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# A Comparative Evaluation of File Breakage in Conventional Versus Contracted Endodontics Cavities

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## Abstract

**Objective**: A nickel-titanium (Ni-Ti) rotary device was used to model the mesiobuccal canal of a mandibular molar with a standard or constricted endodontic cavity in order to compare rotations to failure and tip separation length.

**Methods:** The same lithium disilicate #30 crown was machined twice. An endodontic cavity, either conventional or constricted, was created. Every crown's mesiobuccal orifice was fitted with a specially made glass tube that was held in a silicone mould and had a taper and length that replicated a mesiobuccal canal, including buccal and lingual curvature.

The manufacturer-recommended 1.8 Nm torque and 500 RPM were used to replicate the instrumentation using 30/.04 Ni-Ti rotary files (n = 20 per access type). To calculate the number of rotations and seconds till failure of the instrument, video recordings were made. It was measured how long the shattered points were. In the experimental data were compared using a t-test (significance level 0.05). Stresses in the instruments were examined using finite element analysis.

**Results:** Number of rotations to failure (mean ± standard deviation) was 599±126 for conventional and 465±65 and for contracted access; tip separation lengths (mean ± standard deviation) were 3.99±0.29 for conventional and 4.90±1.02 mm for contracted access. Number of rotations to failure and tip separation lengths were significantly different between the two access openings ($p<0.001$). Finite element analysis confirmed higher file curvature and accompanying higher stress levels with contracted access and the maximum stress further from the tip.

**Conclusion:** Within the limitations of this study, the contracted access caused earlier failure of the Ni-Ti instrument with longer tip separation lengths than the conventional access due to higher stresses towards the middle section of the instrument.

**Keywords:** Ni-Ti, File Breakage, Straight-Line Access, Access Cavities

## Introduction

Sound root canal therapy begins with a crucial initial step: the creation of an endodontic access cavity. The term "straight-line access" refers to a preparation that offers a direct, unhindered approach to the canal system and ultimately to the root apex. Historically, endodontic cavities were made to permit this access into all canal orifices (1, 2). This access design decreases the chance of file breakage and improves debridement of the canal space (2), but at the expense of significantly reducing tooth structure. The ideas behind endodontic access cavities are evolving as minimally invasive dentistry becomes more widely used (3). The constricted cavity, an alternative to a conventional endodontic cavity, reduces the quantity of coronal dentine removal, which is connected to the long-term survival of a tooth (4). Therefore, contracted endodontic procedures are carried out to preserve tooth structure and enhance fracture resistance(5). However, disagreement persists. When examining the effectiveness of canal instrumentation and fracture resistance in mandibular and maxillary molars, studies have indicated that a constricted endodontic cavity did not provide any advantages (6, 7). Additionally, the agreed-upon endodontic cavity demands a greater angle of file access and is less accessible, both of which have been demonstrated to reduce the cyclic fatigue resistance of heat-treated rotary instruments (8).

When rotary instruments are subjected to cyclic loading during instrumentation, fatigue is a process of incremental crack propagation. Ni-Ti alloy, which was first used in endodontic instruments in the late 1980s (9), has excellent elasticity and shape memory, but Ni-Ti file breakage still occurs in clinical settings (10). The cycle fatigue resistance of Ni-Ti (11–13) has been increased using complicated heat-treatment procedures, careful cross-section architecture, and shape. For added flexibility and enhanced fatigue resistance, manufacturers have also added controlled memory wire to these instruments (14). Despite the quick development of file technology (15), file breaking is still a problem. Instrument fractures have occurred in endodontists at a rate of 94.8% and in general practitioners at a rate of 85.1% (16). Because of the volume of patients seen and the handling of more challenging situations, specialists presumably have a higher rate of instrument separation. The majority of the broken tools were found in the mesiobuccal canal of the mandibular molars (17). The radius, location, and degree of canal curvature are a few of the contributing components that account for this (18, 19). With an overall mean separated fragment length of 2.96 mm and 91.4% of these instrument separations occurring in the apical third, canals with a curvature of >25° had the greatest rate of instrument fracture (20).

