Int. j. adv. multidisc. res. stud. 2024; 4(5):442-446

Received: 06-08-2024
Accepted: 16-09-2024

International Journal of Advanced Multidisciplinary Research and Studies

ISSN: 2583-049X

Comparison between Corrosion of Stainless Steel Hand k-file and Nickel-Titanium Rotary Instrument following Immersion in 5.25% NaOCL Irrigation Solution: An *In Vitro* Study

[1] Md Shahidul Hasan, [2] MA Gafur, [3] Mohammed Asaduzzaman, [4] Sujan Neupane, [5] Toushik Hossain, [6] Asaduzzaman Rakib, [7] Mozammal Hossain

[1, 3, 6, 7] Department of Conservative Dentistry and Endodontics, Faculty of Dentistry, Bangabandhu Sheikh Mujib Medical University, Shahbag, Dhaka-1000, Bangladesh

[2] Chief Scientific Officer, Pilot Plant and Processing Development Center, Bangladesh Council for Scientific and Industrial Research (BCSIR), Dhaka-1000, Bangladesh

[4] Department of Conservative Dentistry and Endodontics, Kantipur Dental College, Teaching Hospital and Research Center, Basundhara, Kathmandu, Nepal

[5] Department of Electrical and Electronic Engineering, Brac University, KHA 224, Progati Sarani, Merul Badda, Dhaka-1212, Bangladesh

DOI: https://doi.org/10.62225/2583049X.2024.4.5.3266 Corresponding Author: **Mozammal Hossain**

Abstract

The study was aimed to compare the corrosion of stainless-steel hand K-file and Nickel-titanium rotary instrument following immersion in 5.25% NaOCL irrigation solution, *in vitro*. A total of 20 new Nickel-titanium (NiTi) rotary files and 20 stainless steel (K file) was selected and immersed in 5.25% NaOCL irrigation solution. All files were subjected to the corrosion test: Record the open circuit potential (OCP) for 1 h on a strip chart with high impedance. The strip chart recording for each file was classified into a stability score: (i) stable, (ii) unstable, or (iii) erratic. The percentage of OCP was measured by a potentiostat and a standard calomel electrode reference. The frequencies of visually observed corrosion were further investigated by scanning electron microscope (SEM). The results of the present study confirmed that stainless steel file showed greater corrosion rate than that of NiTi files. Additionally, both files had pitting and crevice corrosion, as seen by scanning electron microscopy (SEM) analysis. However, NiTi files demonstrated a lower rate of corrosion than stainless steel files. In conclusion, NiTi files showed greater corrosion resistance than that of stainless-steel files.

Keywords: Corrosion, Stainless Steel K File, Nickel-titanium Rotary Files

Introduction

Root canal files are used for cleaning and shaping the root canal. The purpose of root canal cleaning and shaping is the elimination of infected pulp tissue, followed by the removal of soft dentine and the elimination of microorganisms from the root canal [1]. Previous studies have reported that many organisms are always found in the infected root canal [2]. Microorganisms might reach the principal and lateral canals migrating from an infected tooth to a healthy pulp due to the contiguousness of the tissues, thereby spreading the infection to an adjacent tooth [3]. Nearly 700 bacterial species can be found in the oral cavity, with any particular individual harboring 100–200 of these species [4]. Various microorganisms are related to intra-radicular and extra-radicular infections and organisms involved in persistent infection [5]. Endodontic infections have a polymicrobial nature, with obligate anaerobic bacteria conspicuously dominating the microbiota in primary infections [6].

