RESEARCH ARTICLE

Alteration in surface roughness of reciprocating endodontic instruments [version 1; peer review: 1 approved with reservations, 1 not approved]

Khoa Van Pham

Department of Operative Dentistry and Endodontics, University of Medicine and Pharmacy at Ho Chi Minh City, Ho Chi Minh, 700000, Vietnam

V1 First published: 01 Sep 2021, 10:875
<https://doi.org/10.12688/f1000research.55443.1>
 Latest published: 01 Sep 2021, 10:875
<https://doi.org/10.12688/f1000research.55443.1>

Abstract

Background: Surface roughness is one of the most important characteristics of endodontic instruments, correlating to instrument fracture. The purpose of this study was to measure the surface roughness values of these instruments before and after resin root canal preparation without previous glide path preparation, with the new method. Data was obtained from field emission scanning electron microscopes (FE-SEM) combined with independent ImageJ software (NIH, Bethesda, MD, USA).

Methods: A total of 20 simulated J-shape resin blocks with a radius of 4.5 mm, length of 16 mm, and angle of inflection of 60° were chosen and distributed into two equal groups. Each group was prepared by the WaveOne Gold Primary (Dentsply Sirona, Maillefer, Ballaigues, Switzerland) or the Reciproc Blue R25 (VDW, Munich, Germany) instruments, without glide path preparation. Special molds were used to confirm the same areas on the cutting blade at 3 mm and the instruments' tips were scanned by FE-SEM, at different observed times. The parameters of R_a , R_q , and R_z in each sample were collected using the ImageJ software for analyses. The data was processed using the paired t-test with a significance level of 0.05.

Results: Right after the first resin canal instrumentation, the surface roughness parameters of the two reciprocating investigated instruments were decreased.

Conclusions: The FE-SEM images processed using the ImageJ software offered a trustworthy and suitable method for assessment of the NiTi endodontic file surface roughness.

Keywords

FE-SEM, root canal instrumentation, surface roughness, reciprocating

Open Peer Review

Approval Status

	1	2
version 1		
01 Sep 2021	view	view

1. **Gianluca Gambarini**, Sapienza University of Rome, Rome, Italy
2. **Murilo Priori Alcalde**, University of São Paulo, São Paulo, Brazil

Any reports and responses or comments on the article can be found at the end of the article.

Corresponding author: Khoa Van Pham (khoapv@ump.edu.vn)

Author roles: Pham KV: Conceptualization, Data Curation, Formal Analysis, Funding Acquisition, Investigation, Methodology, Project Administration, Supervision, Validation, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing

Competing interests: No competing interests were disclosed.

Grant information: The author(s) declared that no grants were involved in supporting this work.

Copyright: © 2021 Pham KV. This is an open access article distributed under the terms of the [Creative Commons Attribution License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

How to cite this article: Pham KV. **Alteration in surface roughness of reciprocating endodontic instruments [version 1; peer review: 1 approved with reservations, 1 not approved]** F1000Research 2021, 10:875 <https://doi.org/10.12688/f1000research.55443.1>

First published: 01 Sep 2021, 10:875 <https://doi.org/10.12688/f1000research.55443.1>

Introduction

Root canal preparation plays an important role in endodontic treatment. This step is critical and facilitates obturation.¹ Advancements in science and technics have led to the production of the rotary nickel-titanium (NiTi) root canal instruments using two manners of movement: continuous or reciprocating motion. To reduce time required, complication of the process, and exhaustion of clinicians in root canal preparation, the single-file instruments are introduced using continuous or reciprocating rotation.² Since the first introduction of the single-file system with proprietary integrated technique, the system has been continuously developed in material improvement, taper modification, and cross-sectional geometry, especially in distinctive heat treatment processes.

