v. 4, n. 21, 2024

International Journal of Health Science

EVALUATION OF THE NUMBER OF CANALS MODELED WITH PRODESIGN M FILES UP TO THEIR FRACTURE IN “EX VIVOS” LOWER TEETH”

Ana Angélica dos Santos
Dental Surgeon, Specialist in Endodontics

Fernanda Patricia Leite de Almeida
Dental Surgeon, Specialist in Endodontics

José Agostinho Blatt
Dental Surgeon, Specialist in Endodontics, Master in Dental Materials

Ricardo Ferreira
Dental Surgeon, Specialist in Endodontics, Master in Radiology and Doctor in Endodontics and Professor at UNIVALI - Dentistry Course

Cassiano Neves Almeida
Dental Surgeon, Specialist in Endodontics, Master in Endodontics and Professor at UNIVALI – Dentistry Course - Advisor

Abstract: This work aimed to evaluate the number of canals modeled with ProDesign M (PDM) files until their fracture in mandibular premolars "ex vivo". An "ex vivo" experimental study was carried out on 40 extracted lower premolar teeth with similar curvatures, containing a single canal in each tooth. An endodontic opening was made on the occlusal surface of each dental element. The selected teeth were intact and healthy. Elements with endodontic treatment, with calcified canal and with accentuated curvature were excluded from the research. Initially, the dental elements were numbered from 1 to 40, the radiographic image of each canal was obtained and they were identified with the respective numbers. Two sets of PDM file instruments were used, each containing three files: 15/05, 25/01 and 25/06, 25 millimeters long. The preparation sequence was 6/25 up to 3 millimeters below the Apparent Tooth Length (CAD), simulating the Exploration Working Length (CTEx). After that, the sequence of files 25/01, 15/05 and 25/06 continued until the tip of each instrument passed one millimeter beyond the apical foramen. After using each file, it was visually evaluated with a millimeter ruler (Dia Dent Group International, Inc., Vancouver, British Columbia, Canada), and checked for the presence of fracture or deformation of the spirals. When an instrument fractured, it was discarded and replaced with an identical one from set number 2, and instrumentation of the canals continued until all three instruments fractured. During data collection, they were entered, stored and tabulated in a database in the Microsoft Excel 2016 ® program (Microsoft Corporation, Redmond, WA). The total and average number of turns given with the 15/05, 25/01 and 25/06 files until the fracture was analyzed and calculated. Therefore, the PDM files demonstrated a good result in relation to the tested dental elements, since the 15/05 and 25/06 files achieved, respectively, a total of 170 and 985 turns on 27 and 40 teeth and had an average number of turns 6.29 and 24.62 per "ex vivo" single-rooted mandibular premolar tooth modeled in the crown-apex technique without the occurrence of fracture.
Keywords: Root Canal. NiTi Hand Files. Fracture of Endodontic Instruments.

INTRODUCTION

In the area of Endodontics, great progress has been made when it comes to the instruments used to perform the technique. Files that previously had piano wires in their composition evolved to carbon steel, moving to stainless steel files and, today, files with nickel-titanium alloys are used, as they have greater flexibility and memory effect. (COHEN; HARGREAVES, 2007)

The stages of endodontic treatment are: opening, cleaning, disinfection, shaping, filling and shielding the root canals. Some complications may arise between these stages of therapy, which are outside the dentist's usual routine, including file fractures during the mechanical preparation of root canals. (LEONARDO; TOLEDO, 2017)

Endodontic files undergo elastic deformations resulting from the anatomy of the canal, dimensions of the instruments (shape and caliber), the dexterity of the professional, the number of uses and even the manufacturing process (PARASHOS, et al., 2006). The anatomical complexity of root canals, linked to the repeated and/or improper use of files, can create a high risk of fracture. (CORREIA DE SOUSA, et al., 2013)

Fracture of a file can occur when its maximum resistance is exceeded or when a fissure opens in such a way that the remaining intact cross-section of the material is no longer capable of tolerating the usual workload. Considering that most patients do not agree to leave a fragment of a file inside the tooth, this becomes worrying for both the patient and the dentist who performed the technique. (CHEUNG, G., 2009) Therefore, the objective of this work was to evaluate the moment in which the ProDesign M (PDM) files fracture occurs in lower teeth "ex vivo" in the crown technique applied to: Universidade do Vale do Itajaí (UNIVALI).

REVIEW OF LITERATURE

One of the points mentioned in Schneider's book (1971) was the comparison of the degree of curvature in single-rooted teeth in humans, and these elements were classified by him according to the degree of curvature obtained in the x-ray of the extracted element. The author classified straight canals when they had a curvature of 5º or less, moderate when they had a curvature of 10º to 20º and severe when the dental elements had a curvature of 25º to 70º. In the same sense, it is worth mentioning that the instrumentation carried out by him was with K files, the movements were filing and the canals were filled with silver cones, so he concluded that straight canals are easier to treat than curved.

The aim of Tepel, Schäfe, and Hopee (1995) was to investigate the cutting efficiency of different manual endodontic instruments and the effects of instrumentation on curved canal shape under standardized experimental conditions using an automatic testing device. The cutting efficiency in rotary motion was evaluated by determining the maximum penetration depth of the instruments in a cylindrical channel in a special resin block (instruments sizes 25 and 35). Changes in canal shape were determined by instrumenting standardized canals (42 degrees of curvature) incrementally from size 15 to size 35. Changes in canal shape differed significantly between the different instruments at 13 of the 14 measurement points. Drastic undesirable changes in canal shape (e.g., straightening or zip and elbow) occurred after instrumentation with reamers and K-files, but these changes were less noticeable after instrumentation with flexible files with conventional tips. After instrumentation with flexible instruments with modified tips, there were few undesirable changes in shape. It was concluded that flexible instruments, especially those with modified tips, are clearly superior to conventional reamers and K-files with regard to cutting efficiency and instrumentation of curved canals. Straightening or zip and elbow occurred after instrumentation with reamers and K files, but these changes were less noticeable after instrumentation with flexible instruments with conventional tips.

Kazemi, Stenman and Spangberg (1996) evaluated the dentin machinability and wear resistance of nickel titanium endodontic files in vitro. Eight different types and brands of nickel titanium files were studied: Ultra-Flex Hedström, Ultra-Flex K, Mity Hedström, Mity K, Mity Turbo, Hedström Naviflex NT, NiTi Flex and Hyflex X-file. 30 files from each brand were evaluated. ANOVA and t-tests were performed to analyze the data. Considerable variation was found in machining efficiency and wear. The best initial machining capacity of all nickel titanium instruments was recorded for the Hyflex-X file (0.60 ± 0.16 mm 2); the worst performance was for the Mity Turbo file, which machined less than a third of the best performing instrument (0.19 ± 0.12 mm 2). The results of the present study were compared with the results of a previous study of stainless-steel endodontic files and it was concluded that nickel-titanium instruments are as aggressive or better than stainless steel instruments in removing dentin. They are also more durable than their stainless-steel counterparts.

The objective of the study by Arens, et al., (2003) was to analyze the number and types of defects observed in single-use nickel-titanium rotary instruments. All ProFile Series 29/04 nickel-titanium tapered instruments used over a 4-week period in an endodontic specialty practice were collected. All instruments were new and were used by experienced professionals. The instruments were routinely used in the crown-apex direction with abundant lubrication and irrigation on a MicroMega 324 pneumatic motor with a 6:1 gear reduction contra-angle at 333 rpm. The instruments were collected, ultrasonically cleaned, sterilized and inspected at 16x magnification. Torsional, flexion and fracture defects were recorded and statistical analysis was performed using Kruskal-Wallis one-way analysis of variance. 14.63% had some type of defect after clinical use. Size 3 instruments had the highest defect rate (22.66%), followed by size 3 instruments.

