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Original Research Article

Comparison of pro taper rotary instruments endurance before initial signs of failure: An in vitro study

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ABSTRACT

Objectives: The study aimed to evaluate the number of canals enlarged with a Pro Taper rotary instrument that could be safely used before the instrument showed initial signs of failure.
Materials and Methods: In the study, we included 150 freshly extracted human molars with canal curvatures of ≤200. Teeth were divided into two groups (n=225 canals for each group) according to the type of rotary file system used. In Group 1, Root canals were instrumented with Pro Taper Universal (PTU) rotary files; in Group 2, Root canals were instrumented with Pro Taper Gold (PTG) rotary files. Each file was used in canals as per the instrument sequence suggested by the manufacturer till the file showed initial signs of failure. Whenever a file showed initial signs of failure, it was discarded, and the number of canals enlarged with that rotary file was noted. A new file of the same size was used in the next canal. The data were analyzed with the independent t-test. The significance level was set at 0.05.
Results: The mean number of canals enlarged using Pro Taper Gold (12) was higher compared to Pro Taper Universal (10). There was a statistically significant difference in the number of canals enlarged by Pro Taper Gold and Pro Taper Universal files (p=0.001).
Conclusions: Pro Taper Gold was used to enlarge more root canals compared with the Pro Taper Universal, before showing initial signs of failure.

1. Introduction

The biological objective of cleaning and shaping is to remove all the pulpal tissue, bacteria, and endodontic toxins from the root canal system.[1] Therefore, the mechanical enlargement of the root canal plays a crucial part in endodontic treatment which facilitates chemical disinfection and three-dimensional obturation.

Advances in rotary endodontic instrument design have made canal shaping more effective. A notable advancement was the introduction of nickel-titanium (NiTi) rotary instruments in endodontic practice. NiTi instruments are super elastic and have more flexibility than stainless steel instruments. So, these instruments enable the safer instrumentation of curved root canals and decrease the chance of canal transportation when compared with that of stainless-steel files.[2] The file systems differ in terms of the design of the cutting blades, taper, and cross-section of the file, which affects the clinical performance of these rotary files.[3]

Despite the many advantages of NiTi instrumentation, unanticipated fractures occur during clinical use.[4] In order to avoid unanticipated fractures, limiting the number of uses of an endodontic instrument is one of the important factors controlling instrument failure.

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Manufacturers often recommend single-use NiTi instruments, but this may not be practically possible due to the cost of NiTi instruments. Moreover, it is common for clinicians to sterilize and reuse the instruments frequently, which increases the cyclic fatigue of instruments and their tendency to separate. However, there is no agreement about the number of usages an instrument can be subjected to before the initial sign of failure. In the literature, cyclic fatigue resistance was tested in vitro on NiTi rotary instruments using metal blanks, but this cannot be correlated to clinical practice because rotary instruments cannot cut metal blanks as effectively as dentin.

So, the present in-vitro study on extracted teeth was carried out to assess the number of canals enlarged safely, using two Pro Taper rotary systems, Pro Taper Gold and Pro Taper Universal, before the file showed initial signs of failure.

2. Materials and Methods

A total of 150 extracted human molar teeth with 450 root canals were taken, and the teeth were decoronated to standardize the tooth length to 20 mm after approval from the ethical committee (ref.no. IEC/DRS.S&NRSIDS/2022/PG/56). Molars with canal curvature ≤ 200 according to the Schneider method and those with initial working widths of either ISO 10 or 15 sizes, measured on preoperative intra-oral peri apical radiographs, were included. Teeth with calcified root canals and molars with more than three canals were excluded from the study. The samples were divided randomly into two groups according to the rotary file system used: Group I (n=225 canals) - Pro Taper Universal (Dentsply Tulsa Dental Specialties, USA), Group II (n=225 canals) - Pro Taper Gold (Dentsply Tulsa Dental Specialties, USA).

The root canals were numbered, and the teeth were mounted in silicone putty to maintain their position throughout the procedure. Access opening was done, the canal orifices were located with an endodontic explorer, and canal patency was verified with ISO #8 K-file (Mani, Inc.). For working length determination, ISO #10 K‑file (Mani, Inc.) was used to negotiate the entire length of the canal. Working width was determined using the initial apical binding file (ten or 15k files). Manual instrumentation was done with ISO #15 and 20 K hand files.