K-Type reamers and files are usually used to enlarge the root canal, made from stainless steel and comprised of two basic designs, K-type instruments (K-files and K reamers) and the Hedstrom files. These instruments may have different spirals and cutting flutes. A triangular cross-sectioned file shows superior cutting and increased flexibility than the file or reamer with a square blank. The file is predominantly used with filing or rasping action in which there is little or no rotation in the root canal

[7]. However, endodontic files are slender, tapered instruments, about 21, 25, and 31 mm long, and for the variations in their size and shape, it is difficult to remove all the biological material during re-sterilization procedures [8].
The introduction of Nickel Titanium (NiTi) rotary instruments into endodontics has provided the profession with rotary instruments of greater taper, with characteristics of super-elasticity and high strength [9]. It has been shown that NiTi Rotary instruments can achieve excellent taper, with less risk of canal transportation and improved tooth-structure preservation, and do so more rapidly than hand files [10-11]. However, various factors such as corrosion, repeated use may cause unexpected fracture during clinical use of NiTi Rotary instruments [12].
Corrosion may occur when K File come into contact with NaOCl during disinfection [13-14]. Or when the solution is present in the pulp chamber and root canal during instrumentation and irrigation [15]. Furthermore, as NaOCl is corrosive to alloys, it may cause selective removal of alloys from the surface followed by creating micropitting [16-17]. These micro-structural defects can lead to areas of stress collection and crack formation, weakening the structure of the instrument [18].
The rate of corrosion of NiTi files also depends on the concentration of NaOCl solution. It was found that within 1-12 h, macroscopically visible corrosion of Ni-Ti instruments can occur after the contact with 5.25% NaOCl solution, and visible traces of corrosion occurred after the immersion of the Ni-Ti instruments in the 5% NaOCl solution at an exposure time of 30 min [19]. Furthermore, Oshida *et al.* [20]. Heated the 5.25% sodium hypochlorite solution so that the liquid maintained a constant temperature of 37°C during the test and found a high corrosion rate. However, nickel-titanium rotary instruments can still be separated without any signs or visible surface changes during clinical use. The irrigation agents used during root canal treatments or sterilization processes implemented subsequently to root canal treatments may cause chemical reactions leading to the corrosion or formation of surface irregularities in the surfaces of NiTi rotary instruments. These irregularities and distortions can lead to instrument fracture during clinical use [21-22]. The problem is severe when the instrument continues to rotate despite its tip is screwed in root canal or when the canal instrument is subjected to consecutive compression and tensile stresses at the level where metal fatigue is exceeded during rotation in a curved root canal.
The corrosion pattern of the previous studies is still controversial due to the variation of corrosion assessment methods. Various techniques such as scanning electron microscope (SEM), atomic force microscopy (AFM) have been suggested to observe the corrosion surface morphology of stainless steel and NiTi instrument surfaces [23-24]. Therefore, the purpose of this study was to evaluate and compare the corrosion susceptibility of stainless-steel and NiTi endodontic files following immersion in 5.25% NaOC1 irrigation solution & then detected corrosion by open circuit potential (OCP) and Scanning microscopic examination, *in vitro*.

Materials and methods

This Quasi Experimental study was performed in the Department of Conservative Dentistry and Endodontics, Faculty of Dentistry, Bangabandhu Sheikh Mujib Medical University (BSMMU), Shahbag, Dhaka and Bangladesh & Bangladesh Council for Scientific and Industrial Research (BCSIR).
A total of 20 stainless steel hand K files (Group A) and 20 new NiTi rotary files (Group B) were selected and they were divided into 2 groups as follows:

- A (n=20): Immersion of K file in 5.25% NaOCL
- B (n=20): Immersion of NiTi file in 5.25% NaOCL.

In each group, 4 different numbers of files were used as #15, #20, #25 and # 30. These files were immersed in 5.25% NaOCL for corrosion test and record the open circuit potential (OCP) for 1 h on a strip chart with high impedance. The strip chart recording for each file was classified into a stability score: (i) stable, (ii) unstable, or (iii) erratic. The percentage of OCP of #15, #20, #25 and # 30 Files was measured by potentiostat and a standard calomel electrode reference (GAMRY Instrument reference 3000). The frequencies of visually observed corrosion were further investigated by scanning electron microscope (SEM) (Model: Evo 18, Curl Ziess.UK).

Data Collection & statistical analysis

The mean between two groups was compared by student's unpaired t –test and a value of $p<0.05$ was considered as statistically significant.

