치의학 석사학위논문

The effect of reciprocating motion on the cyclic fatigue resistance of ProFile and ProTaper

ProFile 과 ProTaper 의

cyclic 피로저항에 미치는

reciprocating 운동의 효과

2013 년 2 월

서울대학교 치의학대학원

치의학과

김승필

The effect of reciprocating motion on the cyclic fatigue resistance of ProFile and ProTaper

지도교수 이우철

이 논문을 치의학 석사학위논문으로 제출함

2012 년 10 월

서울대학교 치의학대학원
치의학과
김승필

김승필의 석사학위논문을 인준함

2012 년 11 월

위 원 장	백승호	(인)
부 위 원 장	이우철	(인)
위 원	손원준	(인)

Abstract

The effect of reciprocating motion on the cyclic fatigue resistance of ProFile and ProTaper

(Directed by Professor WooCheol Lee)

Seung pil Kim

Department of Dentistry

School of Dentistry

Seoul National University

1. Objectives

Recently, it has been shown that the reciprocating movement (RM), extended the lifespan of an F2 ProTaper instrument in comparison with continuous clockwise rotation (CR), in curved canals. The purpose of this study was to investigate the effect of RM on cyclic

flexural stress (fatigue) on NiTi instruments with different cross-sections when they were driven with RM.

2. Methods

F2 ProTaper (PT) and #25/.06 taper ProFile (PF) instruments were used. Cyclic flexural fatigue tests simulating clinical use were carried in curved stainless steel tubes. The instruments were used in either CR or RM resulting in 4 experimental groups (n=12). The instruments were driven at 300rpm and with a standardized 4-mm pecking movement until fracture. For the RM groups, the angles were set at 140° and 45° in clockwise and counter-clockwise directions, respectively. The time of fracture and the number of cycles to fracture (NCF) for each instrument were determined. The length of the fractured file tip was measured and the fractured surface was examined with an SEM. Statistical analysis was performed on the data using two-way ANOVA and t-test.

3. Results

There were no statistically significant differences in the time to fracture or NCF between RM and CR ($p>0.05$) for the PF and PT groups, respectively. ProFile instruments had a significantly greater cyclic fatigue resistance compared to ProTaper regardless of the rotational movement used ($p<0.05$). The length of the fracture segment was not affected by either the type of the rotation

($p>0.05$). The fractographic analysis showed similar features for both instruments and rotational movements with the presence of crack initiation origin, crack propagation region, and overload (fast fracture) zone.

Key words : NiTi rotary file, reciprocating, continuous rotation, cyclic fatigue resistance, cross section

Student number : 2009-22665

Contents

I. Introduction

Nickel-titanium (NiTi) rotary instruments have been used for more than a decade in endodontic practice. Super-elasticity of this NiTi rotary file enables the clinicians to prepare root canal with less transportation, and a more rounded tapered canal[1-3]. Despite these advantages, NiTi instrument has a high risk of separation during the root canal shaping procedure[4].

The fracture of rotary NiTi instruments is caused by torsional failure and flexural cyclic fatigue. Torsional failure occurs when the tip of the file binds in the root canal while the handpiece that holds the shank of the file continuous to rotate. This type of instrument fracture can be controlled by employing torque control motor[1]. On the other hand, flexural fracture of the file occurs because of repeated compressive and tensile stresses accumulated at the point of maximum flexure in a curved canal. To avoid this type of failure, operators should use pecking motion when they feel the resistance exerting on the file during the root canal preparation. [5]

Both modes of fracture can happen simultaneously in the clinical situation. However, cyclic fatigue showed higher prevalence in more than 90% of the file separation incidence [6]. Many studies investigated the cyclic fatigue of NiTi rotary instruments [3, 5, 7]. The instrument geometries such as size, taper flue design and cross-sectional shape have been associated with fatigue fracture. [5, 8, 9]

Root canal shaping strategies such as crown down preparation, single file instrumentation and the application of pecking motion or brushing out motion have been suggested to reduce the chance of NiTi file separation. Recently, the use of reciprocating motion (RM) was introduced and shown to extend the lifespan of a NiTi rotary instrument and to increase its resistance to fatigue in comparison to continuous rotation (CR)[10]. It seems that the concept of

using a single NiTi instrument under RM is more cost-effective and can relieve a lot of stress from the practitioner in learning a new technique[11].

It is presumed that counterclockwise rotation in RM diminishes the torsional stress exerted on the NiTi file during the active canal shaping procedure and this movement ultimately increase the lifespan of the instrument[12]. However, there is limited information on the actual mechanism involved in the cyclic fatigue fracture resistance of the files especially under reciprocation preparation motion.

We hypothesized that these is no difference in the cyclic fatigue resistances between CR and RM regardless of file type. Therefore, the purpose of the present study was to evaluate the cyclic fatigue of 2 rotary instruments with different cross-sections used in CR and RM with a pecking motion.