5 (17.30%), size 2 (17.24%) and size 4 (16.10%). There was no statistically significant difference in the type of failure observed at each file size. This study shows that defects can occur even with new files in the hands of experienced endodontists and a single-use approach must be followed.

The article by Da Silva (2004) intended to verify the knowledge of Dental Surgeons on the technical aspects related to the fracture of root endodontic instruments, as well as its ethical and legal repercussions, in the professional-patient relationship and in the interprofessional relationship, between Surgeons -Dentists who carry out endodontic treatment in the municipalities of Goiânia and Aparecida de Goiânia-GO. To this end, 200 questionnaires distributed randomly were evaluated and the data obtained were grouped according to the classificatory variables and according to the qualification and performance of the individuals performing endodontic treatment. Statistical analysis included Chi-square and Fischer's exact tests. The final results demonstrated that 56% of those interviewed had already fractured some type of endodontic instrument and among endodontists, this figure reached 87.5%. The fracture occurred one to five times, for 46% of those interviewed. The main cause of fracture cited was excessive use of the instrument, cited by 61% of the sample and by 46.9% of endodontists. The lack of technical-scientific knowledge is one of the causes of fracture of endodontic instruments for 39.5% of the sample. 74% of those interviewed feel the need for a continuing education program on accidents and complications in Endodontics and 62.5% of professionals were unaware of any type of technique aimed at removing the fractured instrument. 27% of the sample suggested greater theoretical depth on accidents resulting from endodontic treatment, with a legal dentistry focus. Regarding prior clarification about the risks inherent to endodontic treatment, 59% clarified verbally, 35.5% did not clarify and only 20.5% clarified in writing. It was concluded that Dental Surgeons are not well prepared regarding the technical-scientific knowledge regarding the fracture of endodontic instruments, specifically regarding the therapeutic options and techniques used to remove the fractured endodontic instrument.

The study by Gênova, et al., (2004) aimed to evaluate the behavior regarding fracture of ProTaper files in relation to the number of times they were used in the instrumentation of canals simulated in resin blocks. Six Endodontics specialists participated in the work. Each operator received two sets of ProTaper files that would be reused until a file fracture occurred and the instrumentation was interrupted. Through analysis of the results, it was concluded that the use of ProTaper (r) files in curved canals proved to be safer until the fourth use, there is a tendency for the fracture to occur at the point of greatest angulation of the curvature. When there is no cervical interference, the files that fracture the most are those with the greatest conicities, the "F".

This study by Parashos, Gordon, and Messer (2004) examined used and subsequently discarded nickel-titanium rotary instruments obtained from 14 endodontists in four countries and identified factors that may influence defects produced during clinical use. A total of 7159 instruments were examined for defects. Unwinding occurred in 12% of the instruments and fractures in 5% (1.5% torsion and 3.5% flexion). Defect rates varied significantly among endodontists. Instrument manufacturing factors also influenced the defect rate, but to a lesser extent. The average number of uses of instruments with and without defects was 3.3 +/- 1.8 (range: 1-10) and 4.5 +/- 2.0 (range: 1-16), respectively. The most important influence on complication rates was the operator, which may be related to clinical skill or a conscious decision to use the instruments a certain number of times or until defects are evident.

The aim of Miranzi (2005) in this study was to compare the changes promoted in 20 curved artificial root canals, of approximately 30 degrees according to the methodology proposed by Schneider (1971), after preparation with Pow-R nickel-titanium files, activated motorized taper 0.4, to perform cervical preparation, and taper 0.2 for apical preparation (group 1), cervical preparation with Gates-Glidden drills, and in the curved portion Pow-R taper 0.2 files (group 2). For this, the pre- and post-instrumentation images were superimposed and analyzed using the Image Tool program. The worn distances were evaluated, at a level of 13 millimeters below the apical end of the simulated canals, towards the internal side; external worn area of the curved part (11 millimeters) and internal worn area of the curved part (11 millimeters). The results showed that the preparations for group 1 wore greater extensions, in the apical region, external side of the curvature in relation to the simulated canals of group 2, significant at the 1% level, showing a greater tendency for "zip" formation; the preparations for group 2 wore greater extensions, in the apical region, internal side of the curvature in relation to the simulated canals of group 1, significant at the 1% level. The worn distances at the 13-millimeter level were significantly greater at the 1% level, for group 2 in relation to group 1. Based on the wear averages, internal and external side, the preparations for group 1 were more centered in relation to those of the group 2.

According to Spili, Parashos and Messer (2005), the adoption of nickel-titanium rotary instruments has renewed concerns regarding instrument fracture and its consequences. The frequency of instrument fracture and its impact on treatment outcome were determined from an analysis of specialized endodontic practice involving 8460 cases. A case study was conducted with a total of 146 teeth with a retained instrument fragment (plus 146 matched controls), for which clinical and radiographic follow-up of at least 1 year was available. The radiographs were evaluated by two calibrated examiners. The overall prevalence of retained fractured instruments was 3.3% of treated teeth. In the case study, overall cure rates were 91.8% for cases with a fractured instrument and 94.5% for matched controls ($p > 0.05$, Fisher's exact test). Healing in both groups was lower in teeth with preoperative periapical radiolucency (86.7% versus 92.9%, $p > 0.05$). In the hands of qualified endodontists, the prognosis was not significantly affected by the presence of a retained fractured instrument.

Igbal, Kohli, and Kim (2006) investigated the incidence of Rotary and Manual Instrument Fracture (FI) in the University of Pennsylvania postgraduate endodontics program between 2000 and 2004. In 4865 endodontic residency cases, the incidence of FI manual and rotary

DOI https://doi.org/10.22533/at.ed.1594212420024

was 0.25% and 1.68%, respectively. The odds for rotary IF were seven times greater than for manual IF. The probability of a file fracture in the apical third was 33%, being 6 times more likely when compared to the coronal and middle thirds of the canals. The highest percentage of FI occurred in the lower (55.5%) and upper (33.3%) molars. Furthermore, the chance of file fracture in molars was 2.9 times greater than in premolars. Among the ProFile 29 series rotary instruments, .06 taper files #5 and #6 fragmented the most.

Parashos; Messes (2006) aimed to carry out a literature review on file fractures in rotating instruments together with clinical recommendations and treatments for this incident. File fracture is a major obstacle to the endodontist's clinical routine, which is why much research has been carried out to understand the failures of NiTi alloys. In this sense, changes have occurred in instrument design, instrumentation protocols and manufacturing methods. Furthermore, it can be concluded that clinical, technical experience and professional competence were evident for the clinical success of root canal treatment.

Cohen; Hargreaves (2007) clarified in his book that endodontics has evolved greatly in recent decades, in materials, techniques, equipment, instrument design and types of metals used to manufacture endodontic instruments. Files that previously had piano wires in their composition evolved to carbon steel, moved to stainless steel files and today files with nickel-titanium alloys are used, as they have greater flexibility and memory effect. As a result of this unique crystalline structure, a NiTi file has shape memory, that is, the ability to return to its original shape after being deformed. These instruments continue to evolve constantly and NiTi files made with new alloys are five times more flexible than those currently available.

