Journal of Rare Cardiovascular Diseases
ISSN: 2299-3711 (Print) | e-ISSN: 2300-5505 (Online)
www.jrcd.eu
RESEARCH ARTICLE

Stainless Steel and Ni Ti Files Under 5.25% Sodium Hypochlorite Corrosion Assessment

Shahidul Hasan[1], Mohammed Asaduzzaman1,Asaduzzaman Rakib[2], Riadulzannat[2], Khandoker Rumon[2]
[1]Assistant Professor, Department of Conservative Dentistry and Endodontics, Bangladesh Medical University (BMU), Dhaka, Bangladesh
[2]Medical officer, Conservative Dentistry and Endodontics (BMU), Dhaka, Bangladesh

*Corresponding Author
Dr. Md. Shahidul Hasan

Article History
Received: 16.09.2025
Revised: 25.09.2025
Accepted: 13.10.2025
Published: 29.10.2025

Abstract: ***Background:*** Nickel–titanium (Ni–Ti) rotary files improve root canal therapy due to their flexibility and cutting efficiency but remain susceptible to fracture from fatigue, torsional stress, and corrosion. Sodium hypochlorite (NaOCl), a common irrigant, can weaken files by causing surface defects. Stainless steel (SS) files generally show uniform corrosion, while Ni–Ti files develop localized pitting. Previous studies, including in Bangladesh, indicate higher overall corrosion in SS and more surface irregularities in Ni–Ti. This study aimed to compare the corrosion behavior, rate, and surface changes of SS and Ni–Ti files in NaOCl under controlled conditions. ***Methods:*** In this in vitro study, 30 endodontic files (15 stainless steel hand K-files and 15 NiTi rotary files) of similar lengths and diameters (15, 20, 25, 30 mm) were assessed for corrosion after 24-hour immersion in 5.25% sodium hypochlorite at room temperature. Corrosion susceptibility was evaluated via Initial Corrosion (IC), Corrosion Rate (CR), and Corrosion Potential (CP), along with overall corrosion frequency. Visual inspection and SEM analysis were used to assess surface degradation. Data were analyzed using independent t-tests and chi-square tests, with $p < 0.05$ considered significant. ***Results:*** A total of 30 endodontic files (15 stainless steel [SS] K-files and 15 nickel-titanium [NiTi] rotary files) were evaluated after 24-hour immersion in 5.25% sodium hypochlorite (NaOCl). Corrosion frequency was higher in SS files (80%) than NiTi files (40%). SEM analysis revealed more pronounced pitting and surface roughening in SS files, while NiTi files showed localized pitting and minor micro-cracks (mean severity score: 2.4 ± 0.6 vs. 1.3 ± 0.5). Quantitatively, SS files exhibited significantly higher corrosion rates at all diameters ($p < 0.05$), with notable differences in initial corrosion and corrosion potential at select points. Overall, stainless steel files were more susceptible to NaOCl-induced corrosion than NiTi instruments. ***Conclusion:*** Stainless steel (SS) hand K-files are more susceptible to NaOCl-induced corrosion than nickel–titanium (NiTi) rotary files, exhibiting higher corrosion frequency, greater initial corrosion, and increased corrosion rates. NiTi files demonstrate superior structural integrity and resistance, highlighting their advantage for safer and more durable root canal instrumentation.

Keywords: Stainless Steel, NiTi, Sodium Hypochlorite, Corrosion Assessment .

INTRODUCTION

The introduction of engine-driven nickel–titanium (Ni–Ti) rotary files has revolutionized root canal therapy by utilizing their super-elastic and shape-memory properties to enhance efficiency, reduce operator fatigue, minimize procedural errors, and preserve natural canal curvature for improved clinical outcomes.[1]Nickel–titanium (Ni–Ti) endodontic files, available in various designs and cross-sections, are widely used for root canal preparation due to their superior cutting efficiency, flexibility, and torsional strength.[2]

Despite their advanced mechanical properties and clinical advantages, nickel–titanium (Ni–Ti) files remain susceptible to fracture during root canal instrumentation. This breakage can result from factors such as cyclic fatigue, excessive torsional stress, or surface defects that develop during use or sterilization. Such instrument separation not only complicates the treatment procedure but may also compromise canal cleaning and sealing, potentially affecting the overall success of endodontic therapy.[3]

Ni–Ti rotary instruments may fracture due to torsional stress, when the file tip binds in the canal, or flexural stress from repeated bending. Additionally, the corrosive root canal environment, influenced by irrigants', pH, temperature, and sterilization, can cause pitting or crevice corrosion, reducing cutting efficiency and increasing the risk of instrument fracture.[4]

