A comparative study of root canal shaping using protaper universal and protaper next rotary files in preclinical dental education

Gül Çelik [Corresp., 1] , **Feyza Özdemir Kısacık** [2] , **Emir Yılmaz** [3] , **Arife Yaran** [4] , **İhsan Furkan Ertuğrul** [5] , **Hikmet Orhan** [6]

[1] Faculty of Dentistry, Endodontics, Suleyman Demirel University, Isparta, Turkey

[2] Vefa Oral and Tooth Health Center, Afyonkarahisar, Turkey

[3] Dentplus Oral and Dental Health Center, Bursa, Turkey

[4] Araklı Bayram Halil State Hospital, Trabzon, Turkey

[5] Faculty of Dentistry, Departmant of Endodontics, Pamukkale University, Denizli, Turkey

[6] Faculty of Medicine, Biostatistics and Medical Informatics, Suleyman Demirel University, Isparta, Turkey

Corresponding Author: Gül Çelik
Email address: gulcelik@sdu.edu.tr

Background. One of Dentistry evolution has occurred in Endodontics due to the advancement of rotary techniques for root canal preparation and its subsequent incorporation into the teaching of Dentistry undergraduates. This research aimed to evaluate the shaping ability of the third-year dental students as their first experience in rotary instrumentation using ProTaper Universal (PTU) and ProTaper Next (PTN) (Dentsply Maillefer) rotary instruments in simulated curved canals. **Methods.** Forty students instrumented 200 simulated canals with a 40° curvature in resin blocks according to the manufacturer's instructions with PTU and 39 students 195 canals with PTN files. The canals were prepared at a speed of 300 rpm and using a 16:1 reduction hand-piece powered by an electric motor (Xsmart, Dentsply Maillefer). The final apical preparation was set to F2 for the PTU and X2 for the PTN group. The change in canal curvature was evaluated based on Schneider technique using the AutoCAD 2007 software on post-digital photographs. The incidence of instrument fracture and deformation, the incidence of ledge, the change in working length (WL), and the working time were noted. The data were analyzed with Student's t-test and Chi-Square test at a significance level of 0.05 using SPSS. **Results.** The PTN maintained the original canal curvature better, resulting in fewer fractures and ledges, and shaped the canals faster than the PTU (P˂0.05). The mean curves of the resin canals after the instrumentation for the PTU and PTN groups were 24.03º ± 3.14° and 25.64º ± 2.72°, respectively. Thirty-three (17.4%) PTU and 18 (9.3%) PTN files fractured (p˂0.05). Nine (4.5%) PTU and 2 (2.6%) PTN deformed (p>0.05). The change in WL after instrumentation was 0.97mm± 0.95mm in PTU and 0.96mm± 0.80mm in PTN (p>0.05).

The mean times were 627s ± 18 s for PTU and 379s ± 18 s for PTN (p˂0.000). **Discussion.** PTN can be preferred in severe curved of the root canals in terms of maintenance of the original canal curvature, superior instrument fracture and fewer ledges. Even if short training before preparation provided an acceptable level of canal shaping for preclinical students, the use of NiTi rotary instruments should be included in the undergraduate dental curriculum, contributing to an increase in the quality of root canal shaping, and consequently to an improvement of clinical experience of students.

1 # A COMPARATIVE STUDY OF ROOT CANAL SHAPING

2 # USING PROTAPER UNIVERSAL AND PROTAPER

3 # NEXT ROTARY FILES IN PRECLINICAL DENTAL

4 # EDUCATION

5 Gül ÇELİK[1], Feyza ÖZDEMİR KISACIK[2], Emir YILMAZ[3], Arife YARAN[4], İhsan Furkan
6 ERTUĞRUL[5] , Hikmet Orhan[6]

7 [1] Faculty of Dentistry, Department of Endodontics, Suleyman Demirel University,
8 Isparta, Turkey

9 [2] Vefa Oral and Tooth Health Center, Afyonkarahisar, Turkey

10 [3] Dentplus Oral and Dental Health Center, Bursa, Turkey

11 [4] Araklı Bayram Halil State Hospital, Trabzon, Turkey

12 [5] Faculty of Dentistry, Department of Endodontics, Pamukkale University, Denizli,
13 Turkey

14 [6] Faculty of Medicine, Biostatistics and Medical Informatics, Suleyman Demirel
15 University, Isparta, Turkey

16 **Running Title:** preparation in preclinical education

17 **Corresponding author:**

18 Gül Çelik

19 Department of Endodontics

20 Faculty of Dentistry

21 İzmir Demokrasi University,

22 İzmir, Turkey

23 Phone: +905324730823

24 Fax: +902462370607

25 Email:

26   gulcelik2016@gmail.com

A COMPARATIVE STUDY OF ROOT CANAL SHAPING USING PROTAPER UNIVERSAL AND PROTAPER NEXT ROTARY FILES IN PRECLINICAL DENTAL EDUCATION

Background. One of Dentistry evolution has occurred in Endodontics due to the advancement of rotary techniques for root canal preparation and its subsequent incorporation into the teaching of Dentistry undergraduates. This research aimed to evaluate the shaping ability of the third-year dental students as their first experience in rotary instrumentation using ProTaper Universal (PTU) and ProTaper Next (PTN) (Dentsply Maillefer) rotary instruments in simulated curved canals. **Methods.** Forty students instrumented 200 simulated canals with a 40° curvature in resin blocks according to the manufacturer's instructions with PTU and 39 students 195 canals with PTN files. The canals were prepared at a speed of 300 rpm and using a 16:1 reduction hand-piece powered by an electric motor (Xsmart, Dentsply Maillefer). The final apical preparation was set to F2 for the PTU and X2 for the PTN group. The change in canal curvature was evaluated based on Schneider technique using the AutoCAD 2007 software on post-digital photographs. The incidence of instrument fracture and deformation, the incidence of ledge, the change in working length (WL), and the working time were noted. The data were analyzed with Student's t-test and Chi-Square test at a

46 significance level of 0.05 using SPSS. **Results.** The PTN maintained the original canal

47 curvature better, resulting in fewer fractures and ledges, and shaped the canals faster

48 than the PTU (P<0.05). The mean curves of the resin canals after the instrumentation

49 for the PTU and PTN groups were 24.03º ± 3.14° and 25.64º ± 2.72°, respectively.