Pereira, et al., (2007) aimed to analyze, through post-preparation canal impressions, the quality of instrumentation with manual and rotary files in the cervical, middle and apical thirds and buccal, lingual, mesial and distal surfaces. 32 mesiobuccal roots (upper molars) were used. The coronal openings were made with high-speed diamond drills nº 1016 and 3083 (KG Sorensen), the canals were explored with the instrument type K #08 (Dentsply Maillefer) and the working length was determined with the instrument type K #10 introduced in the canal until reaching the apical foramen. The dental elements were randomly separated into two groups and the canals were instrumented using the "crown-down" technique following two sequences (manual and rotary instrumentation). 1% sodium hypochlorite was used as an auxiliary chemical irrigating solution, EDTA was used to help remove the "smear layer" and the canal was dried with a #15 paper cone. To mold the canal, the impression material used was AQUASIL ULV (Dentsply) applied with the Centrix syringe. After the material set, the teeth were decalcified (10% nitric acid solution at 37º C for 72 hours) to obtain the molding of the canals. To evaluate the quality of the instrumentation, images of the impressions were transmitted to a 29-inch television through a video camera coupled to a surgical microscope at 20 times magnification with medium light intensity. The surfaces examined were classified as GREAT (smooth surface indicating that the wall was touched by the instrument), GOOD (surface with few irregularities) and REGULAR (surface with many irregularities, presence of fins and anatomical complexities such as isthmuses, accessory canals, delta, etc.) When analyzing the thirds and faces, the regular classification predominated for the two types of instrumentation used, with the worst results being in the apical third and on the lingual face. From the analysis of the results, the authors concluded that there was no statistically significant difference between the two techniques used: manual with stainless steel files and rotary with nickel-titanium files.

Cheung, (2009) aimed to carry out a literature review addressing various aspects in relation to instrument fractures such as: mechanisms, contributing factors, prognosis and treatment. During endodontic treatment, instrument fracture can be an unpleasant setback in the dental surgeon's clinical routine. In this regard, most stainless-steel instruments can fail due to excessive amounts of torque, the combined action of torsional stress and cyclic loading is responsible for NiTi rotary files breaking in use. The incidence of failures is due to the instrumentation technique, the use of a torque-controlled motor, the dimension and condition of the instrument surface, the rotation rate, the radius of curvature of the canal and the presence of a straight-line access to the apical portion of the canal. In case of instrument fracture in the clinical environment, the patient must be informed of the incident and must consider whether the fragment must be removed or not and ensure that this fact does not affect the final result of the procedure.

The objective of the study by Martins, Bahia and Buono (2009) was to evaluate the geometric and dimensional characteristics of curved root canals simulated in acrylic resin blocks, prepared with ProTaper instruments, to analyze which regions of these instruments act during instrumentation in curved root canals.

Forty-eight ProTaper instruments were used, 12 of each type: S1, S2, F1 and F2. 20 root canals measuring 16 millimeters long, with a curvature of 3.5 millimeters and an angle of 53º were instrumented by the same operator and irrigated with water throughout the research. Various instrumentation sequences were used and after each sequence the files were inspected to analyze distortion in the cutting blades. The results demonstrated that all ProTaper files had a conical guide tip, with an angle of 65.8 ± 2.25 degrees. The largest variations presented were found in instruments S1 and S2 (66.3 ± 2.91 degrees and 65.5 ± 2.68 degrees, respectively), while the smallest variations were obtained in instruments F1 and F2 65.0 ± 1, 49 degrees and 66.3 ± 1.52 degrees). Instruments S1 and S2 had 15 millimeters of active part, while F1 and F2 had 17 millimeters and 16 millimeters, in that order. During the modeling of the canals, no instrument fractured or presented significant distortion. On the other hand, all instruments showed microcracks after modeling the channels. In instruments S1 and S2 the microcracks observed were finer. The authors concluded that the largest diameters at the end of the instrumented canals were obtained with the F1 and F2 instruments, while most of the modeling in the initial and middle thirds was performed by the S1 and S2 instruments. However, they are prone to failure due to torsion, fatigue or a combination of these two mechanisms.

The article by Dias, et al., (2010) addresses the reasons responsible for the failure of conventional endodontic treatment: when there are perforations, fractured instruments, calcifications and anatomical abnormalities. Among the surgical modalities, root canal filling simultaneously with surgery is indicated when it is not possible to contain the persistent exudate through intracanal medication and systemic medication. The purpose of this work is to describe the surgical technique used and present three clinical cases of apicectomy with transsurgical endodontic treatment, promoting a discussion about its indications within the modern dental clinic.

Haddad Filho, et al., (2011) carried out a study to evaluate the cutting loss of the

ProTaper rotary instrument depending on the number of uses in the autoclave sterilization process. To carry out the study, 10 simulated channels in acrylic resin were used with an angle and curvature of the conduit of 45º and ProTaper instruments with numbers S1, S2, F1, F2 and F3, and #1 Largo drills were also used. The data was analyzed in relation to the cutting loss as a function of the number of uses, comparing the average cutting loss between the first 5 and the last 5 uses. The results demonstrated that the average cutting loss of the instruments in the last 5 uses was significantly lower than in the first 5 uses, which means that the instrument is losing cutting power as the number of uses increases.

The authors concluded that the instrument subtly loses its cutting capacity. However, only after the seventh use, preceded by the moist heat sterilization process, does the ProTaper rotary instrument lose its effectiveness considerably and, at that point, it is recommended to discard it.

Pereira Lopes, H., et al., (2011) comment in their article that endodontic instruments are metallic tools, made of stainless steel or nickel-titanium alloys (NiTi) used as mechanical agents in the instrumentation of root canals. During root canal instrumentation, the instrument undergoes stresses that vary with the anatomy of the canal. Lack of knowledge of the mechanical properties of materials and the professional's lack of clinical skills and experience can lead to fracture inside the canal. Fracture during clinical use can occur due to torsion, rotational flexion and their combinations. Fractured and retained instruments inside the canal can affect the outcome of endodontic treatment. The purpose of this work is to present clinical recommendations to reduce the risk of endodontic instrument fractures during root canal instrumentation.

Pereira, Silva and Filho (2012) proposed to carry out a literature review regarding the reciprocal movement of endodontic instruments. One of the topics of this study was the evolution of endodontic instruments, which seek to achieve greater flexibility. Another point was the search for agility and efficiency, thus coupling rotary motors to the files. Subsequently, with the aim of reducing instrument fatigue and faster treatment, the technique using a reciprocal instrument was proposed. Several comparative studies were carried out between the two techniques (rotary motors and reciprocating motors) in relation to: efficiency in bacterial reduction, channel shape, debris extrusion and cyclic fatigue generated to the instruments during instrumentation. It is concluded, therefore, that although the studies available to date have demonstrated safety and efficiency in the use of reciprocal movement and single file systems for root canal instrumentation, new studies are still necessary in order to evaluate the system instrumentation. of root canals with instruments in reciprocal movement.

Correia de Sousa, et al., (2013) aimed in this article to investigate the prevalence of fracture of endodontic instruments among students of the Integrated Masters in Dental Medicine at the Faculty of Dental Medicine of the University of Porto and determine possible associated factors. A retrospective study was carried out, conducted through the analysis of clinical and radiographic reports of endodontic treatments carried out by academics between September 2008 and July 2012. A total of 1162 treatments (2,177 canals) on molar teeth (420), premolars (365) and anterior teeth (377) were evaluated. Additional data were processed, such as type and location of the tooth, first treatment and retreatment, type of fractured instrument, location of the retained instrument and clinical procedure adopted. Statistical analysis was performed in the R program for 95% confidence intervals and 0.05 significance levels for the Pearson chi-square test. As a result, the prevalence of fractured instruments during endodontic treatment by pre-graduate students was 1.64%. This prevalence was statistically higher in the apical third (63.2%) compared to the middle (21.0%) and coronal third (15.8%) ($p < 0.05$). The frequency of instrument fractures was found to be higher in cases of retreatment ($p < 0.05$). It was concluded that the prevalence of endodontic instruments fractured by academics was low. A higher prevalence of fractures was associated with cases of endodontic retreatment and in situations resulting from preparation of the apical third.