Sodium hypochlorite (NaOCl) is the most widely used irrigant in endodontic therapy due to its strong tissue-dissolving and antimicrobial properties. It effectively removes organic debris, disinfects the canal system by eliminating bacteria and biofilms, and facilitates smoother instrumentation by acting as a lubricant. Its ability to penetrate intricate canal anatomy makes it indispensable for achieving thorough cleaning and successful root canal disinfection.[5] Corrosion can weaken endodontic files by creating surface defects that reduce efficiency and fatigue life, increasing fracture risk. Even corrosion-resistant Ni–Ti alloys can suffer localized damage from sodium hypochlorite's high pH and chloride content. [6,7]

Although stainless steel and Ni–Ti endodontic files are commonly used in practice, comparative studies on their corrosion behavior in sodium hypochlorite under

controlled conditions are still limited. Recent research indicates notable differences in corrosion rates and surface characteristics between the two alloys.[8]

Global studies have shown that both stainless steel (SS) and nickel-titanium (NiTi) endodontic files are susceptible to corrosion when exposed to sodium hypochlorite (NaOCl), though the patterns differ. SS files typically exhibit uniform surface corrosion due to oxide layer breakdown, while NiTi files show localized pitting and micro-cracks from nickel ion release. [9] observed significant surface roughness in NiTi files after NaOCl exposure, and [10] found faster corrosion in SS.

A study in Bangladesh found that both stainless steel K-files and Pro Taper NiTi rotary files experienced corrosion after immersion in sodium hypochlorite. Stainless steel files showed a higher overall corrosion rate, while NiTi files exhibited more localized pitting and surface irregularities. SEM analysis confirmed surface degradation in both file types, and statistical analysis indicated that the differences in corrosion patterns between the two alloys were significant.[8] The aim of this study was to compare the corrosion behavior of stainless steel and nickel-titanium endodontic files in sodium hypochlorite and assess their corrosion rate and surface changes under controlled conditions.

MATERIAL AND METHODS

Study Design:
This study was an in vitro experimental investigation conducted to assess the corrosion susceptibility of stainless steel (SS) hand K-files and nickel-titanium (NiTi) rotary files after immersion in 5.25% sodium hypochlorite (NaOCl) solution. The study was conducted on Conservative Dentistry and Endodontics, Bangladesh Medical University (BMU) from July 2024 to June 2025.

Sample Size and Selection:
A total of 30 endodontic files were evaluated, comprising 15 SS hand K-files and 15 NiTi rotary files. Files of similar length and diameter were selected to minimize variability. The study included four different file sizes: #15, #20, #25, and #30.

Preparation of Samples:
Each file was cleaned using distilled water and dried before immersion. Files were then individually immersed in freshly prepared 5.25% NaOCl solution at room temperature for a standardized duration of 24 hours to simulate clinical exposure conditions. After immersion, files were rinsed with distilled water and air-dried.

Corrosion Assessment:
Corrosion susceptibility was evaluated using the following parameters:

1. **Initial Corrosion (IC):** Visual inspection and quantitative scoring of early surface corrosion.
2. **Corrosion Rate (CR):** Measured using standard electrochemical techniques to assess the rate of material degradation.
3. **Corrosion Potential (CP):** Determined using a potentiostat to evaluate the electrochemical stability of the file material.

Additionally, the overall **corrosion frequency** was recorded, defined as the number and percentage of files showing any visible surface corrosion.

Visual and SEM Assessment:
The files were visually inspected for corrosion, and the frequency of corrosion was further evaluated using a **Scanning Electron Microscope (SEM; Model: Evo 18, Carl Zeiss, UK)** to observe surface degradation patterns.

Surface Morphology Analysis:
After electrochemical testing, representative samples from each group were rinsed thoroughly with distilled water and air-dried at room temperature. The surface morphology of both stainless steel (SS) hand K-files and nickel-titanium (NiTi) rotary files was examined using a Scanning Electron Microscope (SEM) (Model: EVO 18, Carl Zeiss, UK) at various magnifications (×500–×5000) to evaluate corrosion-related surface changes. Observations included pitting, roughness, oxide layer disruption, and crack formation. Each surface feature was scored on a severity scale from 0 to 3 (0 = none, 1 = mild, 2 = moderate, 3 = severe), and mean severity scores were calculated for each file type to compare corrosion intensity.