50 Thirty-three (17.4%) PTU and 18 (9.3%) PTN files fractured (p<0.05). Nine (4.5%) PTU

51 and 2 (2.6%) PTN deformed (p>0.05). The change in WL after instrumentation was

52 0.97mm± 0.95mm in PTU and 0.96mm± 0.80mm in PTN (p>0.05). . The mean times

53 were 627s ± 18 s for PTU and 379s ± 18 s for PTN (p<0.000). **Discussion.** PTN can be

54 preferred in severe curved of the root canals in terms of maintenance of the original

55 canal curvature, superior instrument fracture and fewer ledges. Even if short training

56 before preparation provided an acceptable level of canal shaping for preclinical

57 students, the use of NiTi rotary instruments should be included in the undergraduate

58 dental curriculum, contributing to an increase in the quality of root canal shaping, and

59 consequently to an improvement of clinical experience of students.

60

61

62

63 # A COMPARATIVE STUDY OF ROOT CANAL SHAPING

64 # USING PROTAPER UNIVERSAL AND PROTAPER

65 **NEXT ROTARY FILES IN PRECLINICAL DENTAL**

66 **EDUCATION**

67 **INTRODUCTION**

68 Cleaning and shaping of the root canal, which must be performed mechanically and

69 biologically, is the most important procedure in root canal treatment. A variety of

70 techniques and instruments have been developed to perform this procedure without

71 generating undesirable clinical results, such as canal straigtening, transportation,

72 ledging, strip perforations, or instrument fractures. The European Society of

73 Endodontics (ESE) has published current articles to lead the undergraduate curriculum

74 in endodontics to improve dental students' theoretical and clinical education (*ESE,*

75 *2001*). ESE believes that undergraduate students should receive preclinical and clinical

76 training to be able to successfully treat uncomplicated anterior premolar and molar teeth

77 (*De Moor et al., 2013*). Endodontic education needs to be developed in undergraduate

78 programs (*Dummer, 1991; Qualtrough & Dummer, 1997; Unal et al., 2012*) and the use

79 of new techniques and devices that have proven to be positive contributions to root

80 canal therapy should be included in undergraduate training programs (*Unal et al.,*

81 *2011*).

82 The technical quality of root fillings, assessed radiographically, performed by

83 undergraduate students using hand instruments was investigated in a meta-analysis

84 (*Riberio et al., 2018*). The results revealed a low frequency (48.75%) of acceptable

85 technical quality of root fillings and drew attention to the major procedural errors created

86   (*Riberio et al., 2018*). Many studies have been conducted to evaluate the performance

87   of students in curved root canals (Hänni et al., 2003; Arbab-Chirani & Vulcain 2004;

88   Alrahabi, 2015; Unal et al., 2011). Despite the multiple benefits of using NiTi rotary

89   instruments, the step-back technique using stainless steel files is still a conventional

90   teaching method in endodontic programs for undergraduate students in most countries

91   (*Alrahabi, 2015*). Although students with no experience are reported to be successful in

92   the use of rotary instruments (*Unal et al., 2012; Kwak et al., 2016; Brito-Júnior et al.,*

93   *2014*), it is evident that errors can be minimized by the training to be taken in the

94   curriculum. Georgelin-Gurgel et al. (*2008*) and Alrahabi (*2015*) reported that manual

95   instrumentation is safer than rotary instrumentation in the hands of inexperienced

96   students. They underlined that acquiring skill in the use of NiTi rotary instrumentation

97   requires specific preclinical training to avert file breakage. Martins et al. (*2012*)

98   suggested that the use of NiTi rotary instruments should be included in the

99   undergraduate dental curriculum, as this would contribute to an increase in the number

100 of patients assisted, and consequently, improve the students' clinical experience.

101   Some procedural errors have been minimized after the introduction of the NiTi

102 alloy into endodontics (Walia et al., 1988; Vaudt et al., 2009; Yang et al., 2011).

103 Nevertheless, the fracture of the NiTi rotary root canal instruments suddenly and without

104 any warning creates a disappointment for the dentist (Zuolo & Walton 1997; Arens et

105 al., 2003; Ankrum et al., 2004). The studies are underway to increase the resistance of

106 the root canal instrument against breakage in order to overcome this problem. A recent

107 novelty of the alloy is the so-called m-wire alloy. The M-Wire material has been shown

108 to have longer fatigue resistance and lower fracture risk than conventional NiTi alloy

109 does (Johnson et al., 2008; Montenegro-Santillan et al., 2013).

110   The ProTaper Universal (PTU) system (Dentsply Maillefer, Ballaigues,

111 Switzerland) is currently used by endodontists, and it is one of the most revolving

112 instrument systems researchers have searched for the most (*Peters et al., 2003;*

113 *Schäfer & Vlassis, 2004; Celik Unal et al., 2006; Yang et al., 2007; Alemam et al.,*

114 *2017*). PTU is nickel titanium (NiTi) rotary system of instruments manufactured with

115 progressive tapering over the length of the cutting blades, convex triangular cross-

116 sections, and noncutting tips. In the PTU system, the file is produced in such a way that

117 it does not cut the ends, and its cross-section is a convex triangle. The taper angle of

118 the file is not constant. This angle increases parabolically starting from the end (*Hieawy*

119 *et al., 2015*).