Recently, the Reciproc Blue (RB) (VDW, Munich, Germany) and WaveOne Gold (WOG) (Dentsply Sirona, Maillefer, Ballaigues, Switzerland) instruments have been developed with many distinctive features in designs and thermal treatments.³ The instruments are subjected to the proprietary post-machining heat processes after being ground by machine. This treatment produces the oxide layer with the specific blue or gold.⁴

The risk of fracture is inherent in an endodontic instrument, especially for rotary nickel-titanium files. Both brittleness or ductility are a possible cause of breakage.⁵ Typically, a beginning crack on the material facet could lead to the fracture of the file.⁵ Defect on the surface of the material could be the crack beginning.⁶ There could be a correlation between surface characteristics and the breakage mechanism of the root canal rotary file.⁷

So far, there are limited studies of the root canal instrument surface roughness,^{8–11} especially using the data obtained from the field emission scanning electronic microscope (FE-SEM).¹² There is modest data available for the surface roughness parameters of the WOG Primary (WOGP) and RB R25 (RBR25) instruments for root canal preparation with the previous glide path preparation using the FE-SEM.¹² The purpose of this study was to measure the surface roughness values of these instruments before and after resin root canal preparation without previous glide path preparation, with the new method, using the data obtained from FE-SEM combined with independent ImageJ software (NIH, Bethesda, MD, USA).

Methods

The present study was performed in 2019, at the University of Medicine and Pharmacy at Ho Chi Minh City, Viet Nam. The method used for the present study was introduced in a previous study.¹² An acrylonitrile butadiene styrene (ABS) former was produced using automatically computerized controlled apparatus for ensuring the root canal file at the exact location before and after resin root canal preparation with dimethicone (Sylgard 184, Dow Corning Corp., USA) impression.¹² The combination of the ABS mold and the polydimethylsiloxane (PDMS) impression with instrument inside was then introduced and fastened into the gear of the vacuum room of the FE-SEM (NOVA NanoSEM 450, FEI, UNSW, Sydney, Australia) after complete removal of bubbles and drying at 60°C in 3 hours using the vacuum extractor (Diener Electronic, Germany).¹²

Sample size was calculated using the data of the previous study¹² with a total of 20 J-shape limpid plastic blocks for endodontic training (Dentsply Sirona, Maillefer, Ballaigues, Switzerland). Ten blocks were used for each group. Clear resin simulated root canal was a radius of 4.5 mm, length of 16 mm, and 60° angle of inflection, using the Pruett's manner.¹³ All endodontic preparations were conducted by an endodontist. The resin root canal was first explored using the ISO #10 K-file (Dentsply Sirona, Maillefer, Ballaigues, Switzerland) to confirm the patency of the entire plastic canal. X-Smart IQ cordless handpiece (Dentsply Sirona, Maillefer, Ballaigues, Switzerland) combined with an iPad Mini were operated using proper modules for root canal instrumentation.

In total, ten WOGP (lot no. 1493642) and ten RB25 (lot no. 258192) files were chosen for the study. The marks on the shanks of all files were produced with the tiny round bur #014 ISO (Dentsply Sirona, Maillefer, Ballaigues, Switzerland). These marks assisted in reintroducing the files into the mold after preparation and in inspecting the identical sectors on the file before and after preparation.¹²

Group 1 was prepared (without the glide path preparation) by the WOGP (Dentsply Sirona, Maillefer, Ballaigues, Switzerland) and group 2 was prepared (without the glide path preparation) by the RB25 (VDW, Munich, Germany) until the working length was reached with the gentle in-and-out pecking movement to approach clinical settings. Plastic root canal was thoroughly irrigated using 3% NaOCl solution (Canal Pro, Coltene Whaledent, Altstätten, Switzerland). One reciprocating file was only used for each plastic canal. After complete instrumentation, the instrument's surface was wiped off using moisture gauze, then the instrument was placed into an ultrasonic cleaner to be vibrated with alcohol solution for further cleansing and dried using gauze afterward.

The files were captured before and after endodontic preparation using the FE-SEM ($\times 1000$, 10kV). The surface of the instrument pinpointed at 3 mm from the peak of the file was assessed using the method described the previous study.¹²

Table 1. Mean and standard deviations of R_a , R_q , R_z parameters before and after instrumentation of experimental instruments (μm).

