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Effects Of Kinematics On Shaping Ability Of Protaper Gold: A CBCT Study

Kinematiğin Protaper Gold'un Şekillendirme Yeteneğine Etkileri: Bir CBCT Çalışması

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ABSTRACT

Objective: The aim of this study is to evaluate centering ability and apical transportation in mesiobuccal root canals of extracted human mandibular molars shaped by ProTaper Gold F2 made different kinematic movements by using CBCT.

Material and Method: Fourty five mesio-buccal canals of mandibular molars with the curvature of 20° to 39° were selected. The samples were randomly divided into three groups for shaping with different kinematics (adaptive, reciprocal and rotational motion). Transportation and the centering ratio at the 2, 5 and 8 mm from the apex of the root canals were calculated. Statistical analyses were done by using Kolmogorov-Smirnov test and Duncan tests.

Results: Adaptive and reciprocation motion caused less transportation at the three root levels. At apical level, there was no significant difference in canal transportation between the groups *($p > .05$)*. The data of the centering ratio showed that there was no significant difference among the groups after instrumentation at any level.

Conclusion: The adaptive and reciprocal motion causes less apical transportation in the coronal and middle third of roots. Also, all kinematics produced similar centering ratios during root canal preparation. Protaper Gold systems with adaptive and reciprocal motion would be preferred for respecting the canal curvature.

Anahtar Kelimeler: Shaping ability, Protaper Gold, CBCT, centering ability, apical transportation

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ÖZET

Amaç: Çalışmanın amacı ProTaper Gold F2 eğesinin insan mandibular molar dişlerin mesiobukkal kanallarındaki merkezde kalma yeteğinin ve apikal transportasyon miktarlarının konik ışınlı bilgisayarlı tomografi ile değerlendirilmesidir.

Materyal ve Metot: Kırk beş adet, 20° ila 39° kurvatüre sahip mandibular molar dişlerinin mesio-bukkal kanalı seçildi. Örnekler farklı kinematiklerle (adaptif, resiprokal ve rotary hareketi) şekillendirme için rastgele üç gruba ayrıldı. Kök kanallarının apeksinden itibaren 2, 5 ve 8 mm'de apikal transportasyon ve merkezde kalma oranları hesaplandı. İstatistiksel analizler Kolmogorov-Smirnov testi ve Duncan testleri kullanılarak yapıldı.

Bulgular: Adaptif ve resiprokal hareket, üç kök seviyesinde daha az transportasyona neden olmuştur. Apikal seviyede, gruplar arasında transportasyon miktarlarında anlamlı fark yoktu ($p > .05$). Herhangi bir düzeyde şekillendirme sonrası gruplar arasında merkezde kalma oranları açısından anlamlı bir fark olmadığını gösterdi.

Sonuç: Adaptif ve resiprokal hareket, köklerin koronal ve orta üçlüsünde daha az apikal transportasyona neden olur. Ayrıca, tüm kinematikler, kök kanal şekillendirme sırasında benzer merkezde kalma oranlarına sahipti. Kanalın orijinal kurvatürünün korunması için adaptif ve resiprokal hareketli Protaper Gold sistemleri tercih edilebilir.

Keywords: Şekillendirme yeteneği, Protaper Gold, CBCT, merkezde kalma oranı, apikal transportasyon.

1. Introduction

Chemomechanical shaping is one of the major objectives of non-surgical root canal therapy (1). In this step, a specific flare shaped extending from apical to coronal respecting the original canal curvatures with preserving the apical foramen is recommended (2). However, some procedural errors occur such as straightening the root canal curvature and apical transportation during root canal shaping (1). Canal transportation leads to inappropriate dentine removal (3) and predisposes to perforation and ledge formation. Excess removing dentine may cause weakening the root or compromise the quality of obturation of the root canal system resulting in reinfections (4).

Up to date, various root canal preparation techniques and different kinematics have been defined to overcome these problems and provide better centering while preserving the original canal shape (5), cause less straightening and better centered ability (6). In contrast to these advantages, anatomic factors like; severe curvatures or small cross-sectioned canals raise the risk of instrumentation failure due to flexural/torsional stress (7). The counterclockwise motion reduces stress on file (8) and causes minimal alteration of the canal curvature, reduces the effect of cyclic fatigue (5, 6), and maintains the canal shape (9).