120   The design features of ProTaper Next (PTN, Dentsply Maillefer), made from the

121 new M-Wire alloy, include variable tapers and rectangle sections with a remote center.

122 The M-Wire material has been shown to have longer fatigue resistance and lower

123 fracture risk than conventional NiTi alloy does (*Johnson et al., 2008; Montenegro-*

124 *Santillan et al., 2013*). The number of instruments is similar to that of the PTU in terms

125 of the order of use and each instrument. The PTU contains three files (SX, S1, and S2)

126 for the preparation of the coronal and middle thirds and three files (F1, F2, and F3) for

127 the preparation of the apical third. PTN consists of only three files (X1 is #17/.04, X2 is

128 #25/.06, and X3 is #30/.075), close to the diameters of the files used in the apical third

129 in the PTU system (*Pérez-Higueras et al., 2014*).

130   This study aimed to compare the shaping ability of PTU and PTN rotary

131 instruments used by the third-year dental students inexperienced in any rotary

132 instrumentation techniques in simulated curved canals of resin blocks.

133 **METHODS**

134   Seventy-nine third-year undergraduate dental students (2015–2016 intakes) in

135 preclinical endodontics at the School of the Dentistry of the Suleyman Demirel

136 University, Isparta, Turkey had three 50-min lectures of about the NiTi instruments, their

137 physical properties, and the special constructional features of the files. The present

138 study was based on data obtained from practical courses, which was compulsory for the

139 students to attend. Therefore, there was no need to sign an acceptance form for

140 participation. The results of this study did not affect the course notes of the students.

141 The students instrumented 16 simulated canals in acrylic resin blocks in the 2014-2015

142 academic year and 12 extracted human teeth 2015-2016 in the preclinical dental

143 education. The shaping technique was Modified Double Flared Technique using

144 balanced force principle (Saunders & Saunders, 1992) with stainless steel instrument.

145 The students attended a 2-h lecture on the use of PTU and PTN files two weeks before

146 the end of the term. The study was started in the last week of the term. The students

147 were divided into groups of 10, and an associated professor (G.Ç.) demonstrated the

148 procedures of the shaping of a simulated canal according to the instructions of the

149 manufacturer. A printed script with the manufacturer's step-by-step instructions for the

150 PTU and PTN rotary systems was given to each student.

151   The students instrumented a total of 395 simulated resin canals (Endo Training

152   Block 02 taper, REFA 0177; Dentsply Maillefer, CH-1338 Ballaigues, Switzerland). All

153   simulated resin canals had an apical foramen of 0.15 mm, a taper of 0.02, and an angle

154   of curvature of 40°. Of the 79 students, 40 students assigned randomly instrumented

155   200 canals using PTU files and 39 students instrumented 195 canals using PTN files.

156   Each student instrumented five simulated canals using just one of the two systems and

157   only one set instrument. .. The canals for each file system were instrumented to a

158   working length of 16 mm (0.5 mm from the apex) at a speed of 300 rpm and a torque-

159   control level of 2, using a 16:1 reduction handpiece powered by an electric motor

160   (Xsmart, Dentsply Maillefer). Two mL of distilled water was used as an irrigant at each

161   change of instrument. After the instrumentation, a final rinse with distilled water for 1

162   min was carried out. Each canal was dried using size 25 paper points.

163   The incidence of fractures in the blocks and instrument deformations It were

164   recorded. The blocks which instrument fractured were not taken into account when

165   calculating the curvature and WL change, and incidence of the ledge.. The working time

166   was calculated starting through the insertion of the first file until the end of the

167   instrumentation, including total active instrumentation, cleaning of the flutes of the

168   instruments, and irrigation. The final WL of the canals was determined in mm following

169   instrumentation of canals. An F2 PTU or X2 PTN file was inserted into the canal and its

170   WL within the canal measured to the nearest 0.5 mm. The amount of change in WL was

171   determined by subtracting the final length from 16 mm.. Canal straightening and ledge

172   formation were assessed on digital images (Figure 1 and Figure 2). After the canal

173   instrumentation, the images of the resin blocks were obtained with the help of a light

174   microscope camera (Zeiss Axioskop 2, Münich, Germany) to determine the canal

175   curvature. The images were taken from each block in one direction (mimicking clinical

176   conditions). In these images, canal curvatures were measured by a computer program

177   (AutoCAD 2007) according to Schneider (1971). The change in canal curvature was

178   determined by subtracting the value obtained after instrumentation from 40 degrees. All

179   students were randomly divided into two groups as they are at the same educational

180   level. Therefore, it was accepted that the only variable in the experimental groups was

181   PTU and PTN files. Data were analyzed using SPSS software, version 10.0 (SPSS Inc.,

182   Chicago, USA). The level of significance was set at 5%. Student's t-test was used to

183   evaluate differences in canal straightening, working time, and amount of change in WL.

184   The chi-square test was used to evaluate differences in the incidences of instrument

185   fracture, instrument deformation, while Yates corrected chi-square test was used ledge

186   formation between the groups.

187   **RESULTS**

188   The PTN preserved the original canal curvature (P<0.000) better, resulting in

189   fewer fractures (p<0.05) and ledges (p<0.000), and shaped the canals faster (P<0.000)

190   than the PTU. The mean curvatures of the canals after instrumentation with PTU and

191   PTN were 24.03° ± 3.14° and 25.64°±2.72°°, respectively (P<0.000). The incidence of

192   instrument fracture was 17.4% (33) for PTU and 9.32 % (18) for PTN (p<0.05). The

193   incidence of instrument deformation was 9 (4.5 %) for PTU and 2 (2.6 %) for PTN

194   (P>0.05). The PTN had fewer ledges than PTU (P<0.000). Ledge formation was

195   observed in 33 (18.8% () of the canals in the PTU group, while in 7 (4 %) in the PTN

196   group (P<0.000).. There was no statistically significant difference in the preservation of

197   the WL (P>0.05).The mean change in WL after instrumentation was 0.97mm ± 0.95 mm

198   in the PTU group and 0.96 ± 0.80 mm in the PTN group (p > 0.05) PTN shaped the

199   canals more quickly than PTU (P<0.000).The mean time in instrumentation of the

200   canals was 627s ± 28s for PTU and 379s ± 18s for PTN (P<0.000) (Table 1).

