The incidence of nickel-titanium endodontic hand file fractures: A 7-year retrospective study in a tertiary care hospital

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Abstract

Aim: The present retrospective cross-sectional study aims to evaluate the incidence and factors associated with nickel-titanium hand file fractures in root canal-treated teeth in a tertiary care hospital of western India.

Methodology: The diagnostic records of intraoral periapical (IOPA) radiographs were analyzed to check for file fractures in the root canal-treated teeth. As a part of standardized departmental protocol, Hand ProTaper Universal file system (Dentsply, India) was used for chemomechanical preparation for root canal treatment. The file fractures were analyzed with reference to age group, type of teeth, curvature of the canal, site of file fracture in the canal, length of file fracture, level of file fracture, distance of the file fracture from the apex, and obturation status of the file-fractured tooth. Chi-square test was applied to assess the significance difference between the tested groups.

Results: A total of 19,810 IOPA X-rays were screened and 2728 root canal-treated teeth were found and of these 2728 cases, 109 file-fractured teeth were observed.

Conclusion: The total incidence of file fractures was 3.9/100 root canal-treated cases, and mandibular molars with severely curved canals (>25°) had shown the maximum incidence of file fractures.

Keywords: Canal curvature; cross-sectional study; endodontic file fracture; root canal treatment; ProTaper universal file system

INTRODUCTION

The practice of endodontics arrives with a variety of surplus procedural errors, which can occur in any stage of the root canal therapy. Intracanal file fracture is one of the main and more prevalent procedural errors during root canal treatment. The fractured root canal instruments can be broaches, pathfinders, files, Gates–Gliidden burs, or endodontic spreaders. Endodontic instruments are made up of materials such as nickel-titanium (Ni-Ti), stainless steel, or carbon steel. There may be various reasons for fracture of endodontic instruments such as instrument fatigue and not fully trained operators. These instrument separations commonly occur in the apical third of the root canals. The conflicting opinions regarding the success or failure of root canal treatment resulting out of retained fractured files triggered clinicians take a more evidence-based approach to reduce any further complications.

Previous literature has shown that the incidence of file fracture with Ni-Ti (hand and rotary) instruments range from 0.5% to 5%. Though numerous studies have been published analyzing the incidence rate of instrument fracture of different file systems, no studies have been undertaken analyzing the incidence rate of Ni-Ti (ProTaper Universal System).

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Universal, Dentsply India Pvt Ltd., Gurugram, Haryana, India) hand instruments for file fractures specifically in tertiary care hospital settings. Thus, the primary objective of the study was to evaluate the incidence of fracture of Ni-Ti hand instruments (ProTaper Universal, Dentsply, India) in endodontically treated teeth. The secondary objective of the study was to evaluate the factors responsible for the file (hand ProTaper Universal) fracture in an endodontically treated tooth.

**METHODOLOGY**

The present retrospective cross-sectional study includes the analysis of file fractures in root canal-treated teeth in the department of dentistry in a tertiary care hospital from October 2017 to December 2019. Institutional ethical committee clearance with reference number “AIIMS/IEC/2019-20/1027” was taken prior to starting the study. As per the departmental policy, a unique intraoral periapical (IOPA) radiographic code was given during the routine dental screening procedure. All further IOPAs required for root canal treatment are usually taken according to the unique IOPA code only. Thus, all the diagnostic radiographs from the dental records were screened to select the endodontically treated teeth. Root canal treatment was carried out by a heterogeneous group of residents comprising endodontists, pedodontists, prosthodontists, and nonacademic junior residents as per the institutional policy. The inclusion criteria were IOPAs of participants in the age group of 8–60, participants with decay involving the pulp tissue, participants with endodontically treated permanent teeth, and participants who are treated with hand ProTaper Universal (Dentsply, India). The exclusion criteria were participants with special health-care needs, participants with large periapical lesions that required periapical surgeries, and participants requiring re-root canal treatment.