In addition to different kinematics, different manufacturing techniques are used to reduce the stress on the file. The Protaper Gold is one of the one novel rotary file systems with increased flexibility due to heat-treated NiTi alloy (10). PTG is claimed to have more centering ability (11), with resistance to cyclic fatigue (12) comparatively to PTU although both have the same design (10, 11).

With these developments in the usage of NiTi alloys in rotary file systems, it becomes more valuable to investigate the shaping abilities of different files to know-how design and kinematics affect. This study aims to evaluate the centering ability and transportation of ProTaper Gold F2 file with different kinematic movements (reciprocal, adaptive and rotary motion) by using cone-beam computed tomography imaging (CBCT).

2. Material and Method

Ethical approval for this study was obtained from the Scientific Research Ethics Committee of Trakya University School of Medicine (Protocol Code: TÜTF-BAEK 2021/90).

Selection of the samples

In this study, the mesiobuccal canals of mandibular molars extracted for reasons not related were used. The radiographic images in both mesiodistal and buccolingual directions were examined; teeth with mesiobuccal (MB)-mesiolingual canals started, continued, and ended separately were included; teeth with no comparable root length, root canal calcification, or internal/external root resorption are excluded from the study (Fig 1-2). Teeth were stored in normal saline solution. Standardized access cavities were made to the teeth using a standard diamond cylindrical bur with a 10 mm apical size using water-cooling. Canals were controlled using #10 K-files (Dentsply Maillefer, Ballaigues, Sweden).

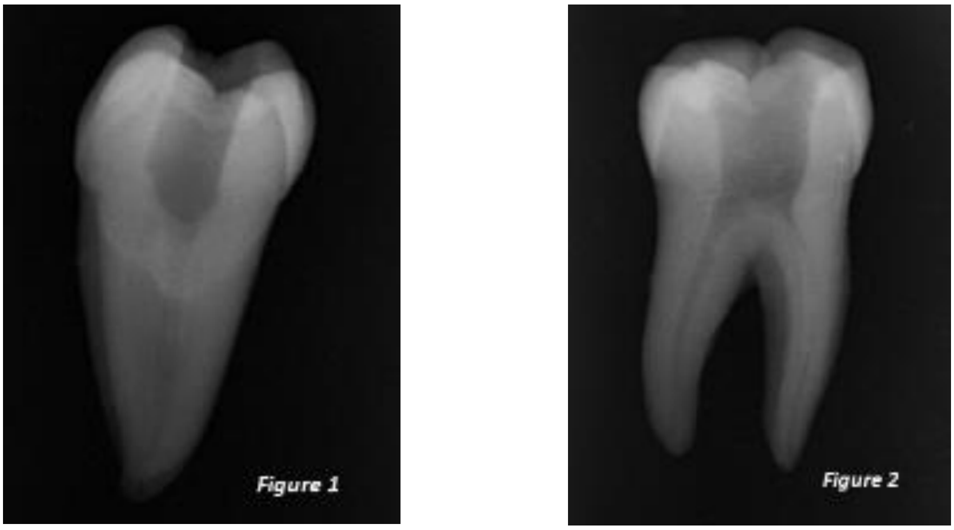

Figure 1-2: Radiographic images of initial root canals

Before root canal instrumentation, the teeth were fixed in a silicone impression material (Zetaflow, Zhermack, Badia Polesine, Italy) and pre-instrumented CBCT (NewTom/NT5G; Nevtom 5G®, QR, Verona, Italy) images were taken whereby the constant exposure parameters of 110 kv tube potential and 0.02 mAs tube current and 12x15 cm field of view were preferred. Axial slice thickness was 0.15mm with a 0.15 mm pixel size.

CBCT images were analyzed and reconstructed with Mimics 15.01 software (Materalise HQ, Levven, Belgium). MB canals curvature angles were calculated according to Estrela et al (13) (Figure 3). The MB canals with the curvature of 20° to 39° (mean 29,2°±4,73) were selected for the study. The samples were randomly divided into three groups according to their angles (n = 15).