Group	WOGP		RBR25	
Scanning area	Cutting blade		Cutting blade	
Values	Before	After	Before	After
R_a	8.7674 ± 3.6170	8.5808 ± 2.1341	18.1019 ± 3.1379^c	7.4011 ± 1.9249^d
R_q	11.3050 ± 4.2682	11.9564 ± 2.8154	22.6933 ± 3.8096^e	9.5421 ± 2.3979^f
R_z	120.3159 ± 26.2844^a	103.3269 ± 31.1982^b	166.2183 ± 29.2271^g	82.8771 ± 25.9694^h

^{a,b,c,d,e,f,g,h} Different superscript letters (in the same group and scanning area) indicate statistically significant differences at 5% level. WOGP: Wave One Gold Primary; RBR25: Reciproc Blue R25.

The marks on the shank of the file were used as reference points. The evaluated sections were located, first by displacing the gear containing specimen from the mark on the instrument's shaft, toward the peak until it could be observed. Then, the backward movement of the gear was performed with the distance of 3 mm, and at this position, the cutting blade was evaluated and captured with the dimensions of $150 \mu\text{m} \times 150 \mu\text{m}$. These figures were analyzed using the ImageJ 1.52 (NIH, Bethesda, MD, USA). The mean roughness parameters (R_a), root-mean-square roughness (R_q), the average length in the range of the highest tip and lowest groove in each length of specimen (R_z), and the three-dimension graphs were calculated and obtained from the ImageJ.¹²

Shapiro-Wilk statistic was performed initially to check the distribution of the data and the paired t-test was executed to interpret the data using the SPSS 22.0 package (IBM-SPSS Inc, Armonk, NY, USA).

Results

The statistical values of the R_a , R_q , and R_z were showed in the Table 1.²² All data were normally distribution using the Shapiro-Wilk test. R_a and R_q parameters of the group 1 decreased after root canal instrumentation ($P > 0.05$). For the group 2, all these values decreased after endodontic, and these values were significantly different ($P < 0.05$).

Discussion

The result of the present study showed that almost all of the surface roughness parameters of both experimental instruments were decreased after root canal instrumentation. In the WOGP group, two of three values were reduced. In the RBR25 group, all values were decreased significantly. This result showed that surface changes, for such small sample of ten instruments, in the very beginning stage of root canal instrumentation, even the tiniest ones, could be discovered by this alternative modality with the FE-SEM at superior preciseness.

The atomic force microscope (AFM) and the conventional SEM were used for assessment of the surface of the root canal file before and after endodontic instrumentation. Although the three-dimension reconstruction feature of the AFM was been highly evaluated, this modality could just be used for scanning on tiny and absolute square, flat and rigid surfaces, whilst the conventional SEM could only capture the two-dimensional figures.¹⁰ In the touch mode of the AFM, the tiny end of the stylus might be damaged itself or it could destruct the scanned surface, affecting the outcome, and increasing the considerable time required for image building as well.¹⁰

Recently, a touchless profilometer has been reported by Ferreira et al. for investigation of the root canal instrument topography.¹⁰ However, this technique has been found to give inaccurate outcomes when scanning in extreme slope inclines or intermissions.¹⁴ One important shortcoming of this modality is that it does not properly work on the breakage areas.¹⁵ The contemporary profilometer does not work properly without integrated software supplied by the manufacturer.

The extreme tiny resolution of 1.4 nm was one of the most advantage of this modern FE-SEM and the specimen treatment was unnecessary. One of the utmost significant advantage of the FE-SEM is the integration of the data obtained from the FE-SEM and the calculation using the ImageJ program in reconstruction of the three-dimension figures and automatic production of the surface roughness values.¹²

Some other studies have affirmed the correctness and reliability of the integration of the data obtained from FE-SEM and the ImageJ program in calculation of the material surface roughness.^{16–18} In the present study, the above viewpoint was securely confirmed with the results of precise and reliable surface roughness and reconstructed three-dimension figures using the data obtained from FE-SEM and the independent ImageJ program.