The IOPAs of root canal-treated teeth were separated from the total diagnostic IOPA X-ray records. The file-fractured IOPAs were selected from the total root canal-treated teeth and were evaluated by an endodontic specialist to draft all the findings such as age (<20, 21–40, 41–60, and more than 60 years) and sex of the participants; tooth in which the file was fractured (maxillary anteriors/mandibular anteriors/maxillary premolars/mandibular premolars/maxillary molars/mandibular molars); the canal in which the file was fractured (buccal/palatal/mesiobuccal/distobuccal/mesiolingual/distal); degree of curvature of the canal (<10°, 10–25 degrees, and more than 25°); site of file fracture in the root canal (above, at, below the curvature, and file fractures in the straight canals); distance of file fracture from the apex (beyond the apex, at the apex, within 2 mm from the apex, and more than 2 mm from the apex); and length of the fractured file (<2 mm, 2–4 mm, 4–6 mm, and > 6 mm).

The identification of the tooth was done based on the tooth number that was present corresponding to each IOPA X-ray. The canal in which the file fractured was determined by comparing the other IOPAs that were taken in different horizontal directions to identify the canal during the instrumentation procedure (SLOB rule). The distance of the file fracture from the root apex and the length of the fractured file were measured using the measuring tool that is given in the digital radiovisiography software. The degree of curvature of the root canals was determined according to the method described by Schneider (1971).

**Statistical analysis**

Analysis for the age group, kind of tooth, curvature of the canals, and site of file fracture in the root canals were assessed using the Chi-square test. The correlation between the curvature of the canal and the length of the file fracture and the correlation between the curvature of the canal and the distance of the file fracture from the apex were tested using the linear regression analysis. Inter- and intraobserver reliability was tested using Cohen’s kappa statistics. The statistical analysis was done using SPSS version 21 (SPSS Inc., Chicago, IL, USA). P ≤ 0.05 was considered statistically significant.

**RESULTS**

A total of 19,810 patient IOPAs were screened in the radiographic diagnostic records of the department of dentistry to identify the root canal-treated teeth, and a total of 2728 root canal-treated teeth were found. A total of 109 file fractures (males: 61 and females: 48) of ProTaper® Universal Hand files were observed among 2728 root canal-treated teeth (males: 1688 and females: 1040) with an incidence rate of 3.9 (out of 100 individuals with root canal-treated tooth, 3.9 individuals suffered file fracture in the root canal-treated tooth). The interobserver reliability was tested for the analysis of file fractures in the first thirty IOPA X-rays, and a high correlation of 0.98 was observed using Cohen’s kappa statistics. The intraobserver variability was tested 1 month after the initial examination and again a high correlation of 0.97 was observed.

The file fracture incidence was more in females (4.6%) (48 file fractures in 1040 root canal-treated teeth) when compared to males (3.6%) (62 file fractures in 1688 root canal-treated teeth). A statistically significant difference (P < 0.0001) was observed when comparing the file fractures in the age group of 21–40 years with the other age groups [Table 1]. The distribution of file fractures according to the root canal-treated teeth is presented in Table 2. A comparison of file fracture in the roots of maxillary and mandibular molars is shown.
in Figure 1a and b, respectively. The results of file fracture analysis according to the curvature of the canal and the site of file fracture are shown in Tables 3 and 4, respectively.

Regarding the length of the separated instrument, the maximum observed values were <2 mm (38%), followed by 2–4 mm (29%), 4–6 mm (21%), and >6 mm (12%). When considering the distance of file fracture from the radiographic apex, the incidence of instrument fracture of canals observed was file fracture within 2 mm from the apex (37%) > at the apex (35%) > more than 2 mm from apex (14%) > beyond the apex (14%). The correlation between the curvature of the canal and length of file fracture and distance of file fracture from the root apex has been plotted in the scatter diagram [Figure 1c and d, respectively].