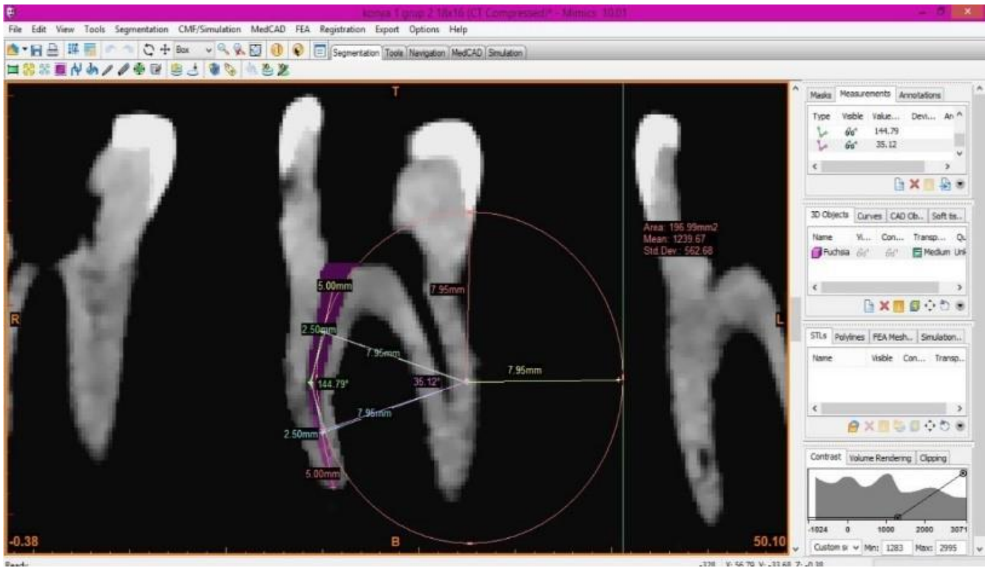

Figure 3: MB canals curvature angles according to Estrela et al.(2008)

Shaping the root canals

Working length was determined by inserting #10K file to the root canal terminus and subtracting 1 mm from this measurement. With a #15 K file (Dentsply Maillefer, Ballaigues, Sweden), a glide path was made. ProTaper Gold Rotary System (Dentsply Tulsa Dental Specialties) were used in the manufacturer's recommended order up to up to the apical size 25 (F2) in all three groups with flushing using 2 ml 2.5% sodium hypochlorite solution after each instrument change. Each instrument was used in three canals.

In group 1, files were used respectively in the adaptive motion with "TF Adaptive Program" in Elements Motor (SybronEndo, Glendora, CA, USA). Files were used with a gentle in-and-out motion till they reached to working length.

In group 2, files were used within the crown-down technique with an endodontic motor (VDW Silver Reciproc, VDW) in "Reciproc all" program, according to Kim et al.(14) this motion operates at 300 rpm and rotates 150° counterclockwise and then 30° clockwise (angle of advance, 120°). The file was used in a gentle in-and-out motion until it reached working length.

In group 3, files were used in the crown-down technique with an endodontic motor (VDW Silver Reciproc, VDW) and rotated with full clockwise rotation at a rate of 300 rpm in a continuous rotary motion according to manufacturer recommendations (300 RPM / 2Nm) until the working length was reached.

Calculating the transportation and centering ratio

Transportation and the centering ratio at the 2, 5 and 8 mm from the apex of the root canals on the same horizontal cross-section were calculated by the formula Gambill et al. (15) described before 2, 5 and 8 mm was preferred to reflect apical, middle, and coronal respectively.

