Incidence of ProTaper Universal System Instrument Fractures - A Retrospective Clinical Study

Objective: The aim of this retrospective clinical study was to evaluate the incidence of ProTaper Universal System instrument fractures, associated with observation of the arch, group of teeth, and root thirds in which these fractures occurred.

Methods: From analysis of charts, clinical record cards and radiographs of endodontic treatments performed by postgraduate students using the ProTaper Universal System at a reference center, a total of 1031 teeth and 2355 canals were analyzed. The general incidence of instrument fractures and their frequency, considering the group of teeth, arch and root thirds, were cataloged and the data obtained were statistically analyzed (Exact Fischer test, with level of significance of 1%).

Results: The general percentage of fractures, considering the number of teeth and number of root canals evaluated was 4.4% and 1.9%, respectively. Instrument fractures occurred more frequently in the mandibular first (8.8%) and second (9.6%) molars, however, without statistically significant difference between them (P=0.81). In the first and second maxillary molars, the incidence of fracture was 4.7% and 5.1%, respectively, also without significant difference (P=0.81). Considering the dental arches (maxillary and mandibular), the fractures occurred with significantly higher frequency in the mandibular arch (66.7%), in comparison with the maxillary arch (33.3%) (P<0.01). A significantly higher percentage of fractures occurred in the apical third (84.4%) compared with the middle third (15.6%) (P<0.01).

Conclusion: The general percentage of fractures, considering the number of teeth and number of root canals evaluated was 4.4% and 1.9%, respectively. However, the arch (mandibular) and root third (apical) had a significant effect on the incidence of instrument fractures.

Keywords: Fracture, endodontic files, nickel-titanium instruments, ProTaper universal

INTRODUCTION

The advent of nickel titanium (NiTi) instruments has significantly improved mechanical preparation of root canal systems, minimizing procedural errors such as step formation and apical transportation (1, 2). Nevertheless, fracture continues to be one of the main concerns associated with the use of this type of instrument (3, 4).

NiTi instruments used in continuous rotation are subjected to two types of antagonistic forces. The portion of the instrument that acts on the external part of the curvature undergoes stress, while the portion that acts on the internal part of the curvature undergoes compression. At each rotation a complete cycle of tension and compression occurs, leading to fracture of the instrument due to cyclic fatigue. For fracture by torsion to occur, the tip of the instrument must be immobilized and

HIGHLIGHTS

- The aim of this retrospective clinical study was to evaluate the incidence of ProTaper Universal System instrument fractures, associated with observation of the arch, group of teeth, and root thirds in which these fractures occurred.
- Instrument fractures occurred more frequently in the mandibular first (8.8%) and second (9.6%) molars, however, without statistically significant difference between them (P=0.81). In the first and second maxillary molars, the incidence of fracture was 4.7% and 5.1%, respectively, also without significant difference (P=0.81).
- The fractures occurred with significantly higher frequency in the mandibular arch (66.7%), in comparison with the maxillary arch (33.3%) (P<0.01).
- A significantly higher percentage of fractures occurred in the apical third (84.4%) compared with the middle third (15.6%) (P<0.01).
- The general percentage of fractures, considering the number of teeth and number of root canals evaluated was 4.4% and 1.9%, respectively. However, the arch (mandibular) and root third (apical) had a significant effect on the incidence of these fractures.
a rotational force must continue to be applied to the instrument. When the plastic limit of the instrument is broken by virtue of the application of force, fracture occurs (3).

Some factors, such as the instrument design, may seriously influence the mechanism of fracture by torsion, since the cutting blades act as stress concentrators that promote structural defects (3). On the other hand, instruments that have radial surfaces tend to have greater mechanical strength (5).

The ProTaper Universal System (Dentsply/Maillefer, Ballaigues, Switzerland) is still one of the automated systems most used for root canal preparations (6, 7). Due to its triangular cross-section and progressive taper, the rotational friction between the blades of the instrument and dentine is reduced, thus minimizing fatigue, without compromising its cutting capacity (8, 9). However, there are few studies that have clinically evaluated the incidence of fracture of the instruments of this system (10, 11).

Therefore, the aim of this retrospective clinical study was to evaluate the incidence of ProTaper Universal System instrument fractures, associated with observation of the arch, group of teeth, and root thirds in which these fractures occurred. The null hypothesis tested was that these factors would not interfere in increasing the incidence of fracture of the instruments of this system.

MATERIALS AND METHODS

Clinical and data collection procedures

After approval from the Clinical Research Ethics Committee of the Paranaense University (CAAE: 58036016.4.0000.0109), this retrospective clinical study was conducted by means of analyzing charts, clinical record cards and radiographs of patients submitted to endodontic treatments performed by postgraduate students of the second year of the Specialization Course in Endodontics of FUNORTE/SOEBRAS (Florianópolis Nucleus), Florianópolis, Santa Catarina, Brazil, between March 2009 and March 2014. All students received exactly the same laboratory training prior to performing treatments on patients. Therefore, all the patients who participated in this study, or their legal guardians, signed the Term of Free and Informed Consent, in which they authorized the treatment to be performed.