All surface roughness parameters of the RBR25 group were significantly reduced, these reductions might be emerged from the efficacy of the instruments in root canal preparation.

Almost all surface roughness values in the WOGP group were receded after endodontic instrumentation, however, the differences were not statistically significant. This showed that the RBR25 files were subjected to the friction more than the WOGP instruments did. This could be led from the discrepancies in the construction, proportions, and substance of the two experimental NiTi instruments.

Although there were still certain disadvantages of resin blocks used for root canal experiments,^{8,19} the plastic blocks might still be used appropriately for endodontic investigation.¹²

The results of the present study were similar to those of the two previous studies.^{11,20} The surface roughness parameters of the WaveOne Primary (WOP) and Reciproc R25 (RR25) were increased after resin root canal preparation in the study using the AFM and those of the ProTaper F2 (Dentsply Sirona, Mailefer, Ballaigues, Switzerland) instruments were reduced.¹¹ The ProTaper F2 instruments were performed following the F1 instruments, therefore, the F2 instruments were subjected to less load than the WaveOne Primary and Reciproc R25. In the present study, the two instruments were subjected to a heavy load when using the resin root canal at the beginning of the preparation without any previous glide path preparation. However, they had the reduced surface roughness after first utilization, therefore; the difference came from the construction, dimension, and substance of these instruments. In the previous study using a non-contact optical profilometer for investigation of the surface roughness of the WOP and RR25, these roughness values also reduced from the second use to the first use and from the second use to the unused instruments after resin root canal preparation.²⁰ This result agreed with the outcome of the present study, came from the wear of cutting blades of the files after root canal preparation.

Opposed to the result of the present study, other studies have reported that the surface roughness of the endodontic instruments increased after endodontic instrumentation.^{8,9,21} All these previous studies used the extracted human teeth, one investigated the files used in the clinical setting,⁹ and two others used the extracted human teeth for the *in vitro* evaluations.^{8,21} The instruments were used five times and sterilized six times in the other study,⁹ and the instruments were used in the severely curved canals for three times before examining under the AFM⁸ or four-time utilizations and subjected to one sterilization cycle before investigation under the non-contact optical profilometer.²¹ All the above different conditions affected the surface roughness of the instruments after instrumentation. Further research on the WOGP and RBR25 using many times both *in-vitro* or *in-vivo* situations needed to be performed to explore more characteristics of these instruments' surface.

Conclusion

The FE-SEM images processed using the ImageJ software offered a trustworthy and suitable method for assessment of the NiTi endodontic file surface roughness. In total, two of the three surface roughness parameters of the WOGP and RBR25 were significantly decreased after the first manipulation in plastic root canal preparation.

Data availability

Underlying data

Mendeley Data: WOGP RB wo GlidePath with FE-SEM Images. <http://doi.org/10.17632/xr749xdwkn.2>.²²

This project contains the following underlying data:

- WOGP RB without Glide Path
- Ket Qua Do Roughness WOGP RB wo GlidePath.xlsx

Data are available under the terms of the [Creative Commons Attribution 4.0 International license](#) (CC-BY 4.0).