The following formulas for transportation was used in determining the amount of transportation; | (xinitial-x2) - (yinitial-y2) |, | (xinitial-x5) - (yinitial-y5) | and | (xinitial-x8) - (yinitial-y8) | (15). The following formula for centering ratio were used (xinitial –x2) / (yinitial-y2), (xinitial-x5) / (yinitial-y5) and (xinitial-x8) / (yinitial-y8) (15). xinitial used here was the shortest mesial length between the original root outer edge and canal, x2, x5 and x8; it refers to the shortest mesial length between the root outer edge and the canal at 2, 5 and 8 mm after it is instrumented. yinitial-used here was the shortest distal length between the original root outer edge and canal; y2, y5 and y8 refers to the shortest distal length between the root outer edge and the root canal at 2, 5 and 8 mm after being instrumented (Figure 4).

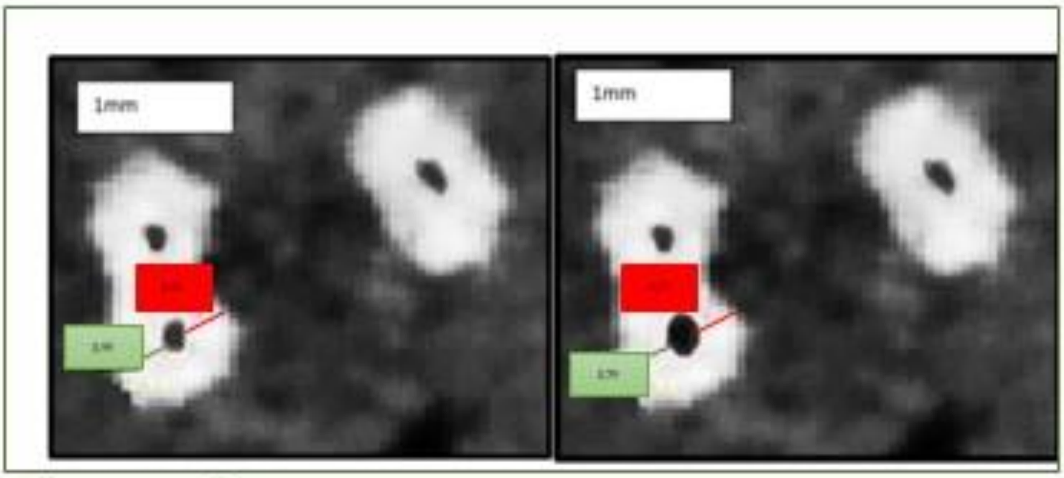

Figure 4

Figure 4: The shortest mesial/distal length between the original root outer edge and canal before and after instrumentation.

Statistical Analysis

IBM Statistics SPSS 22.00 program was used for statistical analysis. The Kolmogorov-Smirnov test was used for normality distributions of the values. It was determined that all data showed parametric distribution ($p < 0.05$). One-way analysis of variance was used for evaluating changes based on the kinematics used in groups and also the measurement length. Multiple comparisons were made by using Duncan tests. The significance level was set at $p = 0.05$.

3. Results

In the study, no fracture occurred, none of the working lengths was lost.

The initial root canal curvatures according to the groups are shown in Table 1 and no significant difference was found based on the groups (p >.05).

The results showed that root canal transportation was less than the shortest distances from the outside of the root in all groups at 2, 5, and 8 mm so the amount of transportation is in the safety zone for all groups. Mean and standard deviation values of the canal transportation and the centering ratio for each group at all levels are displayed in Table 2.

Table 1: Initial root canal curvatures according to groups

Groups	**Mean±SD (Min- Max)**
Group 1 (*Adaptive motion)*	30,7°±4,5° (20°-39°)
Group 2 (*Reciprocal motion)*	29,7°±4,6° (20°-39°)
Group 3 (*Rotational motion)*	27,8°±4,9° (20°-39°)
P value	0,399

*One-way Anavo

Table 2: Mean ± Standard Deviation of Transportation (mm), Centering Ratio Values for Tested Groups, and Statistical Analysis*

Assessment	**Group 1 *Adaptive Motion***	**Group 2 *Reciprocal motion***	**Group 3 *Rotational motion***	***P value***
Transportation	$0,120^{b}$ ± 0,12	$0,068^{b}$ ± 0,13	$0,266^{a}$ ± 0,23	***0,000***
Centering ratio	1,443 ± 1,60	1,204 ± 0,83	1,242 ± 1,21	*0,626*

* One-way Anavo
**Mean values represented with different superscript letters are significantly different according to Duncan tests (P < .05).