Piasecki, et al., (2013) carried out an in vitro study with the objective of evaluating two different types of hand instruments, taper 0.02, made of stainless steel or carbon steel, used in a reciprocating M4 handpiece, for instrumentation in artificial S-shaped channels, comparing which of the different alloys could be more or less efficient in relation to resistance to cyclic fatigue. 2 different types of #0.02 manual instruments were used, divided into 2 different groups: Group SS – stainless steel files, Pathfinders and Group CS – carbon steel files, Pathfinders CS, size K2. Both instruments were produced by the same manufacturer, presenting the same characteristics. Ten instruments of each were used, inside the artificial canals, until the fracture occurred, which was evaluated in relation to the time it took for it to occur. The authors observed that the average time for fractures to occur was 8 minutes and 78 seconds for CS files and 9 minutes and 13 seconds for SS. It was concluded that the different alloys tested do not play a significant role in determining the fatigue resistance of the files tested. Therefore, the clinical use of both SS and CS instruments in more complex curvatures is considered safe.

Borges, et al., (2014) evaluated the reasons why rotary file fractures occur. Within endodontic practice, file fracture is the most common accident in a practice. In this sense, a literature review was carried out addressing this clinical accident. According to the authors researched to carry out this review, the torque of the device must be controlled to perform rotational instrumentation, it is worth highlighting that a lower torque is more advisable. It was evident that successful endodontic treatment requires prior preparation and mastery of the technique while respecting its stages. The results obtained in the analysis indicated that the factors that determine file fractures are due to the operator's inability, excessive force and instrument wear.

The in vitro study by Wefelmeier, M., et al., (2015) aimed to evaluate an alternative method using light-cured composite for the removal of fractured endodontic instruments with the tube technique. Two different stainless-steel endodontic instruments (ISO 20: Hedstrom files, K files; VDW, Munich, Germany) were cut to 0.4 mm diameter. These fragments were fixed leaving a free end of 1- or 2-mm. Cyanoacrylate, dual-cure Rebilda DC, and light-curing SureFil SDR were placed in microtubes and on the instruments. After polymerization, pull-out tests were performed at a constant speed of 2 mm/min; failure load was measured digitally. Data were analyzed using the Kruskal-Wallis test followed by Dunn's test for pairwise comparison. The median failure load was up to 62.5 N for SDR, 35.8 N for Rebilda and 14.7 N for cyanoacrylate. Both tested composites produced significantly higher values in pull-out tests than cyanoacrylate. The detachment force was greater when light-cured composite SDR was used for attachment. Removing Hedstrom files resulted in higher values than removing K files. The median force when using SDR was 79.7 N (interquartile range, 66.0-86.8 N) on Hedstrom files and 53.3 N (interquartile range, 47.1-58.5 N) in K files. Within the limitations of this study, the use of light-cured composite within the microtube was superior compared to the use of cyanoacrylate or chemically cured composite, which are currently being used.

Rodrigues, et al., (2016) aimed to evaluate the removal of filling material after using stainless steel instruments with Gates and nickel-titanium drills in reciprocating and rotating movements in curved canals. Thirty teeth presented apical curvature between 200 and 350 and 19 to 22 mm in length and were selected and divided into 9 groups according to the retreatment procedures. The tooth opening was performed using diamond drills. The working length was established by introducing #10 K files until their tip was visible in the apical foramen and the working length was established one millimeter below this measurement. Then the Reciproc R25 files were used followed by the Mtwo 40/.04 and ProDesignLogic 50 /.01 files; ProDesign R 25/06 followed by ProDesignLogic 40/.05 and ProDesignLogic 50/.01 files; and Gates-Glidden drills, and Hedström file.

The canals were irrigated with one ml of 2.5% sodium hypochlorite and a final rinse was performed with 5 ml of 17% EDTA for 3 minutes. The canals were irrigated with saline, dried with paper tips and obturated by lateral compaction of gutta-percha cones and zinc oxide and eugenol cement (Endofill; Dentsply Ind. Com. Ltda., Petrópolis, RJ, Brazil). According to the experimental conditions of this study, the results demonstrated that the use of rotary systems, especially the ProDesignLogic 50/01 file, improved the removal of filling material after the use of reciprocating instruments, suggesting that a hybrid technique associated with these types of instruments It is valuable in root canal retreatment. The ProDesignLogic 50/.01 instrument, used in this investigation, significantly reduced the amount of filling material in the apical third compared to Reciproc files and appeared suitable for instrumenting and removing filling material in the apical portion without weakening the tooth structure. With this, it was possible to conclude that the association of rotary and reciprocating files were able to remove a large amount of filling material in the retreatment of curved canals, regardless of the type of alloy of the instruments. The use of a ProDesignLogic 50/01 file for apical preparation significantly reduced the amount of material remaining in the apical portion when compared with reciprocating instruments.

Leonardo and Toledo (2017) explained in chapter 4 “Biomechanical preparation of root canals Mechanical means: classical or conventional instrumentation” of the book “Root Canal Treatment: Technical and biological advances in minimally invasive endodontics at the apical and periapical level” convenience, adequate instrumentation, irrigation, cleaning and modeling of the endodontic space in both curved and straight canals. They also comment on surgical techniques and accidents that can occur in practice and focus heavily on instruments: materials and handling.

Arias, et al., (2018) aimed to evaluate the differences in cyclic fatigue of rotary instruments with heat treatment at room and body temperature. There were forty Hyflex files and 40 TRUShape files. The instruments were divided into 2 groups for the cyclic fatigue resistance tests in the water bath, one being an ambient temperature of 22°C and the other being a body temperature of 7°C. The instruments were rotated in a simulated canal (angle = 60°, radius = 3 millimeters and center of curvature 5 millimeters from the tip) until fracture occurred. Two Instruments of each brand were scanned. It can be concluded that Hyflex had a longer shelf life than TRUShape which showed a marked reduction in fatigue at body temperature.

The objective of Shen, et al., (2018) was to carry out a study to evaluate the cyclic fatigue of conventional superelastic and heat-treated NiTi files under the effect of 5 different temperatures (0º C, 10º C, 22º C, 37º C and 60º C), using a new method for fatigue testing on a zirconium oxide model. Six nickel-titanium rotary instruments (size 25/04), Endo Secence (Brasseler USA, Savannah, GA), ProFile, K3, K3XF, HyFlex CM and Vortex were used, these were subjected to cyclic fatigue tests on a new model of artificial ceramic channels. The artificial ceramic canals were milled with an In Coris ZI zirconium oxide disc (Dentsply Sirona, Bensheim, Germany) using the Digital in Lab MC X5 CAD/CAM system (Dentsply Sirona). The size of the artificial canal was 30/.06 with a curvature of 60 degrees and a radius of 5 mm. The model was fixed in a glass container with 300 ml of distilled water. To achieve the desired temperatures, the glass container was filled with ice water at 0°C or placed on a hot plate until the water temperature was stabilized at 10°C. The fatigue strength of all instruments was significantly affected by temperature. When the temperature cycle decreased from 60°C to 0°C, the average number of cycles to failure increased significantly for all groups. There was little difference in the photographic appearance of the fracture at different temperatures, however, the fracture area occupied by the irregular region of some instruments at 0º C was smaller than at 60º C. It can be concluded that cooling at low temperatures can be a strategy interesting to improve the fatigue resistance of NiTi rotary files.