The instrumentation path is additionally curved due to contracted access, which increases the strains on the files and may make fractures more likely. To the best of our knowledge, no other investigations have examined straight-line access in conventional preparations versus angle access in contracted preparations directly in terms of the difference in file breakage. To compare file breakage during instrumentation when accessed through regular versus constricted endodontic cavities was the aim of this investigation. Finite element analysis was used to analyze the stress distributions and measure rotations or time to failure and tip separation lengths of Ni-Ti rotating equipment within an in vitro modelled mesiobuccal canal of a mandibular molars. The null hypothesis was that the rotations to failure and tip separation lengths would not be significantly different between the conventional and the contracted endodontic cavities.

**Methodology**

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Review Board as Not Human Subjects Research since it did not involve “human subjects”.

**In vitro Analysis**

In accordance with average dimensions (occlusal table: mesiodistal 11.0 mm, buccal-lingual 10.5 mm; mesiobuccal cusp to CEJ 6.5 mm), two identical lithium disilicate mandibular right first molar (#30) crowns were milled with CAD/CAM (Sirona MC X Dental Lab CAD/CAM, Ivoclar Vivadent) (21-23). The two crowns were then put into a furnace (Programat CS2, Ivoclar Vivadent) for 15 minutes to crystallise. In each crown, a mesiobuccal orifice was made using a taper diamond bur (Kerr, Brea) and a conventional and constricted endodontic cavity was constructed with a round #2 diamond bur (Kerr, Brea, CA, USA) (Fig. 1a, b). In contrast to the constricted endodontic cavity, which was 3 mm buccolingually and 3 mm mesiodistally, the traditional endodontic cavity measured 5 mm buccolingually and 5 mmmesiodistally. A specially made glass tube was created with a taper and length that replicated the mesiobuccal canal and mesio and distal curve of tooth #30. The glass tube was 13 mm in length, with an inner diameter of 2.5 mm at the orifice level and 2.0 mm at the apex, a wall thickness of 0.8 mm, and a mesiodistal bend of 28° at a distance of 5 mm from the orifice. The glass blower was unable to incorporate a secondary curve in the buccal-lingual direction during the creation of the glass tube. To create the second curve (buccal-lingual), an incision was made 5 mm below orifice level, and the apical section was turned towards the lingual. In an effort to simulate a natural mesiobuccal canal of a lower first tooth, this additional curvature was introduced. The glass tube was placed at the mesiobuccal orifice of each crown in a silicone old (Megabite, DenMat, Lompoc, CA, USA) (Fig. 1c), and fixed to a three-pronged laboratory clamp stand for file breakage testing.

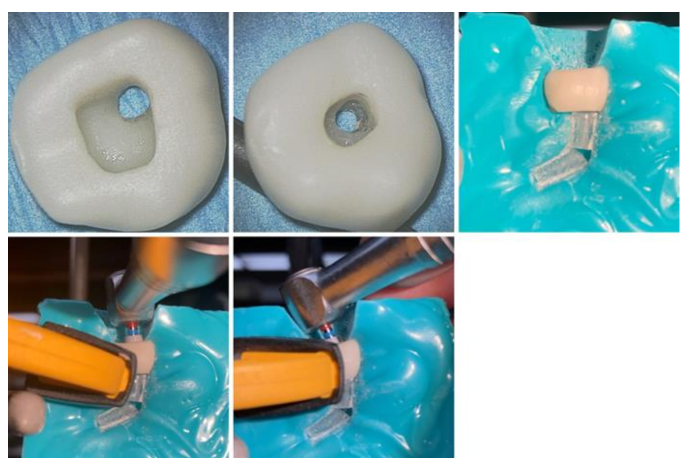

Figure 1. Machined lithium disilicate #30 crowns with (a) conventional endodontic cavity (5 mm×5 mm) and (b) contracted endodon- tic cavity (3 mm×3 mm) with a

mesiobuccal orifice. The curved glass tube was placed at the mesiobuccal orifice of each crown and fixed in a silicone mold for file breakage testing (c). File breakage test with conventional endodontic cavity (d) and contracted endodontic cavity (e), showing the angles of file insertion.