It was shown that Group 1 and 2 caused less transportation than Group 3 at the three studied levels (p <.05) (Table 3). At 2 mm level, there was no significant difference in canal transportation between the groups (p >.05); however, at 5 mm and 8 mm levels, the group 1 and 2 showed a significantly lower transportation value between the groups (p <.05) (Table 3). The data of the centering ratio at any level showed that there was no significant difference between the groups after instrumentation (p >.05) (Table 3).

Table 3: Mean ± Standard Deviation of Transportation (mm) at different level, Centering Ratio Values for Tested Groups, and Statistical Analysis*

Level (mm)	**Assessment**	**Group 1** ***Adaptive motion***	**Group 2** ***Reciprocal motion***	**Group 3** ***Rotational motion***	***P value***
2	Transportation	0,143 ± 0,12	0,102 ± 0,23	0,214 ± 0,15	*0,228*
	Centering ratio	1,907 ± 1,99	1,223 ± 0,88	1,280 ± 0,88	*0,332*
5	Transportation	$0{,}111^{b} \pm 0{,}14$	$0{,}049^{b} \pm 0{,}04$	$0{,}340^{a} \pm 0{,}16$	***0,002***
	Centering ratio	1,437 ± 1,81	1,207 ± 0,90	1,692 ± 1,76	*0,696*
8	Transportation	$0{,}120^{b} \pm 0{,}12$	$0{,}054^{b} \pm 0{,}04$	$0{,}246^{a} \pm 0{,}23$	***0,000***
	Centering ratio	0,980 ± 0,60	1,183 ± 0,75	0,752 ± 0,49	*0,181*
P value for transportation		*0,700*	*0,525*	*0,333*	
P value for centering ratio		*0,298*	*0,992*	*0,102*	

* One-way Anavo
**Mean values represented with different superscript letters are significantly different according to Duncan tests (P < .05).

4. Discussion and Conclusion

One of the main goals of root canal treatment is to make a chemomechanical shaping to preserve the original shape of the root canals (16). The use of NiTi instruments and less invasive shaping reduces the risk of procedural errors like apical transportation and apical zips (1,6, 17). The prevention of apical transportation leads to a well-sealed root filling (5, 6, 18) and reduce the weakening of the tooth structure (19).

Other factors such as canal anatomy, instrument design, instrumentation sequence, rotation speed contribute to the results of optimum mechanical shaping (1, 2). The different movement kinematics are rotary, adaptive, and reciprocal motion change fracture incidence of NiTi instrument (20). NiTi instruments are generally used to shape curved root canals by clockwise rotation motion (21). The reciprocal motion is an alternative movement of the instrument based on the balanced force technique as theorized by Roane et al (9). The reciprocal motion minimizes torsional/flexural stress (22), optimizes endodontic instrumentation by reducing the risk of instrument fracture and root canal deformity (6), reduces the taper lock (21), offers better shaping ability (4) and time required for preparation of curved root canals (23) compared to continuous rotary motion. The instrument, which is provided to the dentine with the rotary technique, is separated from the dentine when it is rotated counterclockwise, and as the stress accumulated on the instrument decreases, torsional fractures due to the taper lock decrease (21), reduces the risk of cyclic and torsional fatigue caused by tension and compression stress on instruments (8, 23, 24).

The NiTi instruments with adaptive motion combine both continuous rotary and reciprocation motion. The studies show that the adaptive motion reduces the stress on the file and that allows it to finish root canal shaping more easily and safely (24).

In our study, mesial roots of mandibular molar teeth with narrow, curved roots and severe curvature angles were used. These roots were used because they increase the difficulty of instrumentation (1). For validity and reliability of the study, the samples were randomized to different groups according to curvature and radius before the instrumentation. The curvatures of all samples were between 25° and 35° and there was no significant difference between the groups (25).

The centering ability and apical transportation were evaluated at three levels (2, 5, and 8 mm from the root apex) representing the apical, curvature, and cervical thirds of the root canal.