II. Materials and Methods

Two different types of NiTi rotary instruments with different cross-sectional shapes and cutting blades selected to see if any differences with the file types. Those were ProTaper (Dentsply Maillefer, Ballaigues, Switzerland) F2 files with convex-triangular cross-section and ProFile (Dentsply Maillefer) 0.06 taper/ size #25 files with triple U-shaped cross-section. All files were 21 mm long and had a diameter 0.25mm at D0, while the ProTaper had the bigger taper than the ProFile. Each new instrument was inspected for gross defects or deformities prior to the experiment with a surgical microscope (Pico; Zeiss, Oberkochen, Germany).

Cyclic fatigue tests simulating the clinical preparation procedure were done uing the experimental design described by Oh et al[5]. In brief, an artificial stainless-steel root canal with 1.5mm inner diameter, 5mm radius and 60° angle of curvature was assembled between two thin metal plate. A continuous up (4mm) and down (4mm) pecking movement was applied at 1cycle per second in order to simulate the pecking motion in a real clinical situation. In each group, 12 files were tested using either CR and RM with an electric torque-controlled motor (ATR Tecnika; Pistoia, Tuscany, Italy); the speed was set at 300 rpm. The rotation angles for the RM were set at clockwise 140° and counterclockwise 45°. The design of the study resulted in four experimental groups (ProTaper and ProFile for either of CR and RM, table 1).

The time to failure of each instrument was automatically recorded by a digital chronometer. The number of cycles to failure (NCF) for each instruments was also calculated by multiplying the time to failure by the number of rotations per minute (rpm). The length of the fractured file tip was measured using a digital caliper (Preco Machine Tool Co., Shandong, China). The NCF was statistically compared using two-way ANOVA. T-test was also executed to understand any differences between CR and RM or the file types and the

statistical significance was set at 95%. The length of fractured fragment was compared using t-test to see any differences between CR and RM for either of ProFile and ProTaper. The fractured surface was examined blindly by one operator using SEM (Hitachi S-4700; Hitachi, Tokyo, Japan) at magnification of X200, X2,000 and X10,000 in order to verify the mode of fracture.

III. Results

The NCF for all four experimental groups are presented in Table 1. There was no significant difference by the mutual action with the rotation movement and file types ($p>0.05$). In both ProFile and ProTaper groups, there were no statistically significant differences in the NCF between CR and RM ($p>0.05$). However, ProFile showed significantly extended fracture resistance compared to ProTaper regardless of preparation technique used ($p<0.05$).

The mean lengths of the fracture fragment of ProFile and ProTaper with both techniques are also presented in Table 1. There were no significant differences between the CR and RM or between PF and PT when the lengths of the fractured file fragments were compared ($p>0.05$).

The fractographic analysis showed similar fractographic features, with the presence of crack initiation origin(s), crack propagation region, and fast fracture (overload) zone for both rotational movements and for both files. Clusters of multiple fatigue striations were observed at the crack initiation area of the both NiTi files under high magnification of fractographic analysis.

IV. Discussion

There have been continuous improvements of preparation technique and instrument design in hope of reducing the separation of NiTi rotary instrument during the root canal treatment. Recently, brand new file systems introduced to the market with claims that the files can shape root canals with the only one file used in reciprocating motion. In fact, this new preparation technique using only one instrument in a reciprocating movement was previously introduced with ProTaper F2[11]. This concept of using a single NiTi instrument to prepare the entire root canal is interesting, because the learning curve would be considerably reduced as a result of technique simplification and the reduced screw-in effect. Moreover, the use of a single NiTi instrument is more cost-effective than the conventional multi-file NiTi rotary systems[13].

The use of a reciprocating movement may reduce the incidence of torsional fracture by taper-lock[2] and extends the lifespan of the instrument[10, 12]. In this regard, Shen et al.[14] have demonstrated that the lifespan of the NiTi rotary instrument depends on instrumentation technique rather than file geometry or number of use. Hence, the design of the present study attempted to investigate the sole effect of cyclic flexural stress on the files from different rotational movements (CR vs RM) using two file systems of different cross-sectional shapes.

Recently, De-Deus et al.[13] demonstrated that the reciprocating movement promoted an extended cyclic fatigue life of F2 ProTaper file when it was compared with conventional continuous rotation. However, present study demonstrated that instruments' rotational movement, CR or RM, did not affect the ability of NiTi rotary instrument to resist cyclic fatigue, which is thought to be the predominant cause of file separation[15, 16]. The differences in the results could be attributed to a variation in the manner of file rotation or the method of calculation of the number of cycles to failure.

The NCF for ProFile in the present study (1586 and 1365 cycles with CR and RM, respectively) were consistent with that of Oh et al.[5] who applied dynamic cyclic pecking motion during the fatigue test. The dynamic pecking motion may reproduce the clinical situation more closely and effectively reduce the stress concentration points and continuously allow distributing the stress on the instrument[17]. Consequently, an increased resistance to fatigue would be expected. The results of the present study might show that the pecking motion would be more critical with regards to resistance to fatigue than the type of rotation of instrument. Meanwhile, the NCF was calculated from the time to fracture for both for the CR and RM because the same flexural stresses were generated during rotation of which directions were clockwise or counterclockwise.