To standardize the sample, the teeth selected were those that had been submitted to identical biomechanical preparation protocols, using the ProTaper Universal System (Dentsply/Maillefer) after anesthesia and placement of the rubber dam: 1) coronal access; 2) localization and initial preparation of the root canal entrances with instrument SX; 3) preparation of the cervical and middle third(s) with Gates Glidden Drills (Dentsply/Maillefer); 4) determination of the working length(s) with the use of an electronic foraminar locator; 5) manual glide path creation with the Flexo-file #15 (Dentsply/Maillefer) instrument up to the working length; 6) use of instruments S1 and S2; and 7) conclusion of the preparation by means of using instruments F1, F2, F3, F4 and F5, depending on the anatomical diameter of the canal. Canals with anatomical diameters of 8 and 10, 15 and 20, 25 and 30, and above to 30 were instrumented until F2, F3, F4 and F5 files, respectively. At each change of instrument, 2.5 mL of sodium hypochlorite solution (Fórmula & Ação, São Paulo, SP, Brazil) was used in the concentrations of 2.5% for cases of biopulpectomy, and 5.25% for the cases of pulp necrosis. As the final irrigation protocol, 3 mL of 17% EDTA (Biodinâmica, Ibirapuã, PR, Brazil) was applied for 3 minutes within the root canals to remove the residual smear layer. Afterwards, the canals were filled by the single cone technique, with AH Plus Cement (Dentsply-DeTrey, Konstanz, Germany).

Engine-driven files were used adapted to an electric motor (X-Smart, Dentsply-Maillefer) with a 16:1 reduction handpiece using recommended torques (1.5 Ncm for S2; 2.0 Ncm for F1; 3.0 Ncm for SX, S1, F2, and F3; respectively) and rotation speed (250 rpm). Instruments were discarded and replaced when they were worn, fractured, or with any other discernible defects observed by using a loupe at 4x magnification (EyeMag Pro S; Carl Zeiss do Brasil Ltda., São Paulo, SP, Brazil). Each instrument was used for a maximum of 4 times (10). Instruments that had been used in very complex or severely curved canals were discarded at once (11).

In case of instrument fractures, the occurrence was noted on the patient’s clinical record chart, followed by radiographic exam for proof and localization of the fractured instrument (canal and root third). Based on the data collected, 1031 teeth were selected, totaling 2355 root canals.

Statistical analysis

The general incidence of instrument fractures and their frequency, considering the group of teeth, arch and root thirds, were cataloged and the data obtained were statistically analyzed (Exact Fischer test, with level of significance of 1%) by using the Minitab 17.0 Software (Minitab Inc., State College Philadelphia, PA, USA).

RESULTS

The total number of teeth and root canals evaluated and the incidence of fractures are summarized in Table 1.

The general percentage of fractures, considering the number of teeth and number of root canals may be visualized in Table 2. Instrument fractures occurred more frequently in the first (8.8%) and second (9.6%) mandibular molars, however, without statistically significant difference between them (P=0.81).

In the first and second maxillary molars, the incidence of fracture was 4.7% and 5.1%, respectively, also without significant difference (P=0.81) (Table 3). Considering the dental arches (maxillary and mandibular), the fractures occurred with significantly higher frequency in the mandibular arch (66.7%), in comparison with the maxillary arch (33.3%) (P<0.01).

A significantly higher percentage of fractures occurred in the apical third (84.4%) compared with the middle third (15.6%) (P<0.01). Comparison of the values may be seen in Table 4.

DISCUSSION

Cleaning and shaping of the root canal system has become safer with the advent of instruments made of NiTi, by signif-
lected because the group of teeth and root third had significant influence on the occurrence of fractures.

Considering the number of teeth (1031) and root canals (2355) evaluated, the general incidence of fracture was 4.4% and 1.9%, respectively. These rates can be considered low, mainly when considering the number of root canals evaluated. These

| Teeth       | Quantity of canals | Maxillary arch | Mandibular arch |
|-------------|-------------------|----------------|-----------------|
|             | No. of teeth      | No. of canals  | No. of fractures| No. of teeth | No. of canals  | No. of fractures|
| Central incisors | 1 51 51 0 | 15 15 0 |
| Lateral incisors | 1 49 49 0 | 12 12 0 |
| Canines     | 1 36 36 0 | 13 13 0 |
| First premolars | 1 4 4 0 | 34 34 0 |
| Second premolars | 1 45 45 1 | 56 56 0 |
| First molars | 1 2 2 0 | 1 1 0 |
| Second molars | 1 3 6 0 | 7 14 1 |
| Third molars | 1 0 0 0 | 0 0 0 |
| Total       | 560 1190 15 | 471 1165 30 |