201

DISCUSSION

203   The ESE, Education and Scholarship Committee, encourages the use of proven

204   new tools, techniques, and training resources in endodontics education (*Dummer et al.,*

205   *2013*). Updated of the endodontic clinical curriculum is an essential step to having

206   acceptable endodontic treatment, for both general practitioners and specialist dentists.

207   Preclinical exercises are extremely important for the acquisition of this skill (De Moor et

208   al, 2013; Georgelin-Gurgel et al., 2008; Alrahabi, 2015).

209   This research presents the experiences of the third-year preclinical students in the

210   Faculty of Dentistry of the University of Suleyman Demirel with rotary instruments

211   following training on root canal preparation with hand instruments. Instrumentation

212   techniques with engine-driven instruments are now almost indispensable for root canal

213   treatment beyond popularization in root canal instrumentation. Along with hand

214   instruments, which are indispensable, instrumentation with rotary instruments is also

215   important. Hänni et al. (*2003*) showed that third-year students can use preclinical course

216   profile 0.04 taper (Dentsply Maillefer, Ballagues, Switzerland) instruments in a

217   satisfactory manner. Moreover, Arbab-Chirani & Vulcain (*2004*) in France and Abu-

218   Tahun et al. (*2014*) in Jordan reported that there is a consensus on the need for the use

219   of rotary instruments in undergraduate education. Following this, the use of rotary

220   instruments in the dentistry faculty was added to the curriculum in France. ; Kang et al.

221   (*2006*) reported that the ProFile is the safest, best instrument for root canal shaping for

222   students and beginners. Peru et al. (*2006*) reported that curved root canals prepared by

223   non-experienced undergraduates with rotary instruments exhibit less procedural errors

224   and require less time than those generated using hand instruments. In addition, Tu et al.

225   (*2008*) showed that undergraduate students could generate more successful root canal

226   shaping with ProTaper rotary instruments than they can with hand ProTaper

227   instruments. Sonntag et al. (*2008*) found that preclinical endodontics training varied

228   significantly according to the curriculum, instructor, and course content, and they

229   announced that, as of 2008, most (63%) faculties in Germany taught root canal

230   instrumentation with rotary Ni-Ti instruments. Unal et al. (*2012*) reported that third-year

231   students with no experience with rotating instruments were successful in molar root

232   canal preparations after 2 h of theoretical education about rotary instruments. Brito-

233   júnior et al. (*2014*) reported that undergraduate students produced lower apical

234   transportation in curved canals with F1 and F2 PTU files. Furthermore, Bruno et al.

235   (*2016*) stated that the low fracture rates observed in their study indicated that the

236   examined instruments can be used safely by students.

237   In the literature, there are many different experiments to evaluate the shaping and

238   cleaning of the root canal. Artificial resin models are preferred in many studies because

239   having a standard canal length, curvature, and form (Kum et al., 2000; Unal et al., 2009;

240   Unal et al., 2012). The μCT is emerging in several endodontic research facilities as a

241   nondestructive and accurate method to analyze canal geometry and the relative effects

242   of shaping techniques (Peters et al., 2003; Peru et al., 2006). As the cost of the µCT

243   assessment method was high, our study was carried out in acrylic resin blocks.

244   Although this experimental model does not fully reflect the morphology of real human

245   teeth, it can give an idea of relation to relation to the performance of the root canal

246   instrument.

247   The most frequently encountered case for procedural errors during the preparation

248   of curved root canals is the straightening of the root canals instrument fracture and

249   deformation, and ledge (*Nagy et al. 1997*). Some of the reasons for these procedural

250   errors are the instrument type and dimension, the type of alloy and the canal curve of

251   before the instrumentation (*Parashos & Messer, 2006; Lambrianidis, 2009*). Further, the

252   test material in which the instrumentation is carried out may also affect the test results

253   (*Alrahabi & Zafar, 2018*). In our study, PTN (25.64°) maintained original canal curvature

254   better than PTU (24.03°) (P<0.000). The amount of straightening was found to be higher

255   compared with Unal et al.'s (*2012*) study. The researchers selected the F1 PTU

256   file as the master apical file. The smaller the size of this file than the F2 PTU file,

257   the less straightening it may have caused. Besides, the shaping ability of the files was

258   examined in acrylic resin blocks in our study, while Unal et al. (2012) tested in extracted

259   human teeth. Alrahabi & Zafar (*2018*) reported that the files show different performance

260   in the extracted human teeth and simulated resin canals.

261   The second of the most frustrating procedural errors encountered during the

262   instrumentation of curved root canals is the abrupt fracturing and deforming of the

263   instruments. Applying enough force to metal causes the shape of the material to

264 change, and this shape change is called deformation. After the force is removed, the

265 permanent shape change that cannot be returned to its original state is called plastic

266 deformation (*Thompson 2000*). The opening in the grooves manifests the permanent

267 deformation. In this study, deformation was detected under a microscope. The

268 incidence rate of deformation was 4.5% (9) for PTU and 2.6% (2) for PTN ($p > 0.05$).