Two different types of NiTi files were introduced to see any different results by the different rotational movements, CR and RM. ProTaper was chosen because its convex triangular cross-sectional shape with neutral cutting edges allows it to cut in both directions under reciprocating motion and provides a uniform distribution of torsional stress[18]. The ProTaper instruments were reported to have a lower cyclic fatigue resistance in comparison to other instruments such as ProFile[5, 18, 19]. ProFile has a concave cross-sectional shape with passive cutting and it was shown to have a high fatigue resistance due to its small center-core. As it was expected, regardless of instrument movements in present study, ProFile showed significantly higher cyclic fatigue resistance than ProTaper when either CR or RM was applied. The superiority of ProFile has been reported and described in several studies and the major factors of the improved flexibility and fatigue resistance were described as not only the small center-core but also the less taper of the shaft[5, 20-22]. The present study also confirmed that the cross-sectional area would be a determinant factor influencing the fatigue resistance of NiTi rotary instruments.

The SEM analysis of this study showed typical fractographic appearances of cyclic fatigue failures with the presence of crack initiation areas and roll-over zones, not only for the CR but also for the RM. The dimples in the central fibrous regions of the instruments also reflected a ductile or flexural failure as well.

It was postulated that extended lifespan of the instrument under RM was due to the superior resistance to the torsional fatigue by reverse rotational direction before stress accumulation[13]. Nevertheless, the present study did not evaluate the influence of the instrument movement on torsional stress which might be reduced with RM. A file with higher resistance to flexural fatigue might not survive due to relatively small torsional stress. This was due to the fact that flexural fatigue resistance and torsional resistance are inversely proportional[23]. Therefore, relation between the lifespan and the torsional fatigue resistance under RM should be investigated.

In conclusion, within the limitations of the present study design, the cross-section of the instrument influenced flexural fatigue resistances regardless of the rotational movement used. The null hypothesis was accepted and thus the methods for instrument rotational movement did not affect the cyclic fatigue resistance of both PF and PT instruments.

V. Reference

1. Gambarini, G., *Cyclic fatigue of nickel-titanium rotary instruments after clinical use with low- and high-torque endodontic motors.* J Endod, 2001. **27**(12): p. 772-4.
2. Peters, O.A., *Current challenges and concepts in the preparation of root canal systems: a review.* J Endod, 2004. **30**(8): p. 559-67.
3. Pruett, J.P., D.J. Clement, and D.L. Carnes, *Cyclic fatigue testing of nickel-titanium endodontic instruments.* J Endod, 1997. **23**(2): p. 77-85.
4. Iqbal, M.K., M.R. Kohli, and J.S. Kim, *A retrospective clinical study of incidence of root canal instrument separation in an endodontics graduate program: a PennEndo database study.* J Endod, 2006. **32**(11): p. 1048-52.
5. Oh, S.R., et al., *A comparison of nickel-titanium rotary instruments manufactured using different methods and cross-sectional areas: ability to resist cyclic fatigue.* Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 2010. **109**(4): p. 622-8.
6. Cheung, G.S., et al., *Defects in ProTaper S1 instruments after clinical use: fractographic examination.* Int Endod J, 2005. **38**(11): p. 802-9.
7. Ounsi, H.F., et al., *Effect of clinical use on the cyclic fatigue resistance of ProTaper nickel-titanium rotary instruments.* J Endod, 2007. **33**(6): p. 737-741.
8. Arbab-Chirani, R., et al., *Comparative analysis of torsional and bending behavior through finite-element models of 5 Ni-Ti endodontic instruments.* Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 2011. **111**(1): p. 115-21.
9. Berutti, E., et al., *Comparative analysis of torsional and bending stresses in two mathematical models of nickel-titanium rotary instruments: ProTaper versus ProFile.* J Endod, 2003. **29**(1): p. 15-9.
10. Varela-Patino, P., et al., *Alternating versus continuous rotation: a comparative study of the effect on instrument life.* J Endod, 2010. **36**(1): p. 157-9.
11. Yared, G., *Canal preparation using only one Ni-Ti rotary instrument: preliminary observations.* Int Endod J, 2008. **41**(4): p. 339-44.
12. You, S.Y., et al., *Lifespan of one nickel-titanium rotary file with reciprocating motion in curved root canals.* J Endod, 2010. **36**(12): p. 1991-4.
13. De-Deus, G., et al., *Extended cyclic fatigue life of F2 ProTaper instruments used in reciprocating movement.* Int Endod J, 2010. **43**(12): p. 1063-8.
14. Shen, Y., et al., *Defects in nickel-titanium instruments after clinical use. Part 1: Relationship between observed imperfections and factors leading to such defects in a cohort study.* J Endod, 2009. **35**(1): p. 129-32.
15. Cheung, G.S., et al., *Comparison of defects in ProTaper hand-operated and engine-driven instruments after clinical use.* Int Endod J, 2007. **40**(3): p. 169-78.
16. Wei, X., et al., *Modes of failure of ProTaper nickel-titanium rotary instruments after clinical use.* J Endod, 2007. **33**(3): p. 276-9.
17. Whipple, S.J., T.C. Kirkpatrick, and R.E. Rutledge, *Cyclic fatigue resistance of two*

variable-taper rotary file systems: ProTaper universal and V-Taper. J Endod, 2009. **35**(4): p. 555-8.