MATERIALS AND METHODS

An "ex vivo" experimental study was carried out with 40 lower premolar teeth extracted by dental surgeons and donated by volunteers who wished to participate in the research. The donors of the dental organ were patients who attended the care services of volunteer dental surgeons who agreed to contribute to research related to the collection of teeth. The volunteer patients, who donated their teeth for research, were aged between 18 and 60 years, with the element indicating extraction due to periodontal disease or orthodontic indication. The criterion for choosing the research element was intact and healthy lower premolars, with only one canal and with similar curvature (from 0° to 25°, according to Schneider, 1971). Lower premolars that had caries cavities, endodontic treatments already carried out, calcified canals and curvatures above 25º were excluded from the research. In addition to these specifications, dental elements that did not have a free and informed consent form signed by their donor were also rejected.

Training was given to the academics/researchers proposed by the professor/advisor so that both are aware of the technique itself and the correct way to use manual instruments, minimizing the chances of error in the research.

Initially, each tooth was numbered from 1 to 40, after which the radiographic image of each element was obtained and the insert was made with the identification of the respective tooth number. These x-rays were later photographed with the iPhone 11 camera (Apple Inc., Los Angeles, United States of America) and the images were stored in the I cloud (Apple Inc., Los Angeles, United States of America). After this step, the endodontic opening was carried out on the occlusal surface of each tooth, with a circular shape for convenience. Next, the premolars were prepared and the canal was instrumented using the crown-apex technique proposed by the Univali undergraduate course.

PREPARATION OF SIMULATED CHANNELS

To prepare the root canals, two sets of ProDesign M file instruments were used. Each set contained 3 files: the 15/05 file identified by the silver-colored handle and with a yellow circular marking on the instrument handle; the 25/01 file has a red handle and a white circular marking on the instrument handle and the 25/06 file also has a red handle and a black circular marking on the instrument handle. To avoid file confusion, the number of the file set to which it belongs was listed on the handle of each instrument and a guide to identify the number of rotations already made. First, the Apparent Tooth Length (CAD) was measured on the radiograph and the canal preparation sequence was followed starting from 25/06, which reached up to three millimeters short of the CAD, simulating the Exploration Working Length (CTEx). Subsequently, the order of files from 25/01 or 15/05 of the PDM was followed until the file passed 1 mm from the apical foramen, to achieve patency of the tooth, that is, discover the file that reaches the apical foramen, the Initial Anatomical File (LAI). When these PDM files did not reach the apical foramen, the K C-Pilot file, 10/02 or 15/02, was used. From the LAI and with the file cursor at the reference point of the tooth (cusp), the Real Canal Length (CRC) was identified, removing the file and measuring it using the millimeter ruler. The foraminal modeling and enlargement sequence was carried out with files 15/05, 25/01 and 25/06 calibrated at the Working Length (CT), that is, one millimeter beyond the apical foramen and the Final Anatomical File (LAF) was always on 06/25. The practice began by inserting the game file number 1 into the canal of the tooth number 1, according to the sequence previously described, until resistance was felt and it was rotated five times, this movement was repeated until the 25/06 file reached the CTEx length. Afterwards, patency was performed with the LAI, and then the canals were modeled with files 15/05, 25/01 and 25/06 up to the CT. After each instrumentation performed by the files, they were cleaned with gauze soaked in alcohol to remove debris from the coils. Between the use of each instrument, prior to filing, the canals were irrigated with 5 ml of distilled water (5 ml syringe and 20x0.55 ml needle) and the root canal was filled using a syringe and needle with chlorhexidine gel. at 2%, until the canal fills completely (3 ml syringe and 20x0.55 ml needle).

INSTRUMENT FRACTURE

After using each instrument, they were visually evaluated with a millimeter ruler (Dia Dent Group International, Inc., Vancouver, British Columbia, Canada) to determine the presence of fracture or visual deformation of the file spirals. When an instrument fractured, it was discarded and replaced with another identical and new file from set number 2. Instrumentation of the canals continued until the fracture of the three instruments from both sets.

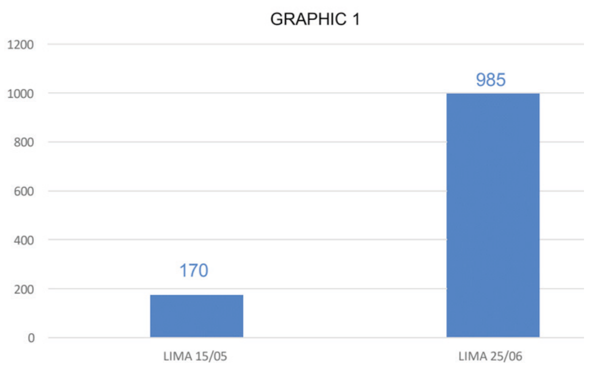
DATA ANALYSIS

During data collection, they were entered, stored and tabulated in a database in the Microsoft Excel 2016 ® program (Microsoft Corporation, Redmond, WA). The total and average number of turns made with files 15/05, 25/01 and 25/06 were analyzed and calculated.

International Journal of Health Science ISSN 2764-0159 DOI https://doi.org/10.22533/at.ed.1594212420024

RESULTS

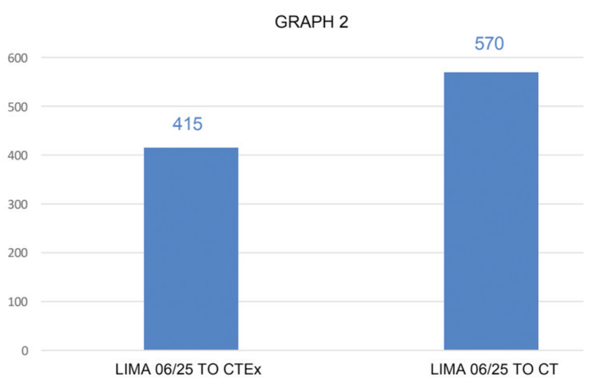
In graph number 1, the total number of turns with the file until the fracture occurs is shown. The high number of files 25/06 was due to working twice on the same channel: first, to CTEx and lastly to CT. The 25/01 file, which was not fractured, performed a total of 502 turns on 40 teeth.



GRAPH 1 – Total number of turns with each file until its fracture.

Source: Santos e Leite, 2021

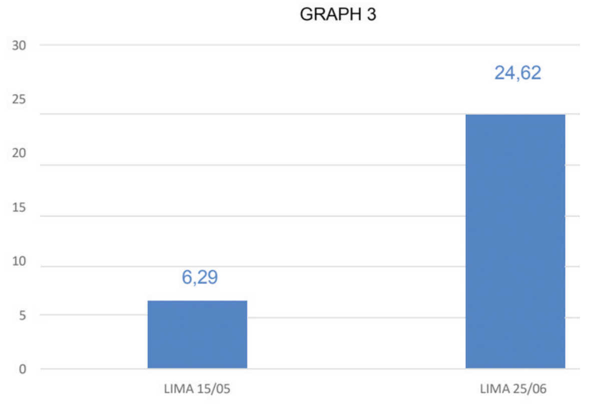
Graph number 2 explains in detail the total number of turns made by the 25/06 file in the same channel: up to the CTEx and up to the CT, totaling 985 turns.



GRAPH 2 – Total number of turns with the 25/06 file until the fracture.