References

1. Pham K, Phan T: **Evaluation of root canal preparation using two nickel-titanium instrument systems via cone-beam computed tomography.** *Saudi Endodontic J.* 2019 September 1; **9**(3): 210–5.
[Publisher Full Text](#)
2. Pham K, Nguyen N: **Cutting efficiency and dentinal defects using two single-file continuous rotary nickel-titanium instruments.** *Saudi Endodontic J.* 2020 January 1; **10**(1): 56–60.
[Publisher Full Text](#)
3. Santos CB, Simões-Carvalho M, Perez R, *et al.*: **Torsional fatigue resistance of R-Pilot and WaveOne Gold Glider NiTi glide path reciprocating systems.** *Int Endod J.* 2019; **52**(6): 874–9. Epub 2019/01/21. eng.
[PubMed Abstract](#) | [Publisher Full Text](#)
4. Zupanc J, Vahdat-Pajouh N, Schäfer E: **New thermomechanically treated NiTi alloys – a review.** *Int Endod J.* 2018 2018/10/01; **51**(10): 1088–103.
[PubMed Abstract](#) | [Publisher Full Text](#)
5. Parashos P, Messer HH: **Rotary NiTi Instrument Fracture and its Consequences.** *J Endod.* 2006; **32**(11): 1031–43.
[PubMed Abstract](#) | [Publisher Full Text](#)
6. Kuhn G, Tavernier B, Jordan L: **Influence of Structure on Nickel-Titanium Endodontic Instruments Failure.** *J Endod.* 2001 2001/08/01; **27**(8): 516–20.
[PubMed Abstract](#) | [Publisher Full Text](#)
7. Valois CRA, Silva LP, Azevedo RB: **Multiple Autoclave Cycles Affect the Surface of Rotary Nickel-Titanium Files: An Atomic Force Microscopy Study.** *J Endod.* 2008; **34**(7): 859–62.
[PubMed Abstract](#) | [Publisher Full Text](#)
8. Özyürek T, Yılmaz K, Uslu G, *et al.*: **The effect of root canal preparation on the surface roughness of WaveOne and WaveOne Gold files: atomic force microscopy study.** *Restor Dent Endod.* 2018; **43**(1): e10.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
9. Inan U, Aydın C, Uzun O, *et al.*: **Evaluation of the Surface Characteristics of Used and New ProTaper Instruments: An Atomic Force Microscopy Study.** *J Endod.* 2007; **33**(11): 1334–7.
[PubMed Abstract](#) | [Publisher Full Text](#)
10. Ferreira F, Barbosa I, Scelza P, *et al.*: **A new method for the assessment of the surface topography of NiTi rotary instruments.** *Int Endod J.* 2017 2017/09/01; **50**(9): 902–9.
[PubMed Abstract](#) | [Publisher Full Text](#)
11. Fatma Y, Ozgur U: **Evaluation of surface topography changes in three NiTi file systems using rotary and reciprocal motion: An atomic force microscopy study.** *Microsc Res Tech.* 2014 2014/03/01; **77**(3): 177–82.
[PubMed Abstract](#) | [Publisher Full Text](#)
12. Pham VK, Vo CQ: **A new method for assessment of nickel-titanium endodontic instrument surface roughness using field emission scanning electronic microscope.** *BMC Oral Health.* 2020 2020/08/31; **20**(1): 240. Epub 2020/09/02.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
13. Pruett JP, Clement DJ, Carnes DL Jr: **Cyclic fatigue testing of nickel-titanium endodontic instruments.** *J Endod.* 1997; **23**(2): 77–85.
[PubMed Abstract](#) | [Publisher Full Text](#)
14. Leach R: **Surface Topography Measurement Instrumentation.** In: Leach R, editor. *Fundamental Principles of Engineering Nanometrology.* Second ed. Oxford: William Andrew Publishing; 2014. p. 133–204.
15. Khokhlov M, Fischer A, Rittel D: **Multi-Scale Stereo-Photogrammetry System for Fractographic Analysis Using Scanning Electron Microscopy.** *Experimental Mechanics.* Springer US; 2011 2012; **52**(8): 975–91.
[Publisher Full Text](#)
16. Safdar A: **Effect of process parameters settings and thickness on surface roughness of EBM produced Ti-6Al-4V.** *Rapid Prototyping J.* 2012; **18**(5): 401–8.
[Publisher Full Text](#)
17. Ersoy O, Aydar E, Gourgaud A, *et al.*: **Quantitative analysis on volcanic ash surfaces: Application of extended depth-of-field (focus) algorithm for light and scanning electron microscopy and 3D reconstruction.** *Micron.* 2008 2008/02/01; **39**(2): 128–36.
[PubMed Abstract](#) | [Publisher Full Text](#)
18. Chinga G, Johnsen PO, Dougherty R, *et al.*: **Quantification of the 3D microstructure of SC surfaces.** *J Microsc.* 2007 2007/09/01; **227**(3): 254–65.
[PubMed Abstract](#) | [Publisher Full Text](#)
19. Kum KY, Spångberg L, Cha BY, *et al.*: **Shaping ability of three ProFile rotary instrumentation techniques in simulated resin root canals.** *J Endod.* 2000 Dec; **26**(12): 719–23. Epub 2001/07/27. eng.
[PubMed Abstract](#) | [Publisher Full Text](#)
20. Ferreira FG, Barbosa IB, Scelza P, *et al.*: **Noncontact three-dimensional evaluation of surface alterations and wear in NiTi endodontic instruments.** *Braz Oral Res.* 2017; **31**.
[PubMed Abstract](#) | [Publisher Full Text](#)
21. Uslu G, Özyürek T, Yılmaz K: **Comparison of Alterations in the Surface Topographies of HyFlex CM and HyFlex EDM Nickel-titanium Files after Root Canal Preparation: A Three-dimensional Optical Profilometry Study.** *J Endod.* 2018; **44**(1): 115–9. Epub 2017/10/09. eng.
[PubMed Abstract](#) | [Publisher Full Text](#)
22. Pham K: **WOGP RB wo GlidePath with FE-SEM Images.** *Mendeley Data.* 2021: V2.
[Publisher Full Text](#)