All the files in Pro Taper Universal and Pro Taper Gold rotary systems were used with an electric endo motor (X‑SMART^{TM}, Dentsply Malliefer), with a handpiece of 16:1 reduction of speed 300 rpm and torque 3N cm. In both groups, the Sx file was advanced till resistance to improve radicular access in all root canals. The remaining files, i.e., S1, S2, F1, F2, and F3, were advanced to working length in a sequential manner.[5]

A single operator completed all root canal preparations; after every instrumentation, the canals were irrigated with 2ml of 5.25% sodium hypochlorite. The rotary files were cleaned after each use and then examined under the dental operating microscope by an observer, who was blinded from the study, for any sign of failure in the rotary file, such as unwinding of flutes and separation of instruments.[6] If any failure sign was observed, that file was discarded and replaced by a new file of the same size. Data were obtained regarding the number of canals enlarged using a rotary file before the file showed initial signs of failure.

2.1. Statistical analysis

Data were analyzed in SPSS V21 software. Descriptive statistics were represented with Mean and SD. As data followed a normal distribution, an independent t-test was carried out. The pair-wise comparison was done using Tukey's test, and one-way ANOVA was performed for intra-group statistics. $P<0.05$ was considered statistically significant.

3. Results

The number of canals enlarged with each file is detailed in Table 1. From Sx to F3, a total of 6 files were instrumented in each canal, resulting in 1350 instrumentations in 225 root canals in each group. A total of 18 files in Pro Taper Universal and 11 files in Pro Taper Gold were fractured in root canals.

There was an overall significant increase in the number of canals enlarged with Pro Taper Gold files compared with Pro Taper Universal files ($P<0.05$), and there was a statistically significant difference in the mean number of canals enlarged with Pro Taper Universal and Pro Taper Gold between the respective files, except S1 detailed in Table 2. In the Pro Taper Universal group, F3 enlarged the maximum number of canals, and Sx enlarged the least number of canals, as detailed in Table 3. In the pair-wise comparison among Pro Taper Universal, there was a significant difference between all pairs except Sx-S1, S1-S2, S1-F1, and S2-F1, as detailed in Table 4. In the Pro Taper Gold group, F3 enlarged the maximum number of canals, and S1 enlarged the least number of canals, as detailed in Table 5. In the pair-wise comparison among Pro Taper Gold, there was a significant difference between all pairs except Sx-S1, Sx-F1, and F2-F3, as detailed in Table 6.

4. Discussion

Nickel Titanium rotary files are extensively used for shaping root canals because of their increased elasticity, efficiency, and cutting efficacy.

The Pro Taper rotary system manufactured by Tulsa Dental is variably tapered over the length of the cutting blades, convex triangular cross sections, and a rotary system with a noncutting tip. The increasing tapers in these files result in a smaller amount of contact area between the

Table 1: Mean number of canals enlarged

	Total number of canals enlarged	Total number of files used	Mean	Std. Deviation	Std. Error Mean	P value
PTU	1332	123	10.8293	3.67693	.33154	0.001*
PTG	1339	106	12.6321	4.51521	.43856	

*Statistically significant, Independent sample t-test

Table 2: Intergroup comparison of each file

		N	Mean	Std. Deviation	Std. Error Mean	P value
SX	PTG	28	8.3929	1.31485	.24848	0.000*
	PTU	23	9.7826	1.08530	.22630	
S1	PTG	25	8.9600	1.05987	.21197	0.255
	PTU	24	9.3750	1.43898	.29373	
S2	PTG	23	9.6522	1.11227	.23193	0.000*
	PTU	18	12.8333	1.58114	.37268	
F1	PTG	22	9.9545	1.39650	.29774	0.023*
	PTU	20	11.0500	1.60509	.35891	
F2	PTG	14	15.5000	1.60528	.42903	0.000*
	PTU	11	20.0000	1.54919	.46710	
F3	PTG	11	19.5455	1.75292	.52853	0.019*
	PTU	10	21.7000	2.11082	.66750	