18. Shen, Y., et al., *Comparison of defects in ProFile and ProTaper systems after clinical use.* J Endod, 2006. **32**(1): p. 61-5.
19. Plotino, G., et al., *Cyclic fatigue of NiTi rotary instruments in a simulated apical abrupt curvature.* Int Endod J, 2010. **43**(3): p. 226-30.
20. Haikel, Y., et al., *Dynamic and cyclic fatigue of engine-driven rotary nickel-titanium endodontic instruments.* J Endod, 1999. **25**(6): p. 434-40.
21. Schafer, E. and M. Vlassis, *Comparative investigation of two rotary nickel-titanium instruments: ProTaper versus RaCe. Part 1. Shaping ability in simulated curved canals.* Int Endod J, 2004. **37**(4): p. 229-38.
22. Tripi, T.R., A. Bonaccorso, and G.G. Condorelli, *Cyclic fatigue of different nickel-titanium endodontic rotary instruments.* Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 2006. **102**(4): p. e106-14.
23. Ullmann, C.J. and O.A. Peters, *Effect of cyclic fatigue on static fracture loads in ProTaper nickel-titanium rotary instruments.* J Endod, 2005. **31**(3): p. 183-6.

Table 1. The number of cycles to failure (NCF) and the length of fractured fragment (mm) of each file group (mean ± SD).

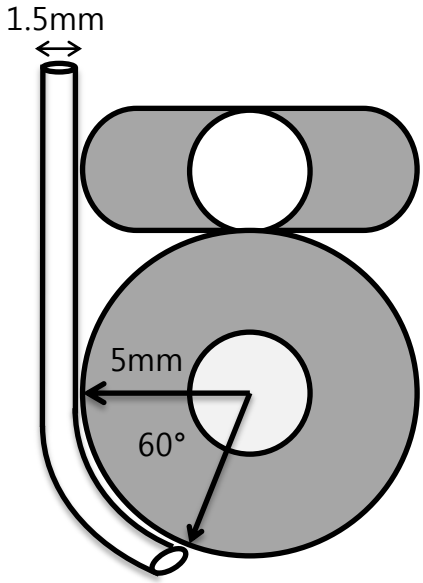
Group	ProFile*		ProTaper	
	CR	RM	CR	RM
NCF	1586 ± 298	1365 ± 310	666 ± 80	625 ± 52
Fragment length**	3.86± 0.63	4.01 ± 0.27	4.61 ± 0.96	4.60 ± 0.97

CR and RM mean continuous rotation and reciprocating motion respectively.

*ProFile had the bigger NCF than ProTaper regardless of instrument movement ($p<0.05$)