Open Peer Review

Current Peer Review Status:

Version 1

Reviewer Report 17 January 2022

<https://doi.org/10.5256/f1000research.59019.r119267>

© 2022 Alcalde M. This is an open access peer review report distributed under the terms of the [Creative Commons Attribution License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Murilo Priori Alcalde

Department of Dentistry, Endodontics and Dental Materials, Bauru School of Dentistry, University of São Paulo, São Paulo, Brazil

1. The authors should discuss better the limitation of the use of resin blocks in comparison with human teeth. Do you really rely that this method simulate similar condition using human teeth?
2. This method to evaluate the surface roughness is different then use profilometer. Therefore, the authors should compare the results using the same methods. Please include in the discussion section why this method can replace the profilometer? And the limitation of this method. The discussion of this part is so poor. The are SEVERAL articles using the profilometer method. The authors should discuss better this section.

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Partly

Are sufficient details of methods and analysis provided to allow replication by others?

Partly

If applicable, is the statistical analysis and its interpretation appropriate?

Yes

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Endodontics

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 19 October 2021

<https://doi.org/10.5256/f1000research.59019.r93259>

© 2021 Gambarini G. This is an open access peer review report distributed under the terms of the [Creative Commons Attribution License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Gianluca Gambarini

Department of Oral and Maxillo-Facial Sciences, Sapienza University of Rome, Rome, Italy

The study is interesting but in present form is only partially developed:

- Indeed the sample size is small and is not clear if there is any clinical significance for the present results.
- Despite the study is realized without a glide path establishment, the resin block diameter is usually up to 15.02. Moreover the authors, to verify the patency have shaped the canal up to 10.02, that can be considered a glide path. Moreover, the resin could influence the results of the study.
- Please repeat the study using extracted teeth if possible, moreover add some statistical test such as cyclic fatigue, torsional resistance and cutting efficiency. This way you can make a clinical translation of these results.

Is the work clearly and accurately presented and does it cite the current literature?

Partly

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Partly

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Endodontology

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

The benefits of publishing with F1000Research:

- Your article is published within days, with no editorial bias
- You can publish traditional articles, null/negative results, case reports, data notes and more
- The peer review process is transparent and collaborative
- Your article is indexed in PubMed after passing peer review
- Dedicated customer support at every stage

For pre-submission enquiries, contact research@f1000.com

F1000Research