Results

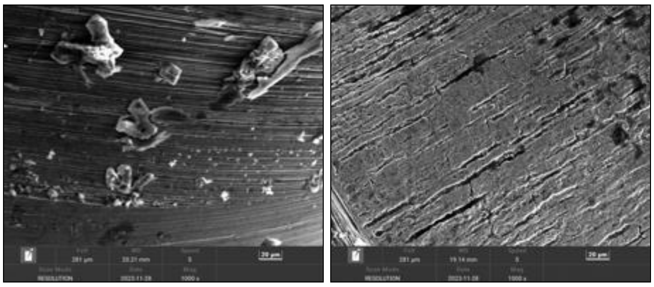
Table 1 showed that the corrosion rate (CR) of stainless steel hand files size of # 15, # 20, # 25 and # 30 after immersion in 5.25% NaOCl were 5.10 ± 0.36, 5.16 ± 0.62, 5.15 ± 0.58 and 5.29 ± 0.09 mpy, respectively. The corrosion current (IC) of stainless steel hand files size of # 15, # 20, # 25 and # 30 after immersion in 5.25% NaOCl were 4.86 ± 0.57, 5.48 ± 1.33, 5.00 ± 0.81 and 5.77 ± 1.45 mpy, respectively. The corrosion potential (CP) of stainless steel hand files size of # 15, # 20, # 25 and # 30 after immersion in 5.25% NaOCl were -265.40 ± 18.84, -251.80 ± 28.09, -231.60 ± 27.17 and -258.00 ± 16.97 mpy, respectively.
The corrosion rate (CR) of NiTi files size of # 15, # 20, # 25 and # 30 after immersion in 5.25% NaOCl were 3.26 ± 0.31, 3.19 ± 0.28, 3.10 ± 0.34 and 3.06 ± 0.11 mpy, respectively. The corrosion current (IC) of NiTi files size of # 15, # 20, # 25 and # 30 after immersion in 5.25% NaOCl were 4.66 ± 0.24, 4.65 ± 0.12, 5.22 ± 0.26 and 5.31 ± 0.37 mpy, respectively. The corrosion potential (CP) of NiTi files size of # 15, # 20, # 25 and # 30 after immersion in 5.25% NaOCl were -269.60 ± 2.07, -280.20 ± 9.12, -280.60 ± 10.04 and -290.00 ± 8.34 mpy, respectively.
Fig 1 showed that both files had pitting and crevice corrosion, as seen by scanning electron microscopy (SEM) analysis.

Table 1: Quantitative analysis of the corrosion susceptibility of stainless steel hand K file and NiTi rotary file after immersion in 5.25% NaOCl

Variables	K File (n=20)	NiTi file (n=20)	p value
	Mean ± SD	Mean ± SD	
15 diameter (n=10)			
IC	4.86±0.57	4.66±0.24	<0.001*
CR	5.10±0.36	3.26±0.31	0.004*
CP	-265.40±18.84	-269.60±2.07	0.149^{ns}
20 diameter (n=10)			
IC	5.48±1.33	4.65±0.12	0.002*
CR	5.16±0.62	3.19±0.28	0.026*
CP	-251.80±28.09	-280.20±9.12	0.937^{ns}
25 diameter (n=10)			
IC	5.00±0.81	5.22±0.26	0.100^{ns}
CR	5.15±0.58	3.10±0.34	0.007*
CP	-231.60±27.17	-280.60±10.04	0.430^{ns}
30 diameter (n=10)			
IC	5.77±1.45	5.31±0.37	0.305^{ns}
CR	5.29±0.09	3.06±0.11	0.001*
CP	-258.00±16.97	-290.00±8.34	0.041*

Data were expressed as mean±SD

Unpaired t-test was performed to compare between two groups, *significant, ns= not significant



(Stainless steel K file) (NiTi File)

Fig 1: Representative SEM photographs of corrosion pattern following immersion in NaOCL solution