269 The incidence rates of fracture were 17.4% for PTU and 9.3 % for PTN ($p < 0.05$) in our

270 study. Vieira et al. (*2008*) reported that unexpected instrument fractures in the automatic

271 systems were closely related to the operator's experience. On contrary, it was reported

272 that inexperienced students could shape the root canal as satisfactory (*Hänni et al.,*

273 *2003; Peru et al., 2006; Unal et al., 2012; Brito-Júnior et al., 2014*). Bruno et al. (*2016*)

274 announced that a total of 30 file fractures were noted during the study period; thus,

275 fractures occurred in 0.37% of total file uses and 2.98% of all works. The authors

276 attributed a low rate of fractures to some factors. These factors are the use of the F3

277 ProTaper, the experience of the operator, and supervised treatment by expert

278 endodontists. Also, Bruno et al. (2016) designed this study under clinical circumstances.

279 Therefore, since the study included all tooth types, the average curvature of the teeth

280 could be assumed to be less than 40 degrees. Besides, working on more curved canals

281 and acrylic resin blocks instead of real teeth could be increased the numbers of

282 instrument fractures and deformations. One of the disadvantages of the use of rotary

283 canal instruments in resin blocks is that they heat the resin while the instruments are in

284 operation, and this heat causes the resin to soften. This heat can also cause the canal

285 instrument to bind to and become entangled in the softened resin, thereby breaking the

286 instrument (*Baumann & Roth, 1999; Kum et al., 2000*). The choice of acrylic resin

287 blocks for standardization is also a limitation of this study. Nevertheless, in a study by

288 Alemann et al. (*2017*) comparing the shaping abilities of the PTU and PTN instruments

289 in S-shaped canals, the students were more successful. This difference may be due to

290 their use of aqueous lubricant during the preparation. Lubrication usually helps prevent

291 fracture of the instrument during root canal preparation by helping the instrument work

292 in the canal without being forced (*Zehnder 2006*). We did not use lubricants in our

293 study; we only used distilled water for irrigation. An aqueous lubricant has been shown

294 to be more effective than a gel-type lubricant. A lubricant may exert a physical effect by

295 floating debris away from the rotating instrument. In addition, chemical additives may

296 act on the root canal dentin to facilitate instrumentation (*Peters et al., 2005,; Boessler et*

297 *al., 2007*). In our study, this difference between PTU and PTN in terms of instrument

298 fracture and instrument deformation can be due to the different levels of flexibility of the

299 instruments. While PTU is produced from a conventional NiTi alloy, PTN is produced

300 from the more flexible M-Wire. Furthermore, The PTN instruments have an innovative

301 off centered rectangular cross-section that gives the file a snake-like swaggering

302 movement as it progresses through the root canal. The manufacturer claims that this

303 asymmetric rotary motion of ProTaper Next allows achieving fully tapered canals with

304 fewer numbers of files (Tulsa Dental Specialties 2017).   In addition, the X2 of PTN has

305 an apical cone of 0.06, while PTU's F2 instrument exhibits a constant taper from D1 to

306 D3 (0.08) (*Alemam et al., 2017*).

307   A ledge is defined as a deviation from the original canal curvature within the apical

308 third which creates or starts to create a new canal at a tangent to the original canal

309 (*Nagy et al. 1997*). In our study, ledges occurred in 19% of the canals prepared with

310 PTU, whereas ledges formed in 4% of PTN cases. One of the reasons why PTN files

311 produce fewer ledges than PTU files can be the superior properties of the m-wire alloy.

312 The alloy structure and cross-sectional shape of the PTU system's F1 and F2

313 instruments will result in a hardened instrument that can cause more ledges to occur

314 than arise in PTN. Furthermore, Alrahabi & Zafar (*2018*) considered contributing to the

315 snake‑like, swaggering movements of the files during advancement into the root canal.

316 This movement serves to minimize the engagement between the file and dentin.

317 Reduced engagement limits any undesirable taper lock, the screw effect, and the torque

318 on any given file (Haapasalo & Shen (*2013*).

319 CONCLUSIONS

320 Within the limitations of this study, the PTN can be preferred in severe curvedof the root

321 canals in terms of maintenance of the original canal curvature, superior fracture, and

322 fewer ledges. Even if short training before preparation provides an acceptable level of

323 canal shaping for preclinical students, the use of NiTi rotary instruments should be

324 included in the undergraduate dental curriculum, contributing to an increase in the

325 quality of root canal shaping, and consequently the improvement of clinical experience

326 of students.

327 ACKNOWLEGDEMENTS

328 The authors thank Dentsply® for the root canal files and resin blocks used in this study.

329

330 REFERENCES

331   Abu-Tahun I, Al-Rabab'ah MA, Hammad M, Khraisat A. 2014. Technical quality of root

332   canal treatment of posterior teeth after rotary or hand preparation by fifth year

333   undergraduate students, The University of Jordan. Australian Endodontic

334   Journal. 40:123-30. DOI 10.1111/aej.12069.

335   Arbab-Chirani R, Vulcain JM. 2004. Undergraduate teaching and clinical use of rotary

336   nickel-titanium endodontic instruments: a survey of French dental schools.

337   International Endodontic Journal. 37:320-4. DOI 10.1111/j.0143-

338   2885.2004.00805.x.

339   Alemam AAH, Dummer PMH, Farnell DJJ. 2017. A Comparative Study of ProTaper

340   Universal and ProTaper Next Used by Undergraduate Students to Prepare Root

341   Canals. Journal of Endodontics. 43:1364. DOI 10.1016/j.joen.2017.03.038.

342   Alrahabi M. 2015. Comparative study of root-canal shaping with stainless steel and

343   rotary NiTi files performed by preclinical dental students. Technol Health Care.

344   23):257-65. DOI 10.3233/THC-150895.