Controlled-Memory Device with 40 Endo sequences Manufacturer-recommended 1.8 Nm torque and 500 RPM were employed with Ni-Ti rotary files of size 30/.04 and 21 mm length (n = 20 per access type). In both accesses, handed instrumentation consisted of an endodontic contra-angle handpiece and a Pro-mark endodontic motor. The contracted endodontic cavity caused the handpiece to deviate to the distal-lingual, and the access cavities had an impact on the angle of file insertion (Fig. 1d, e). A smartphone camera was used to capture the instrumentation and time to failure (seconds) (iPhone SE, Apple, Cupertino, CA, USA). The broken file tip was taken out of the glass channel following each test. The number of rotations to failure was calculated from start of instrumentation to the time to failure, and the length of broken tips (mm) was measured with digital callipers.

**Statistical Analysis**

Following checking for normality (Kolmogorov-Smirnov test) and homogeneity of variance (Levene's test), the number of rotations until failure and the tip separation length data for the conventional and limited access outcomes were compared. 0.05 was the significance level. Tools online for calculating normality and homogeneity and statistical functions built into Excel for the t-test were utilised for the statistical analysis.

**Stress Analysis**

Utilising finite element analysis, distributions of stresses in the file under instrumentation through a conventional or contractual access were computed (MSC. Marc, MSC Software, Santa Ana, CA, USA). Nonuniform rational B-splines (NURBS), dimensioned following the experimental setup, were used to generate three-dimensional stiff surfaces with the two access cavities and mesiobuccal canals. Figure 2 shows the dimensions. Using 7650 8-noded hexahedral elements, a general constant-taper file instrument with a triangular cross-section (15 threads over a 16 mm working length; 0.30 mm diameter at D0 and 1 mm diameter at D16, 0.044 taper) was developed. Elastic modulus of 36 GPa and Poisson's ratio of 0.30 were the applicable Ni-Ti characteristics (24). The file instrument was inserted straight into the canal using the standard access or was 0.5 mm from the apex (Fig. 2). It was held and controlled at the end of the shaft. After that, the file was rotated inside the made-up canal. The stiff hollow and root walls and the filing instrument have a 0.25 coefficient of friction. For the purpose of comparing the stress distributions of the two access scenarios, Von Mises equivalent stress data, which encompass both three-dimensional normal and shear stress components, were gathered for one full rotation (360°).

Results

Table 1 includes the outcomes of the tip separation as well as the duration and number of rotations till collapse. When instrumenting through the contracted access opening as opposed to the normal access opening, the file failed significantly more quickly (22%) (t-test, p=0.0002). In comparison to situations with conventional access, the contracted access also resulted in significantly longer file tip separation lengths (23%) (t-test, p=0.0009).

When instrumenting using the narrowed access as opposed to the traditional access, the degree of file curvature from tip to shaft increased by twofold (mean + standard deviation: 53.73 + 0.58). The average of the maximum stress values (von Mises) determined by the finite element analysis in each cross-section was shown over the file's length (Fig. 3). When apparatus was oriented through the constricted endodontic access aperture as opposed to the traditional straight-line access, the maximum stress values in the file were nearly three times greater. For the traditional approach, the largest strains occurred at a distance of roughly 4 mm from the tip. The largest strains with the contracted access happened 5 to 9 mm away from the tip.