Discussion

The results of the present study confirmed that stainless steel file showed greater corrosion rate than that of NiTi files. The corrosion current and corrosion potential of stainless was also greater than the NiTi files. Furthermore, the corrosion current and corrosion potential of stainless was also greater than the NiTi files after immersion in in NaOCL solution. Statistical analysis showed that the findings between the two files were significant. Additionally, both files had pitting and crevice corrosion, as seen by scanning electron microscopy (SEM) analysis. However, NiTi files demonstrated a lower rate of corrosion than stainless steel files. Furthermore, when the surface structure was assessed with scanning electron microscopy (SEM) it was found that both stainless steel and NiTi files subjected to the immersion corrosion test, there were crevice/ pitting corrosion. This result is corresponded to Jeffrey and Melchers [25] that after electrochemical testing, the corrosion rate of stainless steel was 0.416 MPY (milli-inch per year) which is almost similar to the present study. Bonaccorso *et al*. [23] (2008) also indicated that stainless steel and NiTi files were associated with crevice/ pitting corrosion as seen by scanning electron microscopy (SEM).

Previous studies have reported that pitting corrosion causes metal failure by the creation of small holes in metal surfaces. Therefore, fracture caused by the fatigue failure mechanism occurs due to crack initiation at the cutting surfaces [26]. It is generally associated with chloride containing irrigation solution. Another study has indicated that some sorts of metals (such as stainless steel and NiTi) are more resistant to corrosion, either due to the fundamental nature of the electrochemical processes involved or due to the details of how reaction products form [27]. It is well known that titanium shows high corrosion resistance to chloride compound [28].

The results of the present SEM study also revealed that some microscopic breakdown was observed on stainless steel and titanium which is actually pitting like structure. A thin film of corrosive products was also seen. It may be due on the accumulation of corrosive material on the metal surface spontaneously due to oxidation. Previous study also indicated that oxidation is responsible for further corrosion [29]. Other than oxidation, several reasons of corrosion also have been detected by other studies. Wever *et al.* [30] indicated that the corrosion of NiTi alloys are generally passivated by the surface film of titanium and nickel oxide. The corrosion patterns of NiTi alloy involve selective removal of nickel from the surface [31]. Therefore, it may be considered that after some initial dissolution of nickel from the surface, the nickel-titanium alloy may form a surface containing mainly titanium oxides in the outer layer and nickel-titanium in the inner layer [30]. Surface oxidation seems to be very promising for improving the corrosion resistance and biocompatibility of NiTi [32].

Previous studies have reported that corrosion rate is directly related to corrosion current (IC) [33]. When it is greater, it can increase the corrosion rate. This is also supported by the current study that when it is increased, the corrosion rate is high. Furthermore, different diameters of the stainless steel are used for shaping & finishing of the root canal. NiTi is differing from the stainless steel in the sense of its flexibility because NiTi pro taper rotary System (Dentsply Maillefer, Switzerland) was designed to provide cutting efficiency and flexibility [34]. In the present study, the files were immersed in 5.25% NaOCI and the OCP was recorded for 1 h on a strip chart with high impedance (PerkinElmer Recorder 56, Hitachi, Ltd., Tokyo, Japan). A saturated calomel electrode (SCE) was used as the reference electrode. The OCP was measured by the Potentiostat/ Galvanostat model 263 (EG+G Princeton Applied Research). OCP is the potential between a file and the SCE while immersed in solution. Each file, after being immersed in 5.25% NaOC1 ~br 1 h at room temperature, was rinsed in water and allowed to dry at room temperature on filter paper. The files were stored individually in glass vials (Kimble Glass, Inc., Toledo, OH). The strip chart recording for each file was classified into a stability score: (i) Corrosion Current, (2) Corrosion Rate, (3) Corrosion Potential. After 1 h immersion, a random examination was conducted for each file for visual signs of corrosion. This allowed to each 30 file to be examined without knowing the file type, brand, or stability of its OCP. Furthermore, each of the files was inspected with a Scanning electron microscope (SEM) at × 500 to detect the corrosion.