Data Analysis:
All measurements were recorded as mean ± standard deviation (SD). Statistical comparisons between SS and NiTi files were performed using an independent t-test for continuous variables (IC, CR, CP) and chi-square test for categorical variables (corrosion incidence). A p-value < 0.05 was considered statistically significant.

RESULTS AND OBSERVATIONS:

A total of 30 endodontic files were evaluated in this study, including 15 stainless steel (SS) hand K-files and 15 nickel-titanium (NiTi) rotary files. The corrosion susceptibility of these files was assessed after immersion in 5.25% sodium hypochlorite (NaOCl) solution at four different diameters (15 mm, 20 mm, 25 mm, and 30 mm).

Corrosion Frequency / Incidence: To complement the quantitative measurements, the overall incidence of visible corrosion was assessed for each file type (Table 2). Stainless steel K-files demonstrated a higher frequency of corrosion (80%) compared to NiTi rotary files (40%), confirming their greater susceptibility to NaOCl-induced corrosion. (Table 1)

Table 1. Corrosion Frequency of SS and NiTi Files after Immersion in 5.25% NaOCl

File Type	Total Files (n)	Files with Corrosion (n)	Files without Corrosion (n)	Corrosion Frequency (%)
SS K-file	15	12	3	80%
NiTi file	15	6	9	40%

SEM Morphology

Scanning Electron Microscopy (SEM) analysis revealed distinct surface alterations between the two file types after immersion in 5.25% NaOCl. Stainless steel (SS) K-files exhibited more pronounced surface damage, characterized by generalized pitting, roughening, and partial oxide layer breakdown, predominantly along the flutes and shaft. In contrast, nickel-titanium (NiTi) rotary files showed relatively localized pitting and occasional micro-cracks, mainly at the cutting edges and tips. The mean severity score was significantly higher for SS K-files (2.4 ± 0.6) compared to NiTi rotary instruments (1.3 ± 0.5), indicating that SS files experienced greater corrosion-related degradation. (Table 2)

Table 2. SEM Morphology Findings after 24-h Immersion in 5.25% NaOCl (N = 30)

File Type	n	Surface changes observed (SEM)	Dominant lesion location	Severity score (0–3)*
SS K-file	15	Pitting, general roughening, oxide layer breakdown	Flutes & shaft	2.4 ± 0.6
NiTi rotary	15	Localized pitting, micro-cracks at cutting edge	Tip & cutting edges	1.3 ± 0.5

*Severity score: 0 = none, 1 = mild, 2 = moderate, 3 = severe (mean ± SD).

Initial Corrosion (IC):

The mean IC values of SS files were generally higher than those of NiTi files, with statistically significant differences observed at 15 mm (4.85 ± 0.55 vs. 4.70 ± 0.25, $p < 0.001$) and 20 mm (5.50 ± 1.30 vs. 4.68 ± 0.15, $p = 0.002$). At 25 mm and 30 mm diameters, the differences were not statistically significant ($p > 0.05$). (Table 3)

Corrosion Rate (CR):

SS K-files exhibited consistently higher corrosion rates than NiTi rotary files at all diameters. Statistically significant differences were observed at 15 mm (5.12 ± 0.40 vs. 3.30 ± 0.35, $p = 0.004$), 20 mm (5.18 ± 0.60 vs. 3.22 ± 0.30, $p = 0.026$), 25 mm (5.17 ± 0.55 vs. 3.15 ± 0.35, $p = 0.007$), and 30 mm (5.30 ± 0.10 vs. 3.08 ± 0.12, $p = 0.001$), indicating that stainless steel files are more susceptible to corrosion in NaOCl solution. (Table 3)

Corrosion Potential (CP):

CP values showed minor differences between SS and NiTi files, with statistical significance observed only at 30 mm diameter (-258.0 ± 17.0 vs. -290.0 ± 8.5, $p = 0.041$). For other diameters, no significant differences were noted ($p > 0.05$). (Table 3)

Table 3. Quantitative Analysis of Corrosion Susceptibility of Stainless Steel Hand K-file and NiTi Rotary File after Immersion in 5.25% NaOCl (N = 30)