*Statistically significant, Independent sample t-test

Table 3: Intra group comparision of PTU group

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum	P value
					Lower Bound	Upper Bound			
SX	28	8.3929	1.31485	.24848	7.8830	8.9027	6.00	10.00	0.000*
S1	25	8.9600	1.05987	.21197	8.5225	9.3975	7.00	10.00	
S2	23	9.6522	1.11227	.23193	9.1712	10.1332	8.00	11.00	
F1	22	9.9545	1.39650	.29774	9.3354	10.5737	8.00	13.00	
F2	14	15.5000	1.60528	.42903	14.5731	16.4269	14.00	19.00	
F3	11	19.5455	1.75292	.52853	18.3678	20.7231	18.00	23.00	

*Statistically significant, One way ANOVA

Table 4: Pair-wise comparison of PTU group

(I) VAR00002	(J) VAR00002	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
SX	S1	-.56714	.36515	.631	-1.6252	.4909
SX	S2	-1.25932*	.37344	.013	-2.3414	-.1773
SX	F1	-1.56169*	.37807	.001	-2.6572	-.4662
SX	F2	-7.10714*	.43437	.000	-8.3657	-5.8485
SX	F3	-11.15260*	.47221	.000	-12.5208	-9.7844
S1	S2	-.69217	.38255	.464	-1.8008	.4164
S1	F1	-.99455	.38705	.113	-2.1162	.1271
S1	F2	-6.54000*	.44198	.000	-7.8208	-5.2592
S1	F3	-10.58545*	.47906	.000	-11.9737	-9.1972
S2	F1	-.30237	.39485	.973	-1.4466	.8419
S2	F2	-5.84783*	.44882	.000	-7.1485	-4.5472
S2	F3	-9.89328*	.48538	.000	-11.2999	-8.4867
F1	F2	-5.54545*	.45267	.000	-6.8572	-4.2337
F1	F3	-9.59091*	.48894	.000	-11.0078	-8.1740
F2	F3	-4.04545*	.53347	.000	-5.5914	-2.4995

* Statistically significant Tukey's test done for significance

Table 5: Intra group comparision of PTG

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum	P value
					Lower Bound	Upper Bound			
SX	23	9.7826	1.08530	.22630	9.3133	10.2519	8.00	11.00	0.000*
S1	24	9.3750	1.43898	.29373	8.7674	9.9826	7.00	12.00	
S2	18	12.8333	1.58114	.37268	12.0471	13.6196	11.00	15.00	
F1	20	11.0500	1.60509	.35891	10.2988	11.8012	9.00	14.00	
F2	11	20.0000	1.54919	.46710	18.9592	21.0408	18.00	23.00	
F3	10	21.7000	2.11082	.66750	20.1900	23.2100	18.00	24.00	

*Statistically significant, One way ANOVA

Table 6: Pair wise comparison of PTG

(I) VAR00002	(J) VAR00002	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
SX	S1	.40761	.44165	.940	-.8757	1.6909
SX	S2	-3.05072*	.47631	.000	-4.4348	-1.6667
SX	F1	-1.26739	.46276	.077	-2.6120	.0773
SX	F2	-10.21739*	.55486	.000	-11.8297	-8.6051
SX	F3	-11.91739*	.57332	.000	-13.5833	-10.2515
S1	S2	-3.45833*	.47194	.000	-4.8297	-2.0870
S1	F1	-1.67500*	.45825	.005	-3.0066	-.3434
S1	F2	-10.62500*	.55110	.000	-12.2264	-9.0236
S1	F3	-12.32500*	.56969	.000	-13.9803	-10.6697
S2	F1	1.78333*	.49175	.006	.3545	3.2122
S2	F2	-7.16667*	.57925	.000	-8.8498	-5.4835
S2	F3	-8.86667*	.59696	.000	-10.6013	-7.1321
F1	F2	-8.95000*	.56816	.000	-10.6009	-7.2991
F1	F3	-10.65000*	.58620	.000	-12.3533	-8.9467
F2	F3	-1.70000	.66132	.114	-3.6216	.2216

* Statistically significant, Tukey's test

dentin and the rotary file.[7] Pro Taper Gold instruments have the same geometry principles as Pro Taper Universal instruments but are more flexible as the Pro Taper Gold have a 2-stage specific transformation behavior, indicating that reverse transformation of the alloy passes through the intermediated R-phase, which explains the complex phase transformation behavior tracking back to the manufacturing process. Interestingly, the metallurgical characteristics of Pro Taper Gold files also have high Austenite finish (Af) temperature.[8]