Source: Santos e Leite, 2021

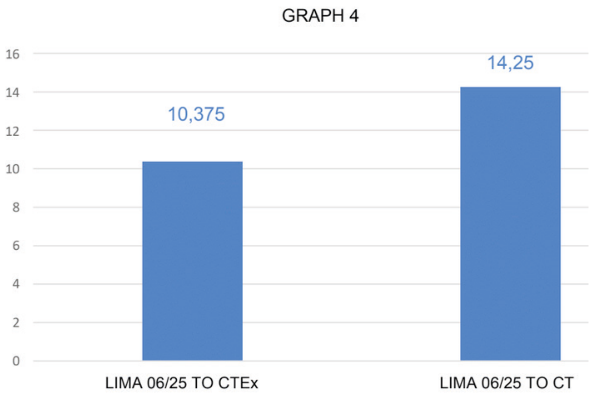
In graph number 3, the average number of turns of each file until its fracture is displayed with a confidence interval. The average number of turns with the 25/06 file is the sum of the average number of turns until the CTEx and CT. Even without the occurrence of fractures until the end of this study, the 25/01 file presented an average of 12.55 turns on 40 teeth.



GRAPH 3 - Average number of turns with each file until fracture.

Source: Santos e Leite, 2021

Graph number 4 shows the average number of turns made with the 25/06 file in the same canal: up to the CTEx and up to the CT.



GRAPH 4 - Average number of turns with the 25/06 file until fracture.

In table 1, you can identify the number of turns with each file on each element, the tooth and the exact moment in which each file fractured. The instruments that suffered fractures were the 15/05 and 25/06. The 15/05 file fractured on tooth number 27, when the foraminal modeling and enlargement was carried out. Instrument 25/06 fractured in tooth number 40, when instrumentation was performed at CTEx. The 25/01 file did not fracture due to its 0.01 taper.

TOOTH NUMBER	LIME	NUMBER OF LAPS	LOCAL	FRACTURE
1	25/06	25	CTEx	
	25/01	15	Forame	
	15/05	20	Forame	
	25/06	40	Forame	
2	25/06	10	CTEx	
	25/01	49	Forame	
	15/05	19	Forame	
	25/06	25	Forame	
3	25/06	25	CTEx	
	25/01	47	Forame	
	15/05	2	Forame	
	25/06	20	Forame	
4	25/06	2	CTEx	
	25/01	1	Forame	
	15/05	1	Forame	
	25/06	2	Forame	
5	25/06	8	CTEx	
	25/01	27	Forame	
	15/05	5	Forame	
	25/06	23	Forame	
6	25/06	2	CTEx	
	25/01	5	Forame	
	15/05	4	Forame	
	25/06	9	Forame	
7	25/06	34	CTEx	
	25/01	60	Forame	
	15/05	19	Forame	
	25/06	15	Forame	
8	25/06	1	CTEx	
	25/01	11	Forame	
	15/05	5	Forame	
	25/06	19	Forame	
9	25/06	3	CTEx	
	25/01	3	Forame	
	15/05	1	Forame	
	25/06	14	Forame	
10	25/06	25	CTEx	
	25/01	25	Forame	
	15/05	18	Forame	
	25/06	19	Forame	
11	25/06	1	CTEx	
	25/01	1	Forame	
	15/05	3	Forame	
	25/06	8	Forame	
12	25/06	15	CTEx	
	25/01	3	Forame	
	15/05	3	Forame	
	25/06	10	Forame	
13	25/06	1	CTEx	
	25/01	2	Forame	
	15/05	0	Forame	
	25/06	4	Forame	
14	25/06	1	CTEx	
	25/01	1	Forame	
	15/05	1	Forame	
	25/06	4	Forame	
15	25/06	6	CTEx	
	25/01	12	Forame	
	15/05	0	Forame	
	25/06	32	Forame	
16	25/06	1	CTEx	
	25/01	8	Forame	
	15/05	4	Forame	
	25/06	17	Forame	
17	25/06	18	CTEx	
	25/01	25	Forame	
	15/05	13	Forame	
	25/06	29	Forame	
18	25/06	20	CTEx	
	25/01	15	Forame	
	15/05	0	Forame	
	25/06	20	Forame	
19	25/06	3	CTEx	
	25/01	6	Forame	
	15/05	2	Forame	
	25/06	19	Forame	
20	25/06	2	CTEx	
	25/01	8	Forame	
	15/05	5	Forame	
	25/06	24	Forame	
21	25/06	3	CTEx	
	25/01	0	Forame	
	15/05	0	Forame	

	25/06	5	Forame	
22	25/06	2	CTEx	
	25/01	2	Forame	
	15/05	1	Forame	
	25/06	9	Forame	
23	25/06	25	CTEx	
	25/01	45	Forame	
	15/05	5	Forame	
	25/06	20	Forame	
24	25/06	11	CTEx	
	25/01	1	Forame	
	15/05	10	Forame	
	25/06	12	Forame	
25	25/06	5	CTEx	
	25/01	3	Forame	
	15/05	15	Forame	
	25/06	35	Forame	
26	25/06	1	CTEx	
	25/01	3	Forame	
	15/05	1	Forame	
	25/06	4	Forame	
27	25/06	4	CTEx	
	25/01	25	Forame	
	15/05	13	Forame	FRACTURE
	25/06	0	Forame	
28	25/06	10	CTEx	
	25/01	4	Forame	
	15/05	19	Forame	
	25/06	10	Forame	
29	25/06	1	CTEx	
	25/01	2	Forame	
	15/05	2	Forame	
	25/06	5	Forame	
30	25/06	5	CTEx	
	25/01	30	Forame	
	15/05	20	Forame	
	25/06	20	Forame	
31	25/06	5	CTEx	
	25/01	3	Forame	
	15/05	2	Forame	
	25/06	7	Forame	
32	25/06	45	CTEx	
	25/01	0	Forame	
	15/05	0	Forame	
	25/06	0	Forame	
33	25/06	25	CTEx	
	25/01	20	Forame	
	15/05	15	Forame	
	25/06	20	Forame	
34	25/06	8	CTEx	
	25/01	5	Forame	
	15/05	5	Forame	
	25/06	10	Forame	
35	25/06	4	CTEx	
	25/01	1	Forame	
	15/05	10	Forame	
	25/06	7	Forame	
36	25/06	5	CTEx	
	25/01	7	Forame	
	15/05	9	Forame	
	25/06	10	Forame	
37	25/06	10	CTEx	
	25/01	7	Forame	
	15/05	10	Forame	
	25/06	9	Forame	
38	25/06	5	CTEx	
	25/01	5	Forame	
	15/05	4	Forame	
	25/06	5	Forame	
39	25/06	14	CTEx	
	25/01	15	Forame	
	15/05	20	Forame	
	25/06	29	Forame	
40	25/06	24	CTEx	FRACTURE
	25/01	0	Forame	
	15/05	0	Forame	
	25/06	0	Forame	

Table 1- Total number of turns with files on each tooth and moment of fracture.

Source: Santos e Leite, 2021

DISCUSSION

The present study was about quantifying the use of ProDesign M files on mandibular premolar teeth "ex vivo" before their fracture. It is believed that because NiTi files have memory control and greater flexibility than other instruments, they end up facilitating the execution technique, improving cleaning, disinfection and modeling of root canals, which was observed in this research. PDM files are made of Nickel-Titanium, files made from these materials have Memory Control (CM) heat treatment and were developed to assist in the anatomical challenge of root canals. (MIRANZI, B. A. S., et al., 2005).