**There was no significant difference between CR and RM for either of file systems ($p>0.05$)

. **Figure 1.** Custom-made cyclic fatigue tester used in this study



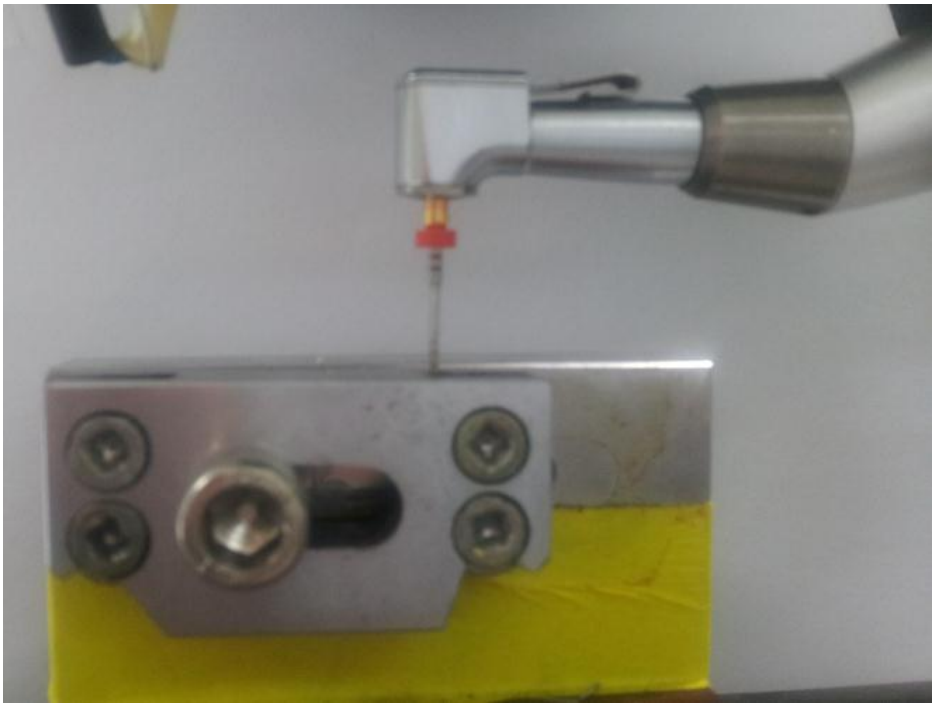


Figure 2. Overall experiment setting

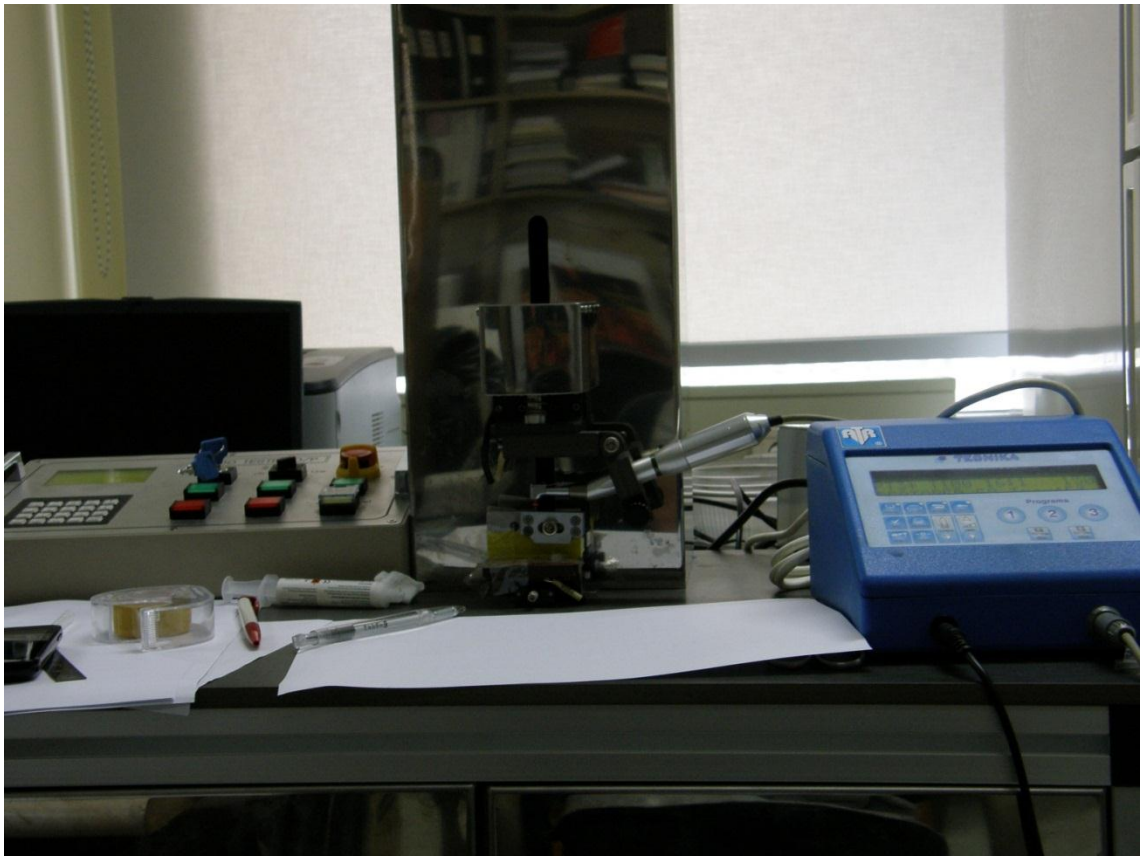


Fig 3. Scanning electron microscope images of the fracture surface of Profile with continuous motion. A(x200) shows crack initiation origins(a) and rollover fast fracture zones(b). Central fibrous regions with dimples similarly observed at the higher magnifications (x2000, B). Clusters of multiple fatigue striations were observed in the crack initiation areas(a) under high-magnification (x10 000, C)