A fracture usually results from the incorrect technique or overuse of an endodontic instrument.[9] To avoid the failure of files, discarding them after a single use, as recommended by the manufacturer, is the best. The only possible way to minimize failure because of overuse is to discard rotary instruments soon after observing any initial signs of failure, which is a consequence of stress and strain developed during the usage of instruments.[3] However, there is no consensus in the literature about how many times a rotary file can be used before showing any initial signs of failure. Several studies evaluated cyclic fatigue testing, which was done using a metal blank to assess the number of cycles an instrument can be subjected to until it gets fractured while the file was rotating continuously at a given length. In a clinical scenario, this cannot be replicated, and it is assumed that an instrument can be used in the canal only for 2-3 seconds at a given pass, unlike the majority of studies, in which the rotating file is in contact with metal blank continuously, without leaving any chance for neutralization of stresses that are developed. In previous clinical studies, the usage of the file was limited to a certain number of canals, and it was examined under a microscope for signs of failure.[10,11] Cyclic fatigue was tested.[2,3] In complex, calcified, and curved canals, the instruments should be discarded after a single use or selectively discarded to increase safety in clinical settings.[12,13] A clinical study done by Wolcott et al. stated that Pro Taper Universal rotary files could be safely used four times before the file showed separation.[4] The previous literature had several limitations and does not answer how many times a rotary file can be used before showing an initial sign of failure, after which there is a higher chance of file separation if used. So, the current study was carried out to assess the number of files used in Pro Taper Universal and Pro Taper Gold systems before they

show initial signs of failure.

In the present study, the initial sign of failure was visualized under a dental operating microscope, because in clinical settings, it poses the warning sign that upon further usage, the instrument may get separated. However, in the absence of a microscope, these signs of failure can be seen with the magnifying lens (6X).

Canal curvature is one of the crucial factors influencing instrument failure. The average canal curvature was around 20 degrees.[14,15] So, in the present study, a canal curvature of ≤20o was included. The number of canals was considered rather than the number of teeth because the number of canals may vary between teeth. In this study, the Pro Taper Gold group Sx rotary file has shown initial signs of failure at the 9th canal, which means Sx can be safely used for eight canals.

In the present study, Pro Taper Gold has shown initial signs of failure after usage in more canals than Pro Taper Universal. This may be due to high Austenite Finish (AF) temperature without shape memory and the two-stage transformation behavior of Pro Taper Gold, thus resembling controlled memory wires. Due to this technology, manufacturers also claim that the Pro Taper Gold system has more fatigue resistance than the Pro Taper Universal. The present study findings correlate with the study done by Hieawy et al.[8] which concluded that the Pro Taper Gold has better cyclic fatigue resistance than the Pro Taper Universal.

In the Pro Taper Universal group and Pro Taper Gold group, Sx and S1 have shown less use because Sx is the first file to enter the canal, which is under resistance and has increased contact with dentin. In both the groups, F3 has the highest number of uses, which is in negative correlation with the authors who found that the smaller the diameter of the NiTi files with a fixed taper, the more resistant they would be to fatigue.[16] This might be due to adherence to the recommended technique. The shaping files were used first, which creates lateral space and allows the larger finishing files to move cautiously and gradually deeper into the canal space.

In the present study, an overall occurrence of 1.5% fractures without any sign of failure was observed. In Susan Walcott et al.[17] study the instrument separation rate was 2.4%. This was 14% in the study done by Shen et al.[10] indicating that Pro Taper files are likely to separate without warning.

Limitations of the present study: included only molar teeth with root canal curvatures of <20 degrees. As the present study was carried out in in-vitro conditions, factors such as the position of the tooth, orientation of file, patient mouth opening, and operator position may affect the outcome in the clinical scenario.

5. Conclusion

Within the limitations of the present study, Pro Taper Gold rotary files showed a greater number of usages before showing any sign of failure when used in canals with curvature of ≤20 degrees. However, it is worth mentioning that clinical studies are needed to confirm these results.

6. Source of Funding

None.

7. Conflict of Interest

None.

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The authors deny any conflicts of interest related to this study.

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