Over the years, the materials and protocols used in endodontic treatments have evolved, which favors an increase in the success rate of endodontic treatment (DA SILVA, 2004). The introduction of Nickel-Titanium alloys in Endodontics caused euphoria in the market and numerous changes in the concepts of biomechanical preparation of root canal systems (BORGES, et al., 2014). Therefore, companies that manufacture endodontic instruments continue to improve and introduce new equipment and qualified materials in order to improve clinical management, providing more convenience for the patient and safety for the dentist when performing the technique.

In this sense, during this research, it was possible to notice the ease in handling PDM files, especially while working at CTEx. NiTi instruments were introduced in endodontics to minimize procedural errors and increase safety during canal preparation, as they have greater flexibility, elastic memory, greater effectiveness, less loss of cutting capacity and biocompatibility, when compared to steel instruments. stainless. (PEREIRA, SILVA, FILHO, 2012).

NiTi files can go through a thermomechanical process, which makes them more flexible and offers greater safety and stability during canal instrumentation to the professional. To obtain memory control, M (M-Wire) and CM wires were introduced into the microstructure of NiTi alloys, making the files contain a special thermal process that controls the instrument's memory. Thus, its flexibility becomes even greater, resists cyclic fatigue and reduces the fracture of instruments in curved canals (SHEN, et al., 2018).

As stated by Arias, et al., (2018), instruments manufactured with CM offer greater advantages than those made solely from NiTi. The PDM files, used during the research process, proved to be easier due to their clockwise rotation kinematics, being able to perform more complete turns in the canals, this is due to their CM heat treatment. This technology was a benefit for teaching endodontic preparations in undergraduate dentistry courses. In the same sense, Rodrigues, et al., (2016) agrees with the author cited previously when he says that files that have CM heat treatment contribute positively to the retreatment of curved canals, due to their characteristics, in addition to reducing the patient and operator fatigue due to reduced working time.

With the evolution of NiTi files, in addition to facilitating handling and technique for the professional, clinical session time and patient chair time can be reduced, which allows for better quality of performance. When comparing #15 files made from nickel-titanium and stainless steel, it is observed that NiTi has two or three times more flexibility, as well as superior resistance to torsional fracture, the advantage of which is generating less transport of debris to the channel during instrumentation. (HADDAD FILHO, et al., 2011)

According to Paleker and Van Der Vyver (2017), nickel-titanium instruments have greater flexibility, efficiency and less loss of cutting capacity, when compared to stainless steel ones. On the other hand, Tepel, Schäfer and Hopee (1995) and Kazemi, Stenman and Spangberg (1996), believe that stainless steel files have a higher cutting capacity than nickel-titanium files, as do Piasecki, et al. (2013) who states that in addition to the type of material, it is necessary to consider that movements influence the performance and safety of endodontic files. Therefore, it can be seen that due to the flexibility of the NiTi files, in some cases it was not possible to achieve patency on some lower teeth with them, making it necessary to use the 10/02 and 15/02 C Pilot files due to their resistance and hardness.

Above all, it is also important to highlight that in the study by Paleker and Van Der Vyver (2017), when K-file files were compared with NiTi files, there was a higher quality in endodontic treatments and better cutting capacity in NiTi instruments, in addition preparation time is shorter than for k-file files in curved canals.

With regard to the safety of the system, authors, according to Gênova et al., (2004), have evaluated the behavior of the instrument regarding fracture in relation to the number of times the files were used in the instrumentation of canals simulated in blocks of resin, realizing that the ProTaper file proved to be safe until the fourth use and that the highest fracture rate occurs in files with greater tapers at the point of greatest curvature angle. According to Martins, Bahia and Buono (2009), the hardness of dentin compared to that of acrylic resin is lower. Therefore, with the aim of reducing the fracture rate, in this study, lower premolar human teeth with curvatures of up to 25º and with CRC ranging from 19 millimeters to 25 millimeters in length were used, thus configuring a more reliable with clinical practice, compared to acrylic resin blocks.

As stated by Da Silva (2004), torsional fracture occurs when the tip of the instrument is immobilized inside the root canal. In this case, the loading effort causes plastic deformation in the instrument's cutting blade. Continued loading may exceed the fracture resistance limit of the instrument, causing it to fail. Flexion fracture occurs when, in the flexion region of an instrument, stresses are generated that vary, alternately, between tension and compression. In the present study, it was observed that the instruments fractured due to torsion in the apical third of the dental element.

During the chemical-mechanical preparation of a root canal, endodontic instruments undergo extremely adverse stresses that vary with the anatomy of the canal, the dimensions of the instrument and the skill of the professional. (PEREIRA, LOPES, et al., 2011). In order to avoid possible fractures of the instrument, it is necessary to remove the endodontic file from the interior of the canal more frequently during instrumentation to carefully observe the turns, checking whether there is twisting of the instrument or signs of flexion. Deformed endodontic instruments must be discarded before failure (fracture) occurs. (DIAS, et al., 2010). Therefore, the importance of using a magnifying glass to check the length of the file and whether there is twisting when it is removed from the inside of the root canal was noted.

The authors Haddad Filho, et al., (2011) state that it is important to note that the cutting surfaces of nickel-titanium file blades deform during subsequent uses, which reduces their cutting power, and what's more, when subjected to cleaning and sterilization processes, they also suffer from corrosion. Thus, during data collection, even though the instruments were not sterilized, it was noted that before the files fractured, they became fatigued, reducing their cutting power, creating difficulty in reaching the apical foramen of the canal. However, no twisting was observed in the instrument before its fracture.

It is worth mentioning that to carry out the entire process during data collection, that is, cleaning, disinfection, emptying, modeling and foraminal enlargement of the canals, the same set of files was used until fracture occurred, and then replaced with one from game number 2. Da Silva (2004), commented that among the possible causes that would be related to the fracture of endodontic instruments, excessive use of the instrument was the most cited.

Borges, et al., (2014) suggested that endodontic instruments be used 5 to 10 times, in addition to being routinely inspected, to avoid fracture of these instruments. However, in the present research the same file was used exceeding the number of times suggested by Borges, without the instrument fracturing.

Fracture of endodontic files is not common, however, when it occurs it is a difficult situation to resolve. However, in the case of root canal retreatment, fractures become more frequent. (WEFELMEIER, et al., 2015). After analyzing 7159 endodontic instruments from different brands, used by 14 endodontists from 4 different countries, it was found that 12% were deformed and 5% fractured. (PARASHOS et al., 2004). Another study, between 1997 and 2003, analyzed 5,103 treated canals, concluding that 0.7% of these canals had fractures from stainless steel files and 0.4% from NiTi files. (SPILI, et al., 2006). In the article by Lobal, et al., (2006) the fracture frequency of stainless-steel hand instruments is 2% to 6%. In another study by Parashos, et al., (2006), it was found that in cases of mechanized NiTi instruments the percentage of fractures is 1.3% to 10%.

In the research by Pereira, et al., (2007), as well as in this research, file fractures occurred in the apical third, where the degree of curvature of the root canals is generally found. Fracture of a file can occur when its maximum strength is exceeded or when a crack opens in such a way that the remaining intact cross-section of the material is no longer able to tolerate the usual workload. (CHEUNG, 2009).

All files used in this study were evaluated with a magnifying glass (Magnifying -3.5 properly speaking. In this sense, it is recommended that other "ex vivo" and "in vivo" studies be carried out and conducted to investigate even more precise results on the useful life of these instruments.

