Comparison of the Effects of Three Different Nickel–titanium Rotary Instruments on the Fracture Resistance of Obturated Roots: An in vitro Study

Saimanaaz AH Shaikh, Vanitha U Shenoy, Sumanthini MV, Ritesh B Pawar

ABSTRACT

Aim: The aim of the article is to compare the effects of three different nickel–titanium (NiTi) rotary instruments on the fracture resistance of obturated roots.

Materials and methods: A total of 100 permanent mandibular premolars were randomly divided into four groups of 25 teeth each and biomechanical preparation was done: group I: stainless steel K-hand files (HFs), group II: ProTaper NiTi instruments (PT), group III: HyFlex CM NiTi instruments (HCM), and group IV: K3XF NiTi instruments. Following root canal preparation, the canals were obturated using lateral condensation. A light body silicone impression material was used to simulate the periodontal ligament (PDL). Fracture resistance was tested in an Instron testing machine.

Statistical analysis: Data were analyzed with Kruskal–Wallis test.

Results: There was no difference in significance (p < 0.05) among the different groups tested with respect to their fracture resistances.

Conclusion: The present study concluded that rotary instrumentation could result in an increased chance for dentinal defects as compared with hand instrumentation. Greater taper rotary NiTi instruments do not increase the fracture susceptibility of roots, which in turn depends on various factors other than instrumentation alone.

Clinical significance: Greater taper achieved by rotary NiTi files during canal preparation facilitates efficient irrigation and complete debridement. Root fracture might occur as a result of microcracks or craze lines that propagate with repeated stress application by occlusal forces and also during canal preparation. Based on the results obtained, it can be decided whether the use of the newer rotary NiTi system contributes to endodontic success and long-term survival of endodontically treated teeth.

Keywords: Dentinal damage, Hand files, Rotary nickel–titanium files.
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Descriptive data regarding fracture resistance of each group is given in Table 1.

The results were statistically analyzed by Statistical Package for the Social Sciences software (version 16) using nonparametric Kruskal–Wallis test, which was used to test the significance of difference of the mean force in Newtons (N) required for fracture resistance of roots of various groups. Since p value of Kruskal–Wallis Test was less than 0.05, it indicated that there was a significant difference between the means of four groups. A Mann–Whitney U-test (Table 2) was done for the pairwise comparison. The fracture resistance of obturated roots in each group is given in Graphs 1 and 2. The bar graph (Graph 1) depicting the mean of the fracture resistance in Newtons (N) for all tested groups shows that HFs required approximately 253.4992 N to fracture, which was highest among all the tested groups followed by 203.2164 N for PT, 130.4032 N for HCM, and 111.32 N for K3XF.

Table 1: The mean force in Newtons (N) required for fracture resistance for all test groups

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>Standard error</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>HF</td>
<td>25</td>
<td>253.4992</td>
<td>94.28107</td>
<td>18.85621</td>
<td>111.32</td>
<td>421.89</td>
</tr>
<tr>
<td>PT</td>
<td>25</td>
<td>234.8108</td>
<td>78.61423</td>
<td>15.72285</td>
<td>107.40</td>
<td>352.80</td>
</tr>
<tr>
<td>HCM</td>
<td>25</td>
<td>203.2164</td>
<td>58.75328</td>
<td>11.75066</td>
<td>93.00</td>
<td>292.13</td>
</tr>
<tr>
<td>K3XF</td>
<td>25</td>
<td>130.4032</td>
<td>56.06347</td>
<td>11.21269</td>
<td>69.87</td>
<td>285.96</td>
</tr>
</tbody>
</table>
by PT requiring approximately 234.8108 N, which was the highest among all the rotary groups. The results obtained from all tested groups are interpreted in the form of box plot (Graph 2). The box area in the box plot represents fracture resistance for all tested groups. The horizontal line represents the median value. The vertical line represents the range of the group. Group I (HF) required approximately 253.49 N to fracture the roots, which was found to be the maximum among all the experimental groups followed by group II (PT) requiring approximately 234.81 N, which was the maximum among the rotary groups. Group III (HCM) and group IV (K3XF) required approximately 203.21 and 130.40 N respectively.

**DISCUSSION**

The VRFs may occur during endodontic procedures, which may be a precipitating factor. The root may be weakened by instrumentation alone, resulting in excessive removal of dentin during root canal preparation increasing susceptibility to root fracture\(^9\) and generating cracks on the apical surface,\(^5\) which could ultimately lead to VRFs.\(^6\) The use of rotary NiTi instruments might result in an increased risk of dentinal defects occurring\(^7\) probably because these files need significantly more rotation in the canal to complete the preparation when compared with HFs.