345   Alrahabi M, Zafar MS. 2018. Assessment of apical transportation caused by nickel-

346   titanium rotary systems with full rotation and reciprocating movements using

347   extracted teeth and resin blocks with simulated root canals: A comparative study.

348   Nigerian Journal of Clinical Practice. 21:772-777. DOI

349   10.4103/njcp.njcp_200_17.

350   Ankrum MT, Hartwell GR, Truitt JE. 2004. K3 Endo, ProTaper, and ProFile systems:

351   breakage and distortion in severely curved roots of molars. Journal of

352   Endodontics.30:234-7. DOI 10.1097/00004770-200404000-00013

353 Arens F C, Hoen M M, Steiman H R, Dietz G C. 2003. Evaluation of single-use rotary

354   nickel-titanium instruments. Journal of Endodontics. 29: 664–666.

355 Baumann MA, Roth A. 1999. Effect of experience on quality of canal preparation with

356   rotary nickel-titanium files. Oral Surgery, Oral Medicine, Oral Pathology, Oral

357   Radiology, and Endodontology. 88:714–8. DOI 10.1016/S1079-2104(99)70015-

358   6.

359 Boessler C, Peters OA, Zehnder M. 2007. Impact of lubricant parameters on rotary

360   instrument torque and force. Journal of Endodontics. 33:280-3. DOI

361   10.1016/j.joen.2006.11.007

362 Brito-Júnior M, Faria-E-Silva AL, Camilo CC, Pereira RD, Braga NM, Sousa-Neto MD.

363   2014. Apical transportation associated with ProTaper® Universal F1, F2 and F3

364   instruments in curved canals prepared by undergraduate students. Journal of

365   Applied Oral Science. 22: 98–102. DOI 10.1590/1678-775720130464.

366 Bruno FA, Nunes E, Horta MC, da Fonseca AM, Silveira FF. 2016. Importance of rotary

367   systems in dental care by undergraduate students in patients of a public health

368   service of Belo Horizonte. Journal of Clinical and Experimental Dentistry. 8:e60-

369   3. DOI 10.4317/jced.52663.

370 Celik Unal G, Kececi AD, Ureyen Kaya B. 2006. Comparison of the shaping abilities of

371   two rotary and a hand instruments in simulated root canals. Acta Odontologica

372   Turcica. 23:11–6.

373 De Moor R, Hülsmann M, Kirkevang LL, Tanalp J, Whitworth J. 2013. Undergraduate

374   curriculum guidelines for endodontology. International Endodontic Journal.

375   46:1105-14. DOI 10.1111/iej.12186.

376   Dummer PM. 1991.Comparison of undergraduate endodontic teaching programmes in

377   the United Kingdom and in some dental schools in Europe and the United States.

378   International Endodontic Journal. 24: 169-77. DOI 10.1111/j.1365-

379   2591.1991.tb00127.x.

380   European Society of Endodontology. 2001.Undergraduate curriculum guidelines for

381   endodontology. International Endodontic Journal. 34: 574-80.

382   Georgelin-Gurgel M, Devillard R, Lauret ME, Diemer F, Calas P, Hennequin M. 2008.

383   Root canal shaping using rotary nickel-titanium files in preclinical teaching.

384   Odonto-stomatologie Tropicale. 31:5–11.

385   Haapasalo M, Shen Y. 2013. Evolution of nickel–titanium instruments: from past to

386   future. Endodontic Topics;29:3–17.

387   Hänni S, Schönenberger K, Peters OA, Barbakow F. 2003. Teaching an engine-driven

388   preparation technique to undergraduates: initial observations. International

389   Endodontic Journal. 36:476-82. DOI 10.1046/j.1365-2591.2003.00677.x.

390   Hieawy A, Haapasalo M, Zhou H, Wang ZJ, Shen Y. 2015. Phase Transformation

391   Behavior and Resistance to Bending and Cyclic Fatigue of ProTaper Gold and

392   ProTaper Universal Instruments. Journal of Endodontics.41:1134-8. DOI

393   10.1016/j.joen.2015.02.030.

394

395   Kang MS, Kim HC, Hur B, Park JK. 2006. Comparison Of Shaping Ability of Rotary Ni-Ti

396   File Systems Used by Undergraduates. Restorative Dentistry & Endodontics.;

397   31:1-10. DOI 10.5395/JKACD.2006.31.1.001.

398   Kum KY, Spängberg L, Cha BY, Il-Young J, Seung-Jong L, Chan-Young L. 2000.

399   Shaping ability of three ProFile rotary instrumentation techniques in simulated

400   resin root canals. Journal of Endodontics.;26:719–23. DOI 10.1097/00004770-

401   200012000-00013.

402   Kwak SW, Cheung GS, Ha JH, Kim SK, Lee H, Kim HC. 2016. Preference of

403   undergraduate students after first experience on nickel-titanium endodontic

404   instruments. Restor Dent Endod. 41:176-81. DOI 10.5395/rde.2016.41.3.176.

405   Lambrianidis T. 2009. Ledging and blockage of rootcanals during canal

406   preparation:causes, recognition, prevention,management, and outcomes.

407   Endodontic Topics 2009, 15, 56–7474.

408   Martins RC1, Seijo MO, Ferreira EF, Paiva SM, Ribeiro Sobrinho AP. 2012. Dental

409   students' perceptions about the endodontic treatments performed using NiTi

410   rotary instruments and hand stainless steel files. Brazilian Dental Journal.

411   23:729-36. DOI 10.1590/S0103-64402012000600018.

412

413   Nagy CD, Bartha K, Bernáth M, Verdes E, Szabó J. 1997.The effect of root canal

414   morphology on canal shape following instrumentation using different techniques.