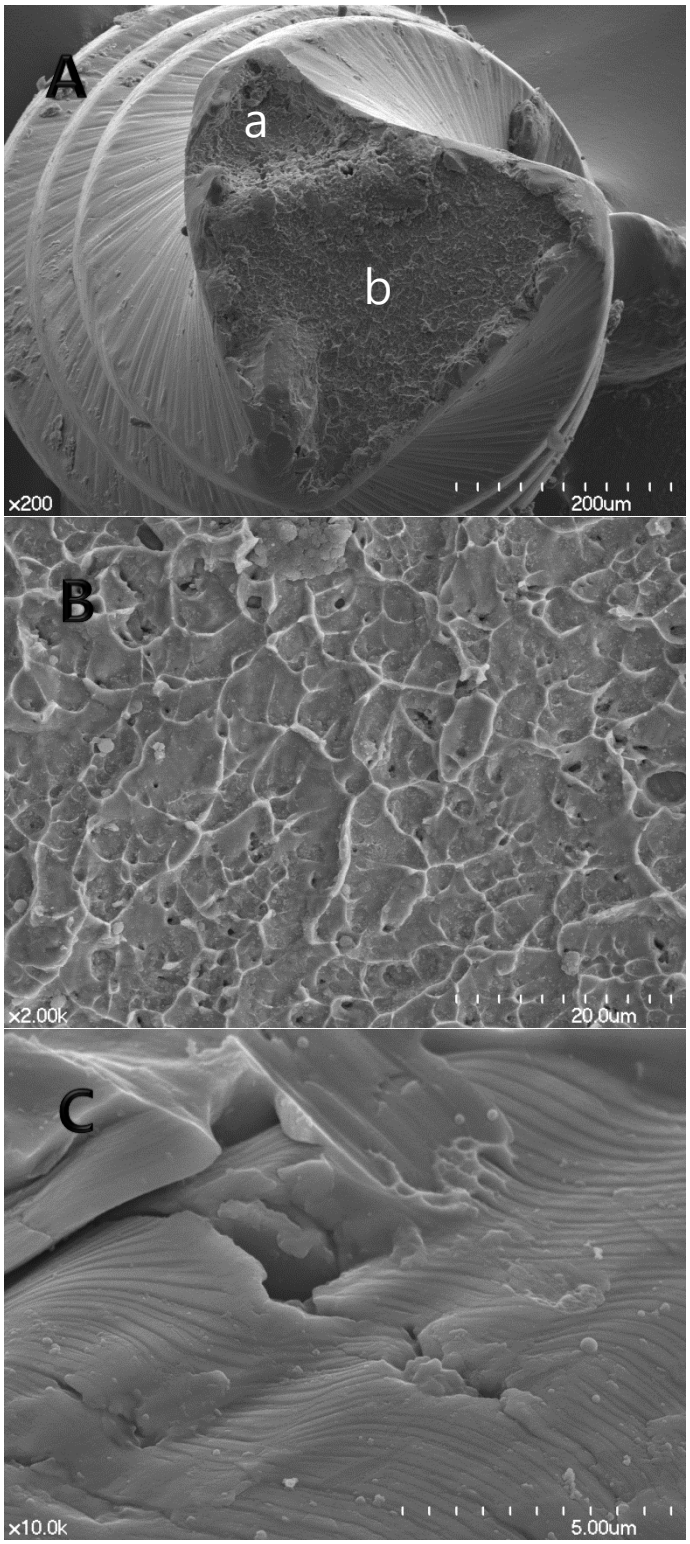


Fig 4. Scanning electron microscope images of the fracture surface of Profile with reciprocating motion. A(x200) shows crack initiation origins and rollover fast fracture zones. Central fibrous regions with dimples similarly observed at the higher magnifications (x2000, B). Clusters of multiple fatigue striations were observed in the crack initiation areas(a) under high-magnification (x10 000, C)

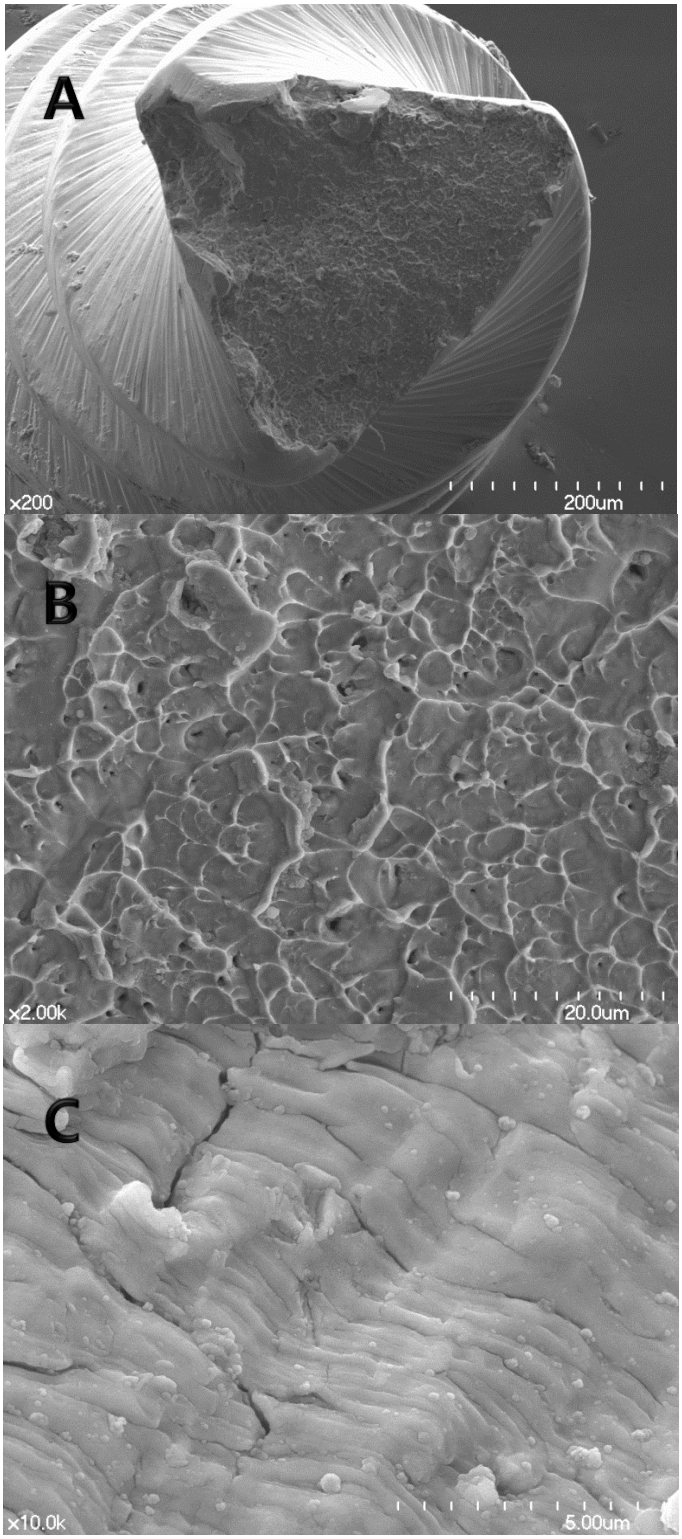


Fig 5. Scanning electron microscope images of the fracture surface of ProTaper with continuous rotation. A(x200) shows crack initiation origins(a) and rollover fast fracture zones(b). Central fibrous regions with dimples similarly observed at the higher magnifications (x2000, B). Clusters of multiple fatigue striations were observed in the crack initiation areas under high-magnification (x5000, C)