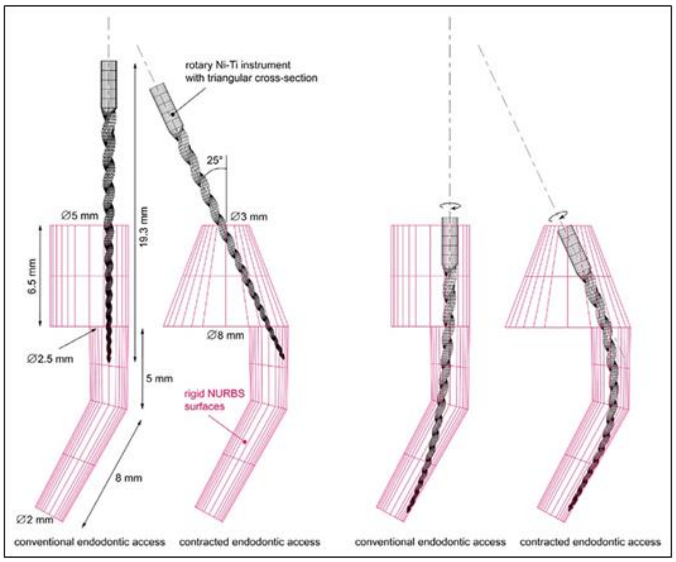


Figure 2. Finite element analysis of instrumentation with a rotary file through a simplified conventional or contracted endodontic access: Model dimensions and rotation after insertion to 0.5 mm from root apex

Table 1: Time and number of rotations to file failure and tip separation lengths (mean ± standard deviation) for two types of access openings

| | Conventional endodontic cavity | Contracted endodontic cavity | p* |
|---|---|---|---|
| Time to failure (seconds) | 71.90± 15.16 | 55.75 ±7.78 | 0.0 002 |
| Number of rotations to failure | 599±1 26 | 465±6 5 | 0.0 002 |
| Tip separation length (mm) | 3.99±0 .29 | 4.90± 1.02 | 0.0 009 |

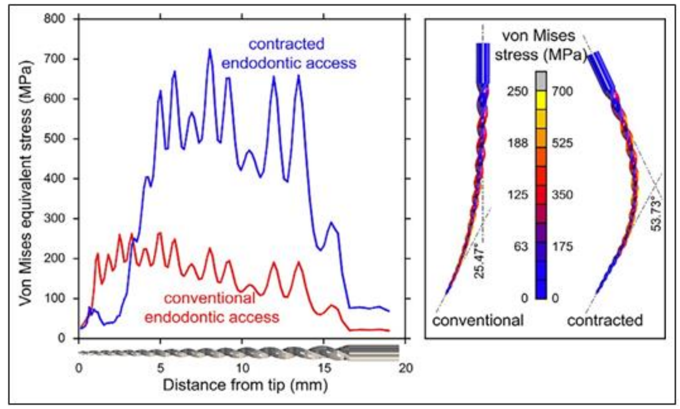


Figure 3. Averaged maximum stress values (von Mises) in cross-sections along the file length during 360° rotation and stress distribution in the file when instrumented through conventional or contracted endodontic access openings. Note the different stress scales for the conventional and contracted access. Tip-to-shaft curvature for both access configurations is indicated in degrees.

**Discussion**

Modern endodontic therapy is incorporating less intrusive procedures in an effort to protect tooth structure (3). To accomplish this, smaller endodontic accesses, also known as contracted endodontic cavities, are used. In order to determine whether smaller constrained accesses could influence when and where files would fracture in comparison to a conventional endodontic cavity—instrument fracture can adversely affect the success of root canal therapy—this study looked at this possibility. We discovered that the mean tip separation length and the number of rotations until failure varied significantly between the two endodontic access canals. When using instruments via a confined endodontic cavity, the file's fracture occurred early and the tip separation length was longer. The null hypothesis that there would be no difference in rotations to fracture and in tip separation length between the conventional and contracted endodontic cavities was therefore rejected.