415   International Endodontic Journal. 30:133–40. DOI 10.1046/j.1365-

416   2591.1997.00049.x

417

418   Parashos P, Messer HH. 2006. Rotary NiTi instrument fracture and its consequences.

419   Journal of Endodontics. 32:1031-43. DOI 10.1016/j.joen.2006.06.008

420 Pérez-Higueras JJ, Arias A, de la Macorra JC, Peters OA. 2014. Differences in cyclic

421   fatigue resistance between ProTaper Next and ProTaper Universal instruments

422   at different levels. Journal of Endodontics. 40:1477-81. DOI

423   10.1016/j.joen.2014.02.025.

424 Peru M, Peru C, Mannocci F, Sherriff M, Buchanan LS, Pitt Ford TR. 2006. Hand and

425   nickel-titanium root canal instrumentation performed by dental students: a micro-

426   computed tomographic study. European Journal of Dental Education. 10:52-9.

427   DOI 10.1111/j.1600-0579.2006.00395.x

428 Peters CI, Schönenberger K, Barbakow F. 2003. ProTaper rotary root canal

429   preparation: effects of canal anatomy on final shape analysed by micro CT.

430   International Endodontic Journal. 36:86-92. DOI 10.1046/j.1365-2591.

431 .Peters OA, Boessler C, Zehnder M. 2005. Effect of liquid and paste-type lubricants on

432   torque values during simulated rotary root canal instrumentation. International

433   Endodontic Journal. DOI 38:223–9. 10.1111/j.1365-2591.2005.00937.x

434 Qualtrough AJ, Dummer PM. 1997. Undergraduate endodontic teaching in the United

435   Kingdom: an update. International Endodontic Journal. 30: 234-9. DOI

436   10.1046/j.1365-2591.1997.t01-1-00072.x.

437 Ribeiro DM, Réus JC, Felippe WT, Pacheco-Pereira C, Dutra KL, Santos JN Porporatti,

438   AL, De Luca Canto G. 2018. Technical quality of root canal treatment performed

439   by undergraduate students using hand instrumentation: a meta-analysis.

440   International Endodontic Journal.51:269-283. doi: 10.1111/iej.12853.

441 Saunders WP, Saunders EM. 1992. Effect of noncutting tipped instruments on the

442   quality of root canal preparation using a modified double-flared technique.

443   Journal of Endodontics. 18: 32-6. DOI 10.1016/S0099-2399(06)81140-4.

444 Schäfer E, Vlassis M. 2004. Comparative investigation of two rotary nickel-titanium

445   instruments: ProTaper versus RaCe. Part 1. Shaping ability in simulated curved

446   canals. International Endodontic Journal. 37: 239-48. DOI 10.1111/j.0143-

447   2885.2004.00783.x.

448 Schneider SW. 1971. A comparison of canal preparations in straight and curved root

449   canals. Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology.32:271-

450   5.

451 Sonntag D, Bärwald R, Hülsmann M, Stachniss V. 2008. Pre-clinical endodontics: a

452   survey amongst German dental schools. International Endodontic Journal.

453   41:863-8. DOI 10.1111/j.1365-2591.2008.01438.x.

454 Thompson SA. 2000. An overview of nickel-titanium alloys used in dentistry.

455   International Endodontic Journal. 33:297-310. DOI 10.1046/j.1365-

456   2591.2000.00339.x

457 Tu MG1, Chen SY, Huang HL, Tsai CC. 2008. Endodontic shaping performance using

458   nickel-titanium hand and motor ProTaper systems by novice dental students.

459   Journal of the Formosan Medical Association. 107:381-8. DOI 10.1016/S0929-

460   6646(08)60103-5.

461 Tulsa Dental Specialties. Protaper Universal. Directions for use (2017)

462   http://www.tulsadentalspecialties.com/Libraries/Tab_Content-

463   Endo_Access_Shaping/DFUPTNF_Rev1_10-ProTaperNext_DFU.sflb.ashx .

464 Unal GC, Kececi AD, Kaya BU, Tac AG. 2011. Quality of root canal fillings performed by
465   undergraduate dental students. European Journal of Dentistry. 5:324-30.

466 Unal GC, Maden M, Orhan EO, Sarıtekin E, Teke A. 2012. Root canal shaping using
467   rotary nickel-titanium files in preclinical dental education in Turkey. Journal of
468   Dental Educutaion. 76:509-13.

469 Unal G.C, Maden M, Savgat A, Orhan EO. 2009 "Comparative investigation of 2 rotary
470   nickel-titanium instruments: protaper universal versus protaper", Oral Surgery
471   Oral Medicine Oral Pathology Oral Radiology and Endodontology (ISI), 886-892
472   pp. DOI 10.1016/j.tripleo.2009.01.010.

473 Vaudt J, Bitter K, Neumann K, Kielbassa AM. 2009. Ex vivo study on root canal
474   instrumentation of two rotary nickel-titanium systems in comparison to stainless
475   steel hand instruments. International Endodontic Journal. 42:22-33. DOI
476   10.1111/j.1365-2591.2008.01489.x.

477 Walia HM, Brantley WA, Gerstein H. 1988. An initial investigation of the bending and
478   torsional properties of Nitinol root canal files. Journal of Endodontics;14:346–51.
479   DOI 10.1016/s0099-2399(88)80196-1.

480 Vieira EP, França EC, Martins RC, Buono VT, Bahia MG.. 2008. Influence of multiple
481   clinical use on fatigue resistance of ProTaper rotary nickel-titanium instruments.
482   International Endodontic Journal. 41:163–72. DOI 10.1111/j.1365-
483   2591.2007.01336.x.

484 Yang GB, Zhou XD, Zheng YL, Zhang H, Shu Y, Wu HK. 2007.Shaping ability of
485   progressive versus constant taper instruments in curved root canals of extracted

486   teeth. International Endodontic Journal. 40: 707-14. DOI 10.1111/j.1365-

487   2591.2007.01296.x.

