incidence of fractured single-file reciprocating systems in a clinical setting. Laboratory studies revealed that reciprocating motion results in greater resistance to fatigue than continuous rotary motion (De-Deus *et al.* 2010, Kiefner *et al.* 2014). The present study has shown a fracture incidence of 0.92% for single-file reciprocating systems, a finding corroborated by Iqbal *et al.* (2006) and Tzanetakis *et al.* (2008), who reported fracture incidences of 0.67% and 0.82% for continuous rotary systems, respectively, thus demonstrating the contradictory results between *in vivo* and laboratory studies.

Fractures occurred in only seven WaveOne and 12 Reciproc instruments during the study period, and the comparison between both systems revealed no significant difference, which is in accordance with previous findings (Bueno *et al.* 2017). These data are contrary to fatigue tests that have reported superiority of the Reciproc system (Kim *et al.* 2012, Plotino *et al.* 2012). This discrepancy may be explained by the varying conditions between *in vivo* and laboratory studies.

The greatest fracture incidence was observed in the apical third of the mesiobuccal root canal of mandibular molars. This result is similar to other studies (Iqbal *et al.* 2006, Tzanetakis *et al.* 2008, Cunha *et al.* 2014, Bueno *et al.* 2017), which was expected because of the anatomical complexity of such root canals as they have double curvatures, which are not always detectable radiographically, especially in the apical third (Sattapan *et al.* 2000). The most frequent size of the fragment was 5 mm, which is in accordance with other studies reporting that fracture of Ni-Ti instruments occurred more often near to the instrument's tip (Sattapan *et al.* 2000, Zelada *et al.* 2002, Shen *et al.* 2016). As for the curvature of roots canals where instruments fractured, fracture occurred in canals with a radius of curvature <3 mm in the apical third (42.1%) and with an arc length of curvature greater than 5 mm in the middle third (42.1%). These results are corroborated by laboratory studies, showing an increased level of stress on instruments as the radius decreases and the arc length increases, with the arc being located in the middle and coronal portions of the root canal (Pruett *et al.* 1997, Necchi *et al.* 2008, Lopes *et al.* 2013).

The manufacturer recommends the single use of reciprocating files based on two points: reduction in cross-infection and damage to the file during root canal preparation. As for the possibility of cross-infection in reused endodontic files, the primary reason for this was the risk of variant Creutzfeldt–Jakob disease (vCJD) transmission via their reuse, according to the Department of Health of the United Kingdom (2007). However, a special committee of the American Association of Endodontics and the Canadian Academy of Endodontics concluded that the risk of vCJD was insufficient to recommend the single use of endodontic instruments because of the very low risk of prion transmission to patients during endodontic treatment (Hartwell *et al.* 2011). The Australian and New Zealand Academy of Endodontists (Messer *et al.* 2003) also denies through scientific evidence the possibility of cross-infection through the single use of endodontic files. On the other hand, the lifespan of instruments used in reciprocating motion has been proven to be longer than that of continuous rotation (De-Deus *et al.* 2010, Kiefner *et al.* 2014) and it was also reported that it is possible to perform instrumentation of up to nine root canals using single-file reciprocating systems with no failure (Caballero *et al.* 2015). In this way, the reuse of reciprocating files has had reasonable results as it is a common practice adopted in many countries around the world for economic reasons (Bueno *et al.* 2017). In the present study, all root canal treatments were performed by reusing sterilized files for a maximum of six root canals, thus demonstrating the possibility of multiple use of reciprocating single files with a low fracture rate. This approach is comparable to studies investigating the single use of these endodontic systems by undergraduate students (Shen *et al.* 2016) and their reuse by experienced endodontists (Bueno *et al.* 2017).

Because of the limited information available for cross-sectional retrospective studies using a database, it suggests that prospective clinical randomized studies should be conducted to further investigate the findings of this study.

## Conclusion

The use of WaveOne and Reciproc systems in an endodontic graduate programme was associated with low incidence of fracture for both systems.

## Conflict of interest

The authors have stated explicitly that there are no conflict of interests in connection with this article.

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