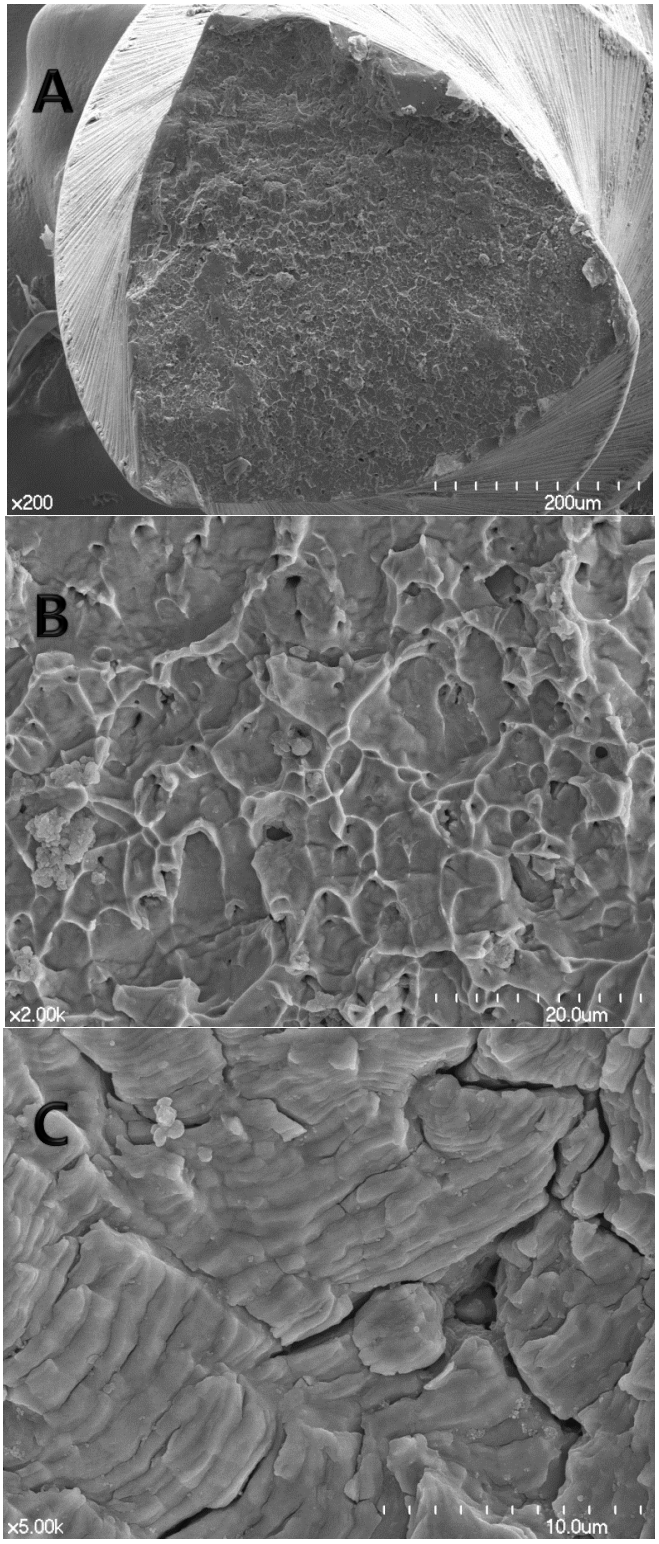
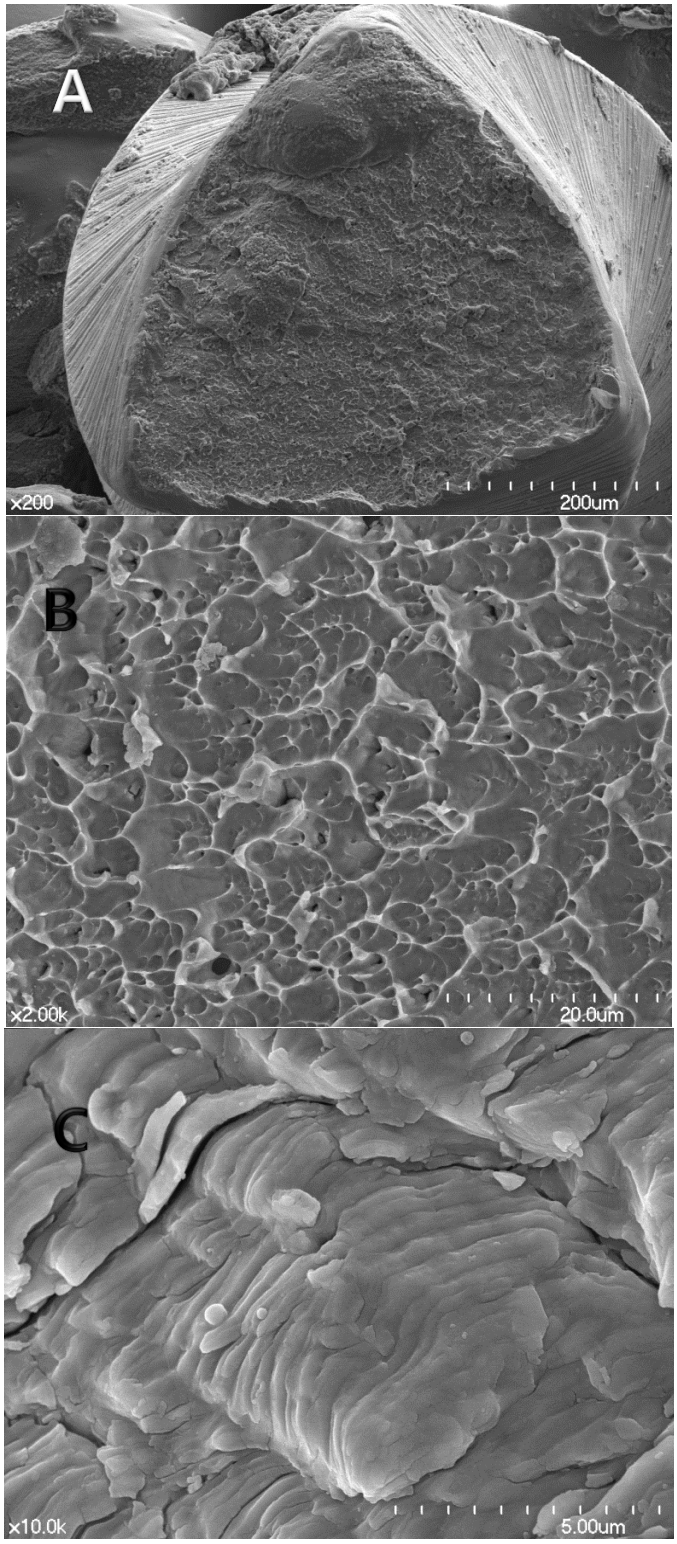