488   Yang G, Yuan G, Yun X, Zhou X, Liu B, Wu H. 2011. Effects of two nickel-titanium

489   instrument systems, Mtwo versus ProTaper universal, on root canal geometry

490   assessed by micro-computed tomography. Journal of Endodontics. 37:1412-6.

491   DOI 10.1016/j.joen.2011.06.024.

492   Zehnder M. 2006. Root canal irrigants. Journal of Endodontics. 32:389 –98. DOI

493   10.1016/j.joen.2005.09.014.

494   Zuolo M L, Walton R E. Instrument deterioration with usage: nickel-titanium versus

495   stainless steel. Quintessence Int 1997; 28: 397–402.

The canal curvature, the change in WL, the working time, the fractured instrument and deformed instrument, and the ledge based on the groups after instrumentation

SD: standard deviation, PTU: ProTaper Universal, PTN: Protaper Next, N: the number of sample

	PTU	N	PTN	N	total	P value
The degree and SD of canal curvature	24.03°±3.14°	174	25.64°±2.72°	176	395	0.000***
Amount of change and SD in WL (mm)	0.97±0.95	155	0.96±0.80	174	395	0.99
Working time and SD (s)	627±28	200	379±18	195	395	0.000
The number and percent of the canal with fractured instrument	17.4 % (n=33)	190	9.32 % (n=18)	194	395	0.020*
The percent of deformed instrument	4.5 % n=9	200	2.6% n=2	78	278	0.403
The percent of ledge	18.8 % n=33	176	4% n=7	176	352	0.000***

Figure 1

Measurement of the canal curvature on the images captured by stereo microscope after instrumentation

a: degree of curvature according to Schneider (*1971*)
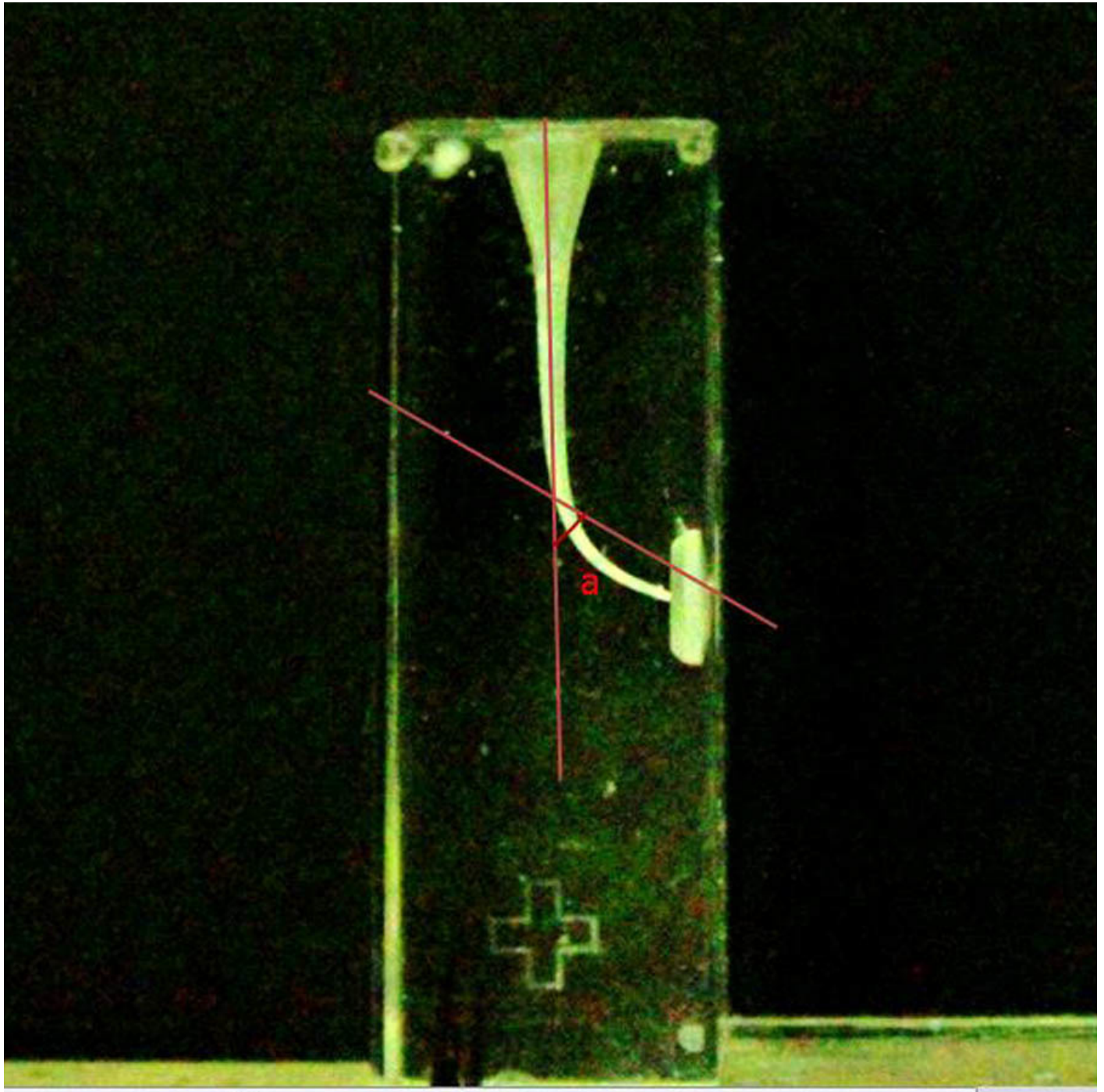
Figure 2

Ledge formation at the beginning of the curvature associated with a marked loss of working length

The arrow indicates the ledge.