The SEM was used to visualize the effect of corrosion and to determine the components of the endodontic file alloy in corroded and non-corroded areas. Presently, there is little information concerning the corrosion of NiTi files, but the results of this study reinforce the conclusions of Stokes *et al.* [35] (1999) that NiTi files showed greater corrosion rate than that of stainless steel files.

There are several electrochemical tests that are used to assess the corrosion properties of alloys. These tests typically investigate the current potential characteristics of the metal-solution interface. OCP represents the potential at which all oxidation and reduction reactions are occurring simultaneously. In this study, 20 of the total 40 files had an OCP, but showed no visual corrosion. This could mean that corrosion was present in the files with unstable OCP.

Conclusion

NiTi files showed less corrosion rate than that of stainless steel files.

References

1. Young GR, Parashos P, Messer HH. The principles of techniques for cleaning root canals. Australian Dental Journal. 2007; 52:S52-S63.
2. Narayanan LL, Vaishnavi C. Endodontic microbiology. Journal of Conservative Dentistry: JCD. 2010; 13(4):233.
3. Siqueira Jr JF. Aetiology of root canal treatment failure: Why well-treated teeth can fail. International Endodontic Journal. 2001; 34(1):1-10.
4. Paster BJ, Dewhirst FE. Molecular microbial diagnosis. Periodontology. 2009; 2000:51:38.
5. Gajan EB, Aghazadeh M, Abashov R, Milani AS, Moosavi Z. Microbial flora of root canals of pulpally-infected teeth: Enterococcus faecalis a prevalent species. Journal of Dental Research, Dental Clinics, Dental Prospects. 2009; 3(1):24.
6. Dahlen G, Basic A, Bylund J. Importance of virulence factors for the persistence of oral bacteria in the inflamed gingival crevice and in the pathogenesis of periodontal disease. Journal of Clinical Medicine. 2019; 8(9):1339.
7. Atmeh AR, Watson TF. Root dentine and endodontic instrumentation: Cutting edge microscopic imaging. Interface Focus. 2016; 6(3):20150113.
8. Smith A, Dickson M, Aitken J, Bagg J. Contaminated dental instruments. Journal of Hospital Infection. 2002; 51(3):233-235.
9. Brantley WA. Introduction of nickel-titanium alloy to endodontics. Ingle's endodontics. 2008; 6:800-813.
10. Peters OA, Schönenberger K, Laib A. Effects of four Ni–Ti preparation techniques on root canal geometry assessed by micro computed tomography. International Endodontic Journal. 2001; 34(3):221-230.
11. Gluskin AH, Brown DC, Buchanan LS. A reconstructed computerized tomographic comparison of Ni–Ti rotary GT™ files versus traditional instruments in canals shaped by novice operators. International Endodontic Journal. 2001; 34(6):476-484.
12. Kosa DA, Marshall G, Baumgartner JC. An analysis of canal centering using mechanical instrumentation techniques. Journal of Endodontics. 1999; 25(6):441-445.
13. Berutti E, Angelini E, Rigolone M, Migliaretti G, Pasqualini D. Influence of sodium hypochlorite on fracture properties and corrosion of ProTaper Rotary instruments. International Endodontic Journal. 2006; 39(9):693-699.
14. Sonntag D, Peters OA. Effect of prion decontamination protocols on nickel-titanium rotary surfaces. Journal of Endodontics. 2007; 33(4):442-446.
15. Kumar N, Shaik GP, Pandurangan S, Khalkho B, Neelakantan L, Chetty R. Corrosion characteristics and fuel cell performance of a cost-effective high Mn–Low Ni austenitic stainless steel as an alternative to SS 316L bipolar plate. International Journal of Energy Research. 2020; 44(8):6804-6818.