Fig 6. Scanning electron microscope images of the fracture surface of Profile with reciprocating motion. A(x200) shows crack initiation origins and rollover fast fracture zones. Central fibrous regions with dimples similarly observed at the higher magnifications (x2000, B). Clusters of multiple fatigue striations were observed in the crack initiation areas under high-magnification (x10 000, C)



국문초록

ProFile 과 ProTaper 의 cyclic 피로저항에 미치는 reciprocating 운동의 효과

(지도교수 이우철)

김승필

서울대학교 치의학대학원

치의학과

1. 목적

만곡된 근관에서 연속회전운동에 비해 reciprocating 운동시에 F2 ProTaper 기구의 수명이 연장된다는 것이 최근에 보고되었다. 이 연구의 목적은 다른 단면을 갖는 NiTi 기구에서 reciprocating 운동이 cyclic 굴곡 피로에 미치는 효과를 비교 연구하는 것이다.

2. 방법

F2 ProTaper(PT)와 #25/.06 taper 의 ProFile(PF) 기구를 사용했다. 임상적인 근관형성과정을 모방하여, 되풀이 굴곡 피로 테스트는 휘어진

stainless steel 튜브에서 수행하였다. 기구들은 연속회전운동 (CR) 또는 reciprocating 운동 (RM)으로 나누어 총 4 개의 실험그룹으로 실험을 진행하였다. 기구는 300rpm 으로 회전하면서 4 mm 의 상하반복운동을 하여 파절 될 때까지 반복하였다. Reciprocating 운동 (RM) 그룹에서는 시계방향, 반시계방향으로 각각 140,45 의 각도로 운동하게 하였다. 파절시간을 측정하여 파절 될 때 까지 회전 수를 계산하였다. 파절된 file tip 길이를 측정하고, 전자주사현미경으로 표면을 관찰하였다. 통계분석은 two-way ANOVA 와 t-test 를 통해 수행하였다.

3. 결과

ProFile과 ProTaper각군에서 회전방법 (RM,CM)에 따른 파절 시간이나 파절 회전수의 차이는 통계적으로 유의성이 없었다($p>0.05$). 사용된 회전방법에 상관없이 ProFile이 ProTaper에비해 큰 cyclic 피로 저항을 보였다($p<0.05$). 파절된 조각의 길이는 회전방식이나 파일종류에 영향을 받지 않았다($p>0.05$). fractographic analysis에서는 기구와 회전방식에 상관없이 균열 시작지점, 균열 진행 영역, 과부하(빠른 파절) 지대가 나타나는 비슷한 특징을 보였다.

주요어 : NiTi회전기구, cyclic 피로저항, reciprocating 운동, 연속회전운동, 횡단면

학번: 2009-22665