During preparation, a canal is shaped by the contact between instrument and dentin walls creating momentary stress concentrations in dentin which are, in turn, determined by the mechanical behavior and cross-sectional and longitudinal design of files. Such stresses may leave dentinal defects and apical cracks in which VRF can initiate.\(^9\)

In the current study, four different instruments were used, one group consisting of HF and the other three groups consisting of different rotary systems namely PT, HCM, and K3XF files. Bier et al\(^9\) and Yoldas et al\(^7\) in their study observed no influence of HFs on the development of dentinal cracks. However, it was observed by Liu et al\(^10\), Hin et al\(^11\), and Zandbiglari et al\(^12\) in their study that HFs caused lesser number of cracks when compared with rotary files. These results are in agreement with the current study. However, it has been stated by Shaheen et al\(^13\) in their study that PT had the highest resistance to fracture, which may be due to increased canal taper of PT preparation in coronal and middle thirds that allowed forces to be better distributed in the apical third of the canal and potentially increase the resistance to fracture of the root.\(^14\)

This finding was supported by Lam et al\(^15\) who concluded that greater apical enlargement did not increase the fracture susceptibility of the roots. The results of the above studies are in agreement with the present in vitro study.

**Table 2: Mann–Whitney U-test**

<table>
<thead>
<tr>
<th>Groups</th>
<th>Mann–Whitney U-test results</th>
<th>p-value</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>HF PT</td>
<td>291.0</td>
<td>616.0</td>
<td>–0.417</td>
</tr>
<tr>
<td>HCM PT</td>
<td>221.0</td>
<td>546.0</td>
<td>–1.775</td>
</tr>
<tr>
<td>K3XF PT</td>
<td>72.0</td>
<td>397.0</td>
<td>–4.67</td>
</tr>
<tr>
<td>Protaper HCM</td>
<td>230.0</td>
<td>555.0</td>
<td>–1.601</td>
</tr>
<tr>
<td>HCM K3XF</td>
<td>80.0</td>
<td>405.0</td>
<td>–4.511</td>
</tr>
<tr>
<td>Protaper K3XF</td>
<td>112.0</td>
<td>437.0</td>
<td>–3.89</td>
</tr>
</tbody>
</table>

NS: Nonsignificant; S: Significant

**Graph 1: Bar graph depicting the mean of the fracture resistance in Newtons (N) for all tested groups**

**Graph 2: Box plot for all tested groups**
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On the contrary, Bier et al., Kansal et al., Liu et al., and Hin et al. observed in their studies comparing PT with other rotary systems other than the ones used in the current study that PT caused significantly more cracks than other rotary systems. Capar et al. compared the incidence of cracks in root dentin after root canal preparation with PT Next, HCM, and PT Universal rotary instruments, and observed that PT Next and HCM instruments caused fewer cracks than the PT Universal instrument. However, in the present study, not much of statistically significant difference between the fracture resistance of PT and HCM files was observed.

In the present study, all of the tested rotary instruments had noncutting tips except HF's having an active cutting tip. The PT and HCM instruments have a triangular cross-sectional geometry, whereas K3XF is a modified triple U. In addition, PT Universal has a variable taper design of 7, 8, and 9% for F1, F2, and F3 respectively, whereas HCM and K3XF are available with constant tapers of 4 and 6%.

In this in vitro study, extracted human premolars were used as reported by many investigators. The root canals were always irrigated with saline before switching to NaOCl in order to avoid any interaction between various irrigants.

Vertical load was applied with a spherical ball tip of diameter 4 mm, which was allowed to contact the flat surface of the prepared roots. Root canals were obturated using lateral condensation technique. Periodontal ligament simulation was done using light body elastomeric impression material allowing limited freedom of movement whilst avoiding external reinforcement.

CONCLUSION

The conclusion drawn from this in vitro study is that instrumentation with rotary files may increase the chances for dentinal defects when compared with hand instrumentation. Greater taper rotary NiTi instruments, such as PT rotary files did not increase the fracture susceptibility of roots, which, in turn, depended on various factors other than instrumentation alone. It was observed that newer rotary NiTi instruments, such as K3XF and HCM had lower fracture resistance as compared with PT instruments. The effects of various rotary NiTi instruments on the propagation of dentinal cracks, increasing the susceptibility to VRFs, have been extensively studied.

Further research needs to be carried out on the fracture resistance of endodontically treated teeth using K3XF and HCM rotary instruments.

CLINICAL SIGNIFICANCE

Greater taper achieved by rotary NiTi files during canal preparation facilitates efficient irrigation and complete debridement. Root fracture might occur as a result of microcracks or craze lines that propagate with repeated stress application by occlusal forces and also during canal preparation. Based on the results obtained, it can be decided whether the use of newer rotary NiTi system contributes to endodontic success and long-term survival of endodontically treated teeth.

REFERENCES