Diameter (mm)	Variable	K-file (n=15) Mean ± SD	NiTi file (n=15) Mean ± SD	p-value
15	IC	4.85 ± 0.55	4.70 ± 0.25	<0.001*
15	CR	5.12 ± 0.40	3.30 ± 0.35	0.004*
15	CP	-265.5 ± 19.0	-268.5 ± 2.5	0.150 ns
20	IC	5.50 ± 1.30	4.68 ± 0.15	0.002*
20	CR	5.18 ± 0.60	3.22 ± 0.30	0.026*
20	CP	-252.0 ± 28.0	-279.5 ± 9.5	0.940 ns
25	IC	5.02 ± 0.80	5.20 ± 0.30	0.100 ns
25	CR	5.17 ± 0.55	3.15 ± 0.35	0.007*
25	CP	-232.0 ± 27.0	-280.5 ± 10.0	0.430 ns
30	IC	5.78 ± 1.40	5.32 ± 0.40	0.305 ns
30	CR	5.30 ± 0.10	3.08 ± 0.12	0.001*
30	CP	-258.0 ± 17.0	-290.0 ± 8.5	0.041*

*Abbreviations: IC = Initial Corrosion, CR = Corrosion Rate, CP = Corrosion Potential; *$p < 0.05$ significant, ns = not significant*

Overall Findings:
These results demonstrate that stainless steel K-files are more prone to NaOCl-induced corrosion than NiTi rotary files, particularly regarding corrosion rate, while NiTi files maintain superior structural integrity.

DISCUSSION

In this study, 80 % of stainless steel K files and 40 % of NiTi rotary files showed visible corrosion after immersion in 5.25 % NaOCl, indicating a markedly higher susceptibility of the SS instruments. Previous work supports that NiTi instruments tend to exhibit greater corrosion resistance compared to stainless steel: for example, Corrosion in stainless steel and nickel titanium files found lower and roughly equal corrosion for both materials (≈8 %) under NaOCl conditions. [11] More recently, Corrosion resistance assessment of nickel titanium endodontic files demonstrated that NiTi rotary files immersed in 5.25 % NaOCl revealed pitting corrosion, although the corrosion onset varied with file design and treatment. [12] Thus, our findings not only align with the general trend (SS more prone than NiTi) but also show considerably higher corrosion incidence, likely due to variations in experimental conditions, file geometry, or surface finish.

The SEM morphology findings (Table 3) revealed that stainless steel (SS) hand K-files exhibited more extensive corrosion damage—characterized by pitting, surface roughening, and oxide layer breakdown—mainly along the flutes and shaft. In contrast, nickel-titanium (NiTi) rotary files showed only localized pitting and minor micro-cracks at the cutting edges, reflected by their lower mean severity score (1.3 ± 0.5 vs. 2.4 ± 0.6). These results align with previous studies reporting that NiTi alloys form a more stable titanium oxide layer, offering greater corrosion resistance than stainless steel in sodium hypochlorite. Costa et al. observed localized pitting in NiTi files exposed to 5.25% NaOCl [12], while Darabara et al. reported uniform oxide breakdown in SS instruments [13]. The present findings therefore confirm that SS files are more vulnerable to NaOCl-induced surface degradation, whereas NiTi files retain better structural integrity.

In the present investigation, stainless steel (SS) hand K files showed markedly higher susceptibility to corrosion than nickel titanium (NiTi) rotary files when immersed in 5.25 % sodium hypochlorite: significantly greater Initial Corrosion (IC) values were observed at 15 mm (4.85 ± 0.55 vs. 4.70 ± 0.25, $p < 0.001$) and 20 mm (5.50 ± 1.30 vs. 4.68 ± 0.15, $p = 0.002$); Corrosion Rate (CR) was consistently and significantly higher for SS at all diameters (e.g., 5.12 ± 0.40 vs. 3.30 ± 0.35 at 15 mm, $p = 0.004$); Corrosion Potential (CP) differences were minimal, with significance only at 30 mm (258.0 ± 17.0 vs. 290.0 ± 8.5, $p = 0.041$). These results support the notion that NiTi files maintain superior corrosion resistance in aggressive irrigants. Indeed, a recent study found that when NiTi files (heat treated and conventional) were immersed in 5.25 % NaOCl, signs of pitting and corrosion appeared in both types, although the extent varied with alloy treatment. [14] Earlier work comparing SS and NiTi files in NaOCl immersion also reported corrosion in both but found no significant difference between the two materials. [13] Thus, our data extend these findings by providing clear quantitative distinctions for IC, CR and CP across multiple diameters, pointing to a higher vulnerability of SS files under comparable conditions. Another study report [15], which did not report size-specific comparisons, highlighting that while NiTi files consistently maintain lower corrosion rates, other measures such as IC and CP may vary depending on instrument diameter. Overall, both studies support the conclusion that NiTi rotary files retain superior structural integrity and are less susceptible to NaOCl-induced corrosion, reinforcing their advantage in endodontic practice.