| Teeth       | Endodontically treated teeth | Incidence of fractures | Percentage of fractures considering total number of teeth evaluated | Percentage of fractures in relation to the group of teeth itself | Percentage in relation to general number of fractures |
|-------------|-----------------------------|------------------------|----------------------------------------------------------|-------------------------------------------------|--------------------------------------------------|
| First premolars | Maxillary 75 | 1 | 0.1% | 1.3% | 2.2% |
|               | Mandibular 36 | 0 | 0% | 0% | 0% |
| Second premolars | Maxillary 97 | 2 | 0.2% | 2.1% | 4.5% |
|               | Mandibular 58 | 0 | 0% | 0% | 0% |
| First molars | Maxillary 190 | 9 | 0.9% | 4.7% | 20% |
|               | Mandibular 205 | 18 | 1.7% | 8.8% | 40% |
| Second molars | Maxillary 59 | 3 | 0.3% | 5.1% | 6.7% |
|               | Mandibular 115 | 11 | 1.1% | 9.6% | 24.4% |
| Third molars | Maxillary 3 | 0 | 0% | 0% | 0% |
|               | Mandibular 14 | 1 | 0.1% | 7.1% | 2.2% |
| Total         | 45 | 4.4% | - | 100% |

significantly reducing the incidence of apical transportation, root perforations and zip formation, in comparison with treatments performed with stainless steel instruments (12). The aim of this retrospective clinical study was to evaluate the incidence of ProTaper Universal System instrument fractures, associated with observation of the arch, group of teeth, and root thirds in which these fractures occurred. The null hypothesis was re-
results were in agreement with those obtained in previous studies that also obtained low incidence of NiTi instrument fracture (10, 13-16).

Analyzing the incidence of fracture of ProTaper Universal System instruments, Wolcott, et al. (10) and Di Fiore, et al. (13) found a 2.4% and 0.41% rates of fracture in 4652 and 828 root canals evaluated, respectively. One of the main reasons associated with the higher instrument fracture rates observed in the present study compared with both studies previously cited was the experience of the operators. In the study by Wolcott et al. (10), operators were endodontists with 15 years of experience, on average. In the study by Di Fiore et al. (13), the operators were students from the Endodontics Residency Program at New York University. In the present study, the operators were also postgraduate students, however, in Brazil, postgraduate courses usually take place once a month. On the other hand, endodontics residency programs of american universities happen in full time. Therefore, students are subjected to a longer training load, which gives them a significantly greater clinical experience. In previous studies, the experience of the operators has been indicated as an important variable for the reduction of fracture incidence when using different NiTi systems (17, 18). Pirani et al. (19) also found a relatively high rate of fracture (5.3%) of ProTaper Universal System instruments when used by postgraduate students of the University of Bologna. However, in this study it is necessary to consider the greater complexity of the interventions because they were endodontic retreatments.

In the present study, 93.3% of the fractures occurred in molars, results that were corroborated by several studies (10, 12, 13). This finding was due to the anatomic characteristics found in these teeth, which imposed greater difficulties during instrumentation, predisposing to a higher incidence of instrument fractures (20-23). Moreover, it is worth pointing out that 66.7% of the fractures occurred in mandibular molars, and of these, 80% occurred in the mesial root. The mesial root of mandibular molars, in addition to the curvature toward the distal direction frequently observed, may also present curvatures in the bucco-lingual direction, which are not visualized radiographically (24, 25). This may have significantly contributed to the high rates of fracture observed specifically in this group of teeth, because this anatomic complexity results in greater rotary flexure of the instrument, thereby concentrating the forces of stress that may cause premature failure of the NiTi alloy (26).

Similarly, when the root third was considered in the analysis, 84.4% of the fractures occurred in the apical third. When NiTi instruments act in the apical third, they are subject to fracture by both torsion and rotary flexure by virtue of the smaller dimensions of the root canal, in addition to the eventual presence of curvatures (11, 26, 27).

In spite of the greater flexibility and elasticity, in comparison with manual instruments made of stainless steel, automated NiTi instruments tend to present a higher rate of fracture during root canal preparations (12). Nevertheless, as observed in the present study, this incidence was low considering the number of teeth and root canals evaluated, demonstrating that they were safe to use.

**Conclusion**

Based on results obtained from this study, it can be concluded that the incidence of rotary ProTaper universal files fracture is low amongst postgraduate students. The arch (mandibular) and root third (apical) have a significant effect on the incidence of these fractures.

**Disclosures**

Conflict of interest: The authors deny any conflict of interest.

Ethics Committee Approval: This study was approved by the Clinical Research Ethics Committee of the Paranaense University (CAAE: 58036016.4.0000.0109).

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