File access at an elevated angle has been found to reduce cycles to failure of Ni-Ti rotary files (8), even though this is the first study to compare the differences in file breakage between the two access methods directly. According to the current investigation, the contracted approach caused twice as much bending of the rotary instrument as the traditional straight-line access, indicating a substantial difference in the amount of stress. Further study was necessary to establish how much the increase in curvature would raise stresses and how those stresses would spread over the file length. When a rotary instrument was oriented through a confined endodontic cavity, finite element stress analysis showed that noticeably greater stress levels (nearly three times higher) were produced in the instrument. The reduced fatigue life we discovered for the equipment employed in the confined cavity can be attributed to these increased forces. Although the majority of clinicians wouldn't instrument a single canal for the 71 seconds (conventional) or 55 seconds (contracted) it took for a file to separate in this study, instrumenting multiple canals in a single tooth or multiple teeth and reusing instruments could add up to this time, increasing the likelihood of file separation.

In the in vitro experiment, tip separation lengths between the two access cavities were significantly varied in addition to the number of cycles until failure. When instrumentation was done at an angle through the blade, the finite element analysis showed that the largest stresses occurred further from the tip.

This clarifies why the contracted cavities had the longest separation lengths since instruments are prone to become fatigued faster in high-stress locations. The larger likelihood of fracture farther from the tip is clinically significant because removal of these instruments is made more challenging by longer separated file lengths and a higher degree of curvature, which can significantly worsen the prognosis for effective therapy (25, 26).

Since this was an in vitro investigation, not all clinically relevant variables could be taken into account. There were various research design decisions that needed to be taken in order to standardise the experiment. Due to the high incidence of instrument breakage, we decided to simulate the size and canal curvature for a mandibular first molar's mesiobuccal canal (17).

Materials for the cavities and roots were chosen to be resistant to wear so that all testing would be conducted under the same conditions. Using an actual tooth would have prevented standardisation since during instrumentation, tooth structure would have been removed, changing the canal's shape (27). Therefore, crowns were made of lithium disilicate, while the root was made of a curved glass tube. For the same reasons, glass tubes have been employed in a number of investigations as substitute canals to investigate fatigue failure (28,29). Because of their improved cycle fatigue resistance and capacity to manoeuvre challenging anatomy, heat-treated controlled memory Ni-Ti rotary files were employed (14). Since the mini- mum apical preparation size is 30/.04, a size 30/.04 file was used for instrumentation to properly debride. The cutting and debriding processes that occur in a real root canal during clinical instrumentation were not simulated by the lithium disilicate cavity and glass canal, despite the fact that they allowed us to compare the fatigue behaviour of the instruments consistently under the two endodontic access conditions. Torsion may see more spikes as a result of cutting and debriding forces. Additional studies may examine the extent to which fatigue resistance can be further reduced.

By utilizing a model that resembled the mesiobuccal canal of a lower first molar, this study attempted to simulate a clinical situation. According to our findings, heat-treated controlled memory Ni-Ti rotary files with larger separated tip lengths failed sooner due to constrained endodontic access cavities. More research on this access design and file breakage is necessary in light of this result. This study's experimental design is ideal for comparing breakage behaviour across various access scenarios and rotational file types. For instance, among the several types currently available on the market, reciprocating rotary instruments are rising in popularity. It has been demonstrated that rotary Ni-Ti instruments with reciprocating rotation exhibit higher fatigue resistance than those with continuous rotation (31). A future study should therefore also compare the effect of fatigue resistance in conventional and contracted endodontic cavities for reciprocating instruments.

**Conclusion**

As far as this study's limitations allowed, the contracted access led to early failure of a Ni-Ti instrument with longer tip separation lengths than the conventional access because of increased bending and consequently higher loads in the coronal third of the curved canal. When instrumenting canals via a constricted endodontic cavity, vigilance must be used even when Ni-Ti instruments have been heat-treated and made more flexible.

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