CONCLUSION

The PDM files demonstrated a good result in the experiment carried out, since the 15/05 file managed to reach 170 turns in 27 canals, at which point it fractured. The 25/01 file did not fracture, but managed to reach 502 turns by the end of the study, that is, also 40 teeth. The 25/06 file had its fracture exposed after 985 turns in 40 canals, totaling 415 turns to the CTEx and 570 turns to the CT. all in single-rooted lower premolar teeth "ex vivo", modeled using the crown-apex technique.

Regarding the average number of turns made with the files inside the root canal, an average of 6.29 turns per tooth was achieved with the 15/05 instrument until fracture. With the 25/01 file, even though it did not fracture, it reached an average of 12.55 turns per tooth and, finally, the 25/06 reached an average of 24.62 turns per tooth, with 10.375 being an average in CTEx and 14 .25 laps on the CT.

In this sense, the quality of the Pro Design M (PDM) files stands out due to the material from which they are made, as it was the Nickel-Titanium alloy, which has a Memory Control heat treatment, which enabled a large number of turns through the canal until it fractures.

Therefore, we suggest that future studies be carried out with a greater number of tooth samples to confirm the information.

REFERENCES

ARENS, F., et al. Evaluation of single-use Rotary nickel-titanium instruments. **J. Endod**, Baltimore, v.29, n.10, p. 664-6, 2003.

ARIAS, A. et al. Correlation between temperature-dependent fatigue resistance and differential scanning calorimetry analysis for 2 contemporary Rotary instruments. **J. Endod**., Baltimore, v.44, n.4, p. 630-634, apr. 2018.

BORGES, L. E., et al. Fractures de limas rotatórias: os principais fatores que influenciam na fracture do instrumento. **REVISTA FAIPE**. Cuiabá, v. 4, n. 1, p. 33-37, jan./jun. 2014.

CHEUNG, G. Instrument fracture: mechanisms, removal of fragments, and clinical out comes. **Endod. Topics.**, Oxford, v. 16, n. 1, p. 1-26, 2009.

COHEN, S; HARGREAVES, K. **Caminhos da Polpa.** 11. ed. Rio de Janeiro: Elsevier, 2017.

CORREIA de, SOUZA, S, J. de.et al. Prevalência da fracture dos instrumentos endodônticos por alunos de pré-graduação: estudo clínico retrospectivo de 4 anos. **Rev. port. estomatol. Cir. maxilofac.,** Lisboa, v. 54, n. 3, p. 115-176, 2013.

DA SILVA, R. F. **Aspectos éticos, legais e terapêuticos da fracture de instrumentos endodônticos.** Dissertação (Mestrado em Odontologia Legal e Deontologia) - Faculdade de Odontologia de Piracicaba, da Universidade Estadual de Campinas. Piracicaba, p. 173, 2004.

DIAS, A. C. S et al., Trans-surgical endodontict reatment: anoption for special cases. **Rev. Cir. Traumatologia. Buco Maxilo-face**., Camaragibe, v. 10, n. 2, p. 49-53, abr./jun. 2010.

GÊNOVA, A. P. S., et al. Avaliação do índice de fractures das limas ProTaper em canais simulados. **Ver. Inst. Invest. Cienc. Salud.**, Cuenca, v. 22, n. 1, p. 51-4, jan./mar., 2004.

HADDAD FILHO, M. S., H *et al.* Perda de corte da lima ProTaper quanto a esterilização e número de uso. **Rev. Odontol. Univ. Cid. São Paulo.,** São Paulo, v. 22, n. 3, p. 228-237, set./dez. 2011.

IQBAL, M., KOHLI M., KIM J. A Retrospective Clinical Study of Incidence of Root Canal Instrument Separation in na Endodontics Graduate Program: a Penn Endo Database Study. **J Endod.,** Baltimore, v. 32, n. 11, p. 1048-52, 2006.

KAZEMI, R.B.; STENMAN, E.; SPANGBERG, L.S.W. Machining efficiency and wear resistence of nickel-titanium endodontic files. **Oral Surg. Oral Med. Oral Pathol.**, St. Louis, v. 81, n. 5, p. 596-602, may. 1996.

LEONARDO, R. M.; TOLEDO, de, R. **Tratamento de Canais Radiculares: Avanços técnicos e biológicos de uma endodontia minimamente invasiva em nível apical e periapical.** 2ª edição, São Paulo, Artes Médicas, 2017.

MARTINS, R.C.; BAHIA, M.G.A.; BUONO, V.T.L. Geometric and dimensional characteristics of simulated curved canals prepared with Pro Taper instruments. **J. Appl. Oral Sci.**, Bauru, v. 18, n. 1, p. 44-49, aug. 2009.

MIRANZI, B.A.S. Avaliação *in vitro* das distorções promovidas em canais radiculares artificiais curvos comparando o preparo cervical com limas de níquel-titânio acionadas a motor e brocas de gates-glidden. **Rev. odontociênc.,** Porto Alegre, v. 20, n. 49, p. 245-250, jul./set. 2005.

PARASHOS, P; MESSER, H. Rotary NiTi Instrument Fracture and its Consequences. **J Endod.,** Baltimore, v. 32, n. 11, p. 1031-1043, 2006.

PARASHOS, P., GORDON I. e MESSER H. Factors influencing defects of Rotary nickel titanium endodontic instruments after clinical use. **J Endod.,** Baltimore, v. 30, n. 10, p. 722-5, 2004.

PEREIRA, H. S. C., SILVA, E. J. N. L., FILHO, T. S. C. Movimento reciprocante em Endodontia: revisão de literatura. **Rev. Bras. Odontol**. Rio de Janeiro, v. 69, n. 2, p. 246-9, jul./dez. 2012.

PEREIRA, K. F. S. et al. Análise qualitativa pós instrumentação utilizando instrumentos manuais de aço inoxidável e rotatórios de níquel titânio. **Pesqui. bras. odontopediatria clín. Integr.**, João Pessoa, v. 7, n. 3, p. 247-252, set./dez. 2007.

PEREIRA LOPES, H., et al. Fracture dos instrumentos endodônticos. Recomendações clínicas. **Rev. Bras. Odontol**, v. 68, n. 2, p. 152-6, 2011.

PIASECKI, L. *et al.* Mechanical resistance of carbon and stainless-steel hand used in a reciprocating handpiece. **Ann Stomatol.**, Roma, v. 3, n. 4, p. 259-262, jul./set., 2013.

RODRIGUES, C. T. et al. Efficacy of CM-Wire, M-Wire, and nickel-titanium instruments for removing filling material from curved root canal: a micro-computed tomography study. **J. Endod.**, Baltimore, v. 42, n. 11, p.1651-1655, nov. 2016.

SCHNEIDER, S.W.A. Comparation of canal preparation in straight and curved rott canals. **Oral Surg. Oral Med. Oral Pathol**., St. Louis, v. 32, n. 2, p. 271-5, Aug. 1971.

SHEN, Y. et al., Low environmental temperature influences the fatigue resistance of nickel-titanium files. **J Endod.**, Baltimore, v. 44, n. 4, p. 626-9. 2018.

SPILI, P., PARASHOS, P. e MESSER, H. The Impact of Instrument Fracture on Out come of Endodontic Treatment. **J Endod.**, Baltimore, v. 31, n. 12, p. 845-50, 2005.

TEPEL, J.; SCHÄFER, E.; HOPEE, W. Root canal instruments for manual use: cutting efficiency and instrumentation of curved canals. **Int. Endod. J.**, Oxford, v. 28, n. 2, p. 68-76, mar. 1995.

WEFELMEIER, M., et al. Removing Fractured Endodontic Instruments with a Modified Tube Technique Using a Light- Curing Composite. **J Endod.**, Baltimore, v. 41, n. 5, p. 733-36, 2015.