**DISCUSSION**

The total incidence of file fractures in the present study was 3.9 patients/100 root canal-treated patients, which was higher when compared to that of earlier literature.[9–12] Multiple factors need to be addressed before comparing the present study results with those of the past literature. Variations in the study methodology, operator expertise, and instrumentation file systems of earlier studies, limit the comparison of the present study results with those of the past literature. Indeed, the present study can be considered the first retrospective cross-sectional study which assesses the incidence of file fractures in a tertiary care hospital of national importance, where there were wide variations in operator expertise, inter-appointment delay, and patient-related constraints.

In the present study, maximum percentage of the root canal treatments (55%) were done in the age group of 21–40 years. The percentage of file fractures was maximum in the age group of >60 years in the present study, which can be attributed to the increased secondary dentin formation along with reduced pulp space and increased pulpal calcifications.[13] Moreover, the past literature indicates the need for endodontic microscopes[14] and careful instrumentation techniques[15] to reduce endodontic mishaps and to increase the success rate of root canal treatments in older age groups. Various factors such as constraints in time and nonavailability of increased magnification tools and endodontic microscopes, could have increased the incidence of instrument fracture in the older age group in the present study.

Mandibular molars had shown the highest incidence (7.1 teeth/100 root canal-treated teeth) of file fractures among all other groups. In the mandibular teeth, mesiobuccal root in the mandibular molars had shown the maximum file fractures (31%), with no statistically significant difference between the mesiolingual and distal roots ($P \geq 0.05$). The increased incidence of file fractures observed can be attributed to the fact that the most indicated tooth (42% of all the root canal-indicated teeth) for endodontic intervention was mandibular molar. The other factors responsible for the increased incidence of file fractures in the mandibular teeth can also be, varied morphological configurations in the root canal anatomy and varied degree of root canal curvatures of mandibular

### Table 1: Analysis of file fractures according to age group

| Age group (years) | Number of root canal-treated teeth | Number of file fractures (%) | $P$ ($\chi^2$ analysis) |
|-------------------|-----------------------------------|------------------------------|-------------------------|
| < 20              |                                   | 16 (3.1)                     | <0.0001*; 0.41; 0.10*   |
| 21–40             | 1497                              | 64 (4.3)                     | <0.0001; <0.0001*        |
| 41–60             | 573                               | 21 (3.6)                     | 0.01**                  |
| > 60              | 151                               | 8 (5.3)                      |                         |
| Total             | 2728                              | 109 (3.9)                    |                         |

*Analysis between <20 years and 21–40 years; †Analysis between <20 years and 41–60 years; ‡Analysis between <20 years and >60 years; §Analysis between >40 and 41–60 years; ¶Analysis between <21 and 40 years and >0 years; **Analysis between <41 and 60 years and >60 years; ‡Analysis between file fractures above the curvature and file fractures at the curvature; †Analysis between file fractures above the curvature and file fractures below the curvature; ‡Analysis between file fractures above the curvature and file fractures in the straight canals; §Analysis between file fractures at the curvature and file fractures below the curvature; ¶Analysis between file fractures at the curvature and file fractures in the straight canals; *Analysis between canals with <10° and 10–25°; †Analysis between canals with <10° and >25°; **Analysis between canals with >10° and >25°. $P < 0.05$ was considered statistically significant.

### Table 2: Analysis of file fractures according to the teeth

| Teeth                | Number of root canal-treated teeth | Number of file fractures (%) | $P$ ($\chi^2$ analysis) |
|----------------------|-----------------------------------|------------------------------|-------------------------|
| Maxillary anteriors  | 389                               | -                            |                         |
| Mandibular anteriors | 218                               | -                            |                         |
| Maxillary premolars  | 213                               | 8 (3.7)                      |                         |
| Mandibular premolars | 218                               | 1 (0.4)                      |                         |
| Maxillary molars     | 522                               | 16 (3)                       | <0.0001*                |
| Mandibular molars    | 1169                              | 84 (7.1)                     |                         |

*Analysis between maxillary and mandibular molars. $P < 0.05$ was considered statistically significant.