16. Sağlam BC, Koçak S, Koçak MM, Topuz Ö. Effects of irrigation solutions on the surface of ProTaper instruments: A microscopy study. Microscopy research and technique. 2012; 75(11):1534-1538.
17. Pineda Hernández DA, Restrepo Parra E, Arango Arango PJ, Segura Giraldo B, Acosta Medina CD. Innovative method for coating of natural corrosion inhibitor based on Artemisia vulgaris. Materials. 2021; 14(9):2234.
18. Pedulla E, Grande NM, Plotino G, Pappalardo A, Rapisarda E. Cyclic fatigue resistance of three different nickel-titanium instruments after immersion in sodium hypochlorite. Journal of Endodontics. 2011; 37(8):1139-1142.
19. Fayyad DM, Mahran AH. Atomic force microscopic evaluation of nanostructure alterations of rotary N i T i instruments after immersion in irrigating solutions. International Endodontic Journal. 2014; 47(6):567-573.
20. Oshida Y, Sellers CB, Mirza K, Farzin-Nia F. Corrosion of dental metallic materials by dental treatment agents. Materials Science and Engineering: C. 2005; 25(3):343-348.
21. Parashos P, Messer HH. Rotary NiTi instrument fracture and its consequences. Journal of Endodontics. 2006; 32(11):1031-1043.
22. Coelho MS, de Azevêdo Rios M, da Silveira Bueno CE. Separation of nickel-titanium rotary and reciprocating instruments: A mini-review of clinical studies. The Open Dentistry Journal. 2018; 12:864.
23. Bonaccorso A, Tripi TR, Rondelli G, Condorelli GG, Cantatore G, Schäfer E. Pitting corrosion resistance of nickel–titanium rotary instruments with different surface treatments in seventeen percent ethylenediaminetetraacetic acid and sodium chloride solutions. Journal of Endodontics. 2008; 34(2):208-211.
24. Toloei A, Stoilov V, Northwood D. Simultaneous effect of surface roughness and passivity on corrosion resistance of metals. WIT Trans. Eng. Sci. 2015; 90:355-367.
25. Melchers RE, Jeffrey RJ. Corrosion of steel piling in seawater harbours. In Proceedings of the Institution of Civil Engineers-Maritime Engineering. 2014; 167(4):159-172.
26. McGuigan MB, Louca C, Duncan HF. Endodontic instrument fracture: Causes and prevention. British Dental Journal. 2013; 214(7):341-348.
27. Huang HH. Effect of chemical composition on the corrosion behavior of Ni-Cr-Mo dental casting alloys. Journal of Biomedical Materials Research. 2002; 60(3):458-465.
28. Endo K, Suzuki M, Ohno H. Corrosion characteristics of ferric and austenitic stainless steels for dental magnetic attachment. Dental Materials Journal. 2000; 19(1):34-49.
29. Oshida Y, Tominaga T. Corrosion and oxidation. In Nickel-Titanium Materials, 2020, 297-388.
30. Wever DJ, Veldhuizen AG, De Vries J, Busscher HJ,

Uges DRA, Van Horn JR. Electrochemical and surface characterization of a nickel–titanium alloy. Biomaterials. 1998; 19(7-9):761-769.
31. Montero-Ocampo C, Lopez H, Salinas Rodriguez A. Effect of compressive straining on corrosion resistance of a shape memory (Ni-Ti alloy in ringer's solution. Journal of Biomedical Materials Research: An Official Journal of The Society for Biomaterials and the Japanese Society for Biomaterials. 1996; 32(4):583-591.
32. Lü X, Bao X, Huang Y, Qu Y, Lu H, Lu Z. Mechanisms of cytotoxicity of nickel ions based on gene expression profiles. Biomaterials. 2009; 30(2):141-148.
33. Ogle K, Baudu V, Garrigues L, Philippe X. Localized electrochemical methods applied to cut edge corrosion. Journal of the Electrochemical Society. 2000; 147(10):3654.
34. West JD. Introduction of a new endodontic system: Progressively tapered files' Dentistry Today. 2001; 20:50-57.
35. Stokes OW, Di Fiore PM, Barss JT, Koerber A, Gilbert JL, Lautenschlager EP. Corrosion in stainless-steel and nickel-titanium files. Journal of Endodontics. 1999; 25(1):17-20.