To evaluate the efficiency of instruments and shaping techniques, various methods have been used to compare canal shape before and after preparation. One of these methods is superposing the radiographical pre/post instrumented image. However, radiography provides only a 2-dimensional image and it is not possible to observe a cross-section of the root canal (1).

The serial sectioning techniques are the more commonly used techniques (26) because CT imaging technique offers the possibility to evaluate the canal geometry using non-invasive methods (1), to analyze more distinctive changes in root canals than photographic or radiographic measurements (27) and to evaluate the transportation and centering ratio values using non-invasive methods (28).

Yared (21) conducted a study using NiTi instruments with reciprocal motion when the instruments were generally used with rotary motion. The first intention of the study was to evaluate how is shaping ability of the ProTaper F2 (Dentsply Maillefer, Ballaigues, Switzerland) in clockwise and counterclockwise movements to shape root canals because the F2 ProTaper file can cut dentine in both motion directions (21).

Alternative motions were reducing torsional stress (29), promoting a cyclic fatigue life of conventional rotary motion (8), and causing centered preparation (4). In our study, the centering ability and apical transportation during the shaping root canals with alternative movements were evaluated considering these advantages.

In our study, a statistically significant difference was not found between the centering abilities of the ProTaper F2 in different movements. Although there is no significant difference statistically between movement types when evaluated according to root parts, centering ability shows the most ideal value in the cervical region for reciprocal and adaptive motion. When the values were close to 1 (one), they indicated optimum centering ability; and when close to 0 (zero), they indicated the lower ability of the instrument to maintain centralization in the root canal (30).

When apical transportation is evaluated, there is no significant difference statistically in the apical part but reciprocal and adaptive motion are statistically significantly less at curvature and cervical part compared to rotary motion. There is no statistically significant difference between reciprocal and adaptive movement in apical transportation. These results were consistent with a similar study (24).

However, in the apical third, no difference was found in canal transportation and centering ability of the different kinematics tested (rotary and adaptive motion). These results are consistent with our study and previous studies (21, 34), which reported no effect on apical canal transport and centralization due to mechanical movements

Gergi et al (1) compare centering ability and apical transformation of adaptive and rotary movements. According to the results of the study, the adaptive movement showed better centering ratio and less apical transportation, findings are consistent with our study.

Berutti et al (6) reported that ProTaper NiTi instruments had a lower centering ability than WaveOne, whereas the studies (19, 23, 25) did not observe any significant difference between different kinematics.

The reciprocating motion, a combination of clockwise and counterclockwise, can contribute to the improvement of the shaping ability of endodontic instruments (31) with a large contact area between the instrument and the canal walls, allowing equal canal expansion in the inner and outer side of the root canal curvature (7). According to the results of the study, the reciprocal movement removed equal amounts of resin at the mesial and distal side of the canal, while the rotary movement removed the different amount of resin (7). This situation deteriorates the original shape of the canal and causes transportation.

Wu et al (18) reported that apical transportation of more than 0.3 mm could affect adversely the sealing ability of the obturating material. Rotary motion at curvature (5 mm at apex) of the apical transportation values recorded in this study exceeded this limit. This may be due to the increased taper of the file and its less flexibility. An instrument with a fixed 0.08 mm mm-1 taper would be too rigid to be used in curved canals (21). Since the file contact with the canal walls is more in curvature, it causes to flatten canal curvature and transportation in the canal.

Within the limitations of the present study, the adaptive and reciprocal motion causes less apical transportation in the coronal and middle third of roots. Also, all kinematics produced similar centering ratios during root canal preparation. Protaper Gold systems with adaptive and reciprocal motion would be preferred for respecting the canal curvature.

Declaration of Ethical Code

In this study, we undertake that all the rules required to be followed within the scope of the "Higher Education Institutions Scientific Research and Publication Ethics Directive" are complied with and that none of the actions stated under the heading "Actions Against Scientific Research and Publication Ethics" is not carried out.

Ethical approval for this study was obtained from the Scientific Research Ethics Committee of Trakya University School of Medicine (Protocol Code: TÜTF-BAEK 2021/90).

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