### Table 3: Analysis of file fractures according to curvature of the canals

| Curvature of the canals | Number of file fractures (%) | $P$ ($\chi^2$ analysis) |
|-------------------------|-------------------------------|-------------------------|
| < 10°                   | 12 (11)                       | 0.0007*; <0.0001*       |
| 10–25°                  | 35 (32)                       | 0.006*                  |
| > 25°                   | 62 (57)                       |                         |

*Analysis between canals with <10° and 10–25°; †Analysis between canals with <10° and >25°; ‡Analysis between canals with 10–25° and >25°. $P < 0.05$ was considered statistically significant.

### Table 4: Analysis of file fractures according to the site of fracture

| Site of fracture | Number of file fractures (percentage) | $P$ ($\chi^2$ analysis) |
|------------------|---------------------------------------|-------------------------|
| Above the curvature | 7 (6)                           | <0.0001*; <0.0001*; 0.79* |
| At the curvature  | 50 (46)                              | 0.53*; <0.0001*         |
| Below the curvature | 44 (40)                           | <0.0001**               |
| Straight canal    | 8 (8)                                |                         |

*Analysis between file fractures above the curvature and file fractures at the curvature; †Analysis between file fractures above the curvature and file fractures below the curvature; ‡Analysis between file fractures above the curvature and file fractures in the straight canals; §Analysis between file fractures at the curvature and file fractures below the curvature; ¶Analysis between file fractures at the curvature and file fractures in the straight canals; *Analysis between file fractures below the curvature and file fractures in the straight canals. $P < 0.05$ was considered statistically significant.
In maxillary molars, file fracture incidence was maximum (62% of the total fractures in maxillary molars) in the mesiobuccal root in the present study. The complicated canal configuration[19] and the incidence of second mesiobuccal canal in the mesiobuccal root[20] could be the main reason for maximum file fractures in the mesiobuccal root of the maxillary molars. In addition, the inappropriate access cavity preparation along with limited access to the mesiobuccal root may also result in the increased incidence of file fractures in the mesiobuccal root of maxillary molars. The maximum incidence of file fracture was observed in the canals with >25° curvatures (57% of the total file fractures). The present study results are in accordance with those of the past literature where severely curved canals tend to show more file fractures than the straight canals.[21] The increased flexural fatigue stresses at the area of maximum canal curvature could be the main reason for more file fractures in severely curved root canals.[21] Similarly, maximum file fractures were observed at and below the root curvatures (46% and 40%, respectively). Contrary to the past literature[12] where the file fractures were analyzed according to divisions made in the apical and middle thirds, in the present study, file fractures were analyzed based on the level of canal curvature which directly measures the influence of curvature on file fractures.

Majority of the fractures were observed within 2 mm from the apex (37%) and at the apex (35%), which may be attributed to the overzealous approach of the part of the operator to instrument and manipulate the apical third even when faced with obstruction or mechanical resistance of tortuous apical root canal anatomy. Similar findings were observed in the past literature as well, where the apical third of the roots usually show the maximum file fractures.[22,23] In the present study, according to the length of the separated instrument, majority of the file fractures belong to the group of <2 mm (38%) followed by 2–4 mm length (29%). These observations may be reflection on the instrument fatigue left undetected by the operators.

CONCLUSION

The total incidence of Ni-Ti hand file fractures in the present study was 3.9/100 root canal-treated cases. The reasons for file fractures in the present study were not only variations in the operator’s expertise but also patient-related factors such as age-related changes in pulpal anatomy and variations in the morphologic placement of root canals within the tooth. The strict implementation of the root canal treatment protocol and adequate operator expertise reduce the frequency of file fractures during root canal treatment.

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Conflicts of interest
There are no conflicts of interest.

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