CONCLUSION

Stainless steel (SS) hand K-files are generally more prone to corrosion when exposed to sodium hypochlorite (NaOCl) compared to nickel–titanium (NiTi) rotary files, exhibiting a higher overall frequency of corrosion, greater initial surface degradation, and consistently elevated corrosion rates across multiple file diameters. In contrast, NiTi rotary files demonstrate superior resistance to chemical attack, maintaining better structural integrity and showing only localized surface defects, which reflects their enhanced durability and longevity during clinical use. The pronounced susceptibility of SS files to NaOCl-induced corrosion not only compromises their cutting efficiency but may also increase the risk of instrument fracture, potentially affecting the quality and safety of root canal therapy. These findings highlight the clinical advantage of NiTi rotary files, suggesting that their use can improve procedural safety, reduce the likelihood of file separation, and contribute to more predictable and effective endodontic treatment outcomes. Overall, careful selection of file material, considering both mechanical performance and corrosion resistance, is essential for optimizing the success and longevity of root canal instrumentation.

REFERENCES

1. Liu JF, Lin MC, Hsu ML, Li UM, Lin CP, Tsai WF, Ai CF, Chen LK, Huang HH. Effect of nitriding surface treatment on the corrosion resistance of dental nickel–titanium files in 5.25% sodium hypochlorite solution. Journal of alloys and compounds. 2009 May 5;475(1-2):789-93.

2. 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 Jan 1;25(1):17-20.
3. Walia H, Brantley WA, Gerstein H. An initial investigation of the bending and torsional properties of Nitinol root canal files. Journal of endodontics. 1988 Jan 1;14(7):346-51.
4. Özcan T, Sonat B, Öztan MD, Basmaci F, Aksoy U. The Determination of the Corrosion Rates of Rotary Ni-Ti Instruments in Various Irrigation Solutions. Cyprus Journal of Medical Sciences. 2023 May 9.
5. 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 Sep;39(9):693-9.
6. Yum JW, Park JK, Hur B, Kim HC. Comparative analysis of various corrosive environmental conditions for NiTi rotary files. Journal of Korean Academy of Conservative Dentistry. 2008 Jul 1;33(4):377-88.
7. Mohammadi Z, Kinoshita JI, Manabe A, Kobayashi M, Shalavi S, Jafarzadeh H. Corrosion of Ni-Ti Rotary Instruments: A Review. Journal of Dental Materials & Techniques. 2019 Oct 1;8(4).
8. Rakib A, Moral MA, Gafur A, Dil M, AfrozBhuiyan MH. Influence of Sodium Hypochlorite Corrosion on Stainless Steel K-file and Pro Taper Rotary Nickel-Titanium Instrument.
9. Smith MS, Liewehr FR, Moon PC. The Effect of Sodium Hypochlorite on Nickel-Titanium Rotary Instruments and its Effect on Resistance to Fracture: OR 24. Journal of Endodontics. 2007 Mar;33(3):334.
10. George R. The Effects of Degassed Sodium Hypochlorite on Cytotoxicity and Biofilm Reduction Potential (Master's thesis, Saint Louis University).
11. Weine FS, Kelly RF, Lio PJ. The effect of preparation procedures on original canal shape and on apical foramen shape. Journal of endodontics. 1975 Aug 1;1(8):255-62.
12. Costa TD, e Silva ED, Caetano PL, da Silva Campos MJ, Resende LM, Machado AG, do Carmo AM. Corrosion resistance assessment of nickel-titanium endodontic files with and without heat treatment. Restorative dentistry & endodontics. 2020 Dec 28;46(1).
13. Darabara M, Bourithis L, Zinelis S, Papadimitriou GD. Susceptibility to localized corrosion of stainless steel and NiTi endodontic instruments in irrigating solutions. International endodontic journal. 2004 Oct;37(10):705-10.
14. Gavini G, Santos MD, Caldeira CL, Machado ME, Freire LG, Iglecias EF, Peters OA, Candeiro GT. Nickel–titanium instruments in endodontics: a concise review of the state of the art. Brazilian oral research. 2018 Oct 18;32:e67.
15. Hasan MS, Gafur MA, Asaduzzaman M, Neupane S, Hossain T, Rakib A, Hossain M. 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. INTERNATIONAL JOURNAL. 2024;4(5):442-6.