Original Article

Evaluation of Alloy Composition of A Brand of Stainless Steel K-Files

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ABSTRACT

Objective: The purpose of this experimental study was to determine the alloy composition of a brand of handheld stainless steel K files, acquired from different countries, in accordance with available standards.
Study Design: Comparative study.
Place and Duration of Study: This study was conducted at the Institute of Space & Technology (IST) Islamabad from November 2021 to March 2022.
Materials and Methods: 20 Mani stainless-steel K files of identical size (ISO#25), were acquired from Pakistan and were designated as Group A while 20 Mani K files were purchased from London, UK and designated as Group B. Alloy composition of both the sets of files was evaluated using energy dispersive X-ray spectroscopy. Data was statistically analyzed by independent sample T test and compared with American Iron and Steel Institute types 304 and 316.
Results: No significant difference was found between the two groups. Nickel and chromium contents of both the groups fell within AISI 304 but content of nickel in the alloy was found to be in the lower applicable range of the specified limit.
Conclusion: The results of this study indicate towards a general inclination of manufacturers towards using the lower applicable range of expensive alloying elements.
Key Words: Stainless steel endodontic K files, austenitic stainless steel, alloy composition, cost effectiveness, clinical efficiency.

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INTRODUCTION

Stainless steel also known as INOX steel constitutes a group of corrosion and heat resistant alloys containing a minimum of 10.5% chromium[1]. Stainless steel has its usage dating back to more than a 100 years owing to its unique set of properties which makes it an ideal material for many applications[2]. Its resilience and high resistance to corrosion makes it an exemplary material for surgical tools and medical equipment. In dentistry, it has its applications in the manufacture of endodontic files for root canal cleaning and shaping, metal posts for root canal treated teeth, crowns and arch wires[2,3].

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The first endodontic file was designed by Edward Mynard in 1838 which he made by filing a watch spring. Stainless steel K-files, basically cutting instruments used for root canal debridement and shaping are the strongest of the handheld files, bypassing obstructions with far greater ease and are produced to give the operator a smooth tactile sensation within the canal during instrumentation[4]. The properties of endodontic files vary from one another depending upon their metallic composition. They also differ in terms of dentine cutting efficacy[5]. Consequently, their resistance to defect origination and breakage also varies[6]. Stainless steel files and reamers were established to be superior to carbon steel files in this regard[7]. Ni Ti files are three times more elastic than the stainless steel files but stainless steel files are more efficient cutting tools as compared to Ni Ti instruments[8]. However, their strength and resistance to corrosion is greatly affected by the composition of alloy used in fabrication of these files[5,9-11].

Most of the standard grades still employed today were discovered from 1913 to 1935, and then from 1970s onwards in Britain, Germany, America and France[1]. Stainless steel alloys can be divided into 5 basic categories depending on their crystalline structure. These are austenitic, ferritic, martensitic (named after the German metallurgist Adolf Martins), duplex and precipitation hardened alloys. Choosing the appropriate stainless steel grades comprises considering four attributes in the following sequence of significance: corrosion resistance, mechanical properties, fabrication techniques and cost effectiveness[12]. Austenitic grades, known for their formability and high resistance to corrosion are the most widely utilized stainless steels, accounting for more than 70% of the total manufacture. The most commonly used austenitic stainless steel grades are 304 and 316. 304L and 316L are the low carbon versions of these alloys with a carbon content of less than 0.03%[2]. Type 304 is commonly known as 18/8 for its typical composition of nickel ranging from 8-10% and that of chromium from 18-20% by weight. Type 316 is also referred to as 18/10, with nickel content ranging from 10-14% and chromium ranging from 16-18% by weight[13].

Darbara, M., et al., concluded from their studies that AISI types 303 and 304 are the most commonly used austenitic grades for stainless steel files and reamers[13]. Previous studies have shown that alloy type has a an influence on the corrosion resistance of endodontic instruments as well as their strength and cutting efficiency[11,14]. Optimum amount of nickel, chromium as well as molybdenum in stainless steel gives the alloy its strength and high corrosion resistance. The addition of nickel, manganese and or molybdenum also helps in maintaining the austenitic structure of the alloy, improving its strength. Furthermore, nickel imparts ductility to the alloy[14].

For elemental investigation or chemical categorization of a sample, a methodical approach called Energy Dispersive X-ray spectroscopy (EDX) is employed. EDX has been used to determine the elemental composition of endodontic files in numerous studies[13,15]. It fundamentally works on the principle that each element has a distinctive atomic configuration permitting a distinctive set of crests on its electromagnetic emission spectrum. It is based on the interaction of a source of high energy particles (photons, electrons or a ray of x rays) and electrons within a specimen. To excite the emanation of specific x-rays from a sample, a high-energy ray of charged particle is directed onto the specimen being investigated. The incident ray stimulates an electron in an inner shell, releasing it while producing an electron hole in the shell. An electron from an external, higher-energy shell then occupies the empty space. The difference in energy between the higher and lower energy shells is emitted in the form of an x-ray photon.

During chemo-mechanical preparation as well as during autoclaving, endodontic files are exposed to highly corrosive products including sodium hypochlorite which may debilitate the strength of the instruments as a result of pitting corrosion. These pits acting as stress raisers may cause sudden breakage of the instruments during the course of clinical use[11]. Hence, the role of material selection in maintaining the integrity of endodontic files, based on favorable chemical properties cannot be over emphasized. Pertaining to the dearth of information regarding the alloy composition of endodontic files, this study was aimed at evaluating and comparing the chemical composition of a brand of stainless K files (Mani Inc. Japan), acquired from Pakistan and United Kingdom in accordance with American Iron and Steel Institute (AISI) 304 and 316. Files of this particular brand were selected because of the availability of their non-standardized files in both local and international markets[12].

MATERIALS AND METHODS

Sample comprised of 40 stainless-steel K files (Mani, Inc. 8-3 Kiyohara Industrial Park Utsunomiya, Tochigi, Japan) of identical sizes, (ISO#25, 21mm). Out of the total, 20 K files, were obtained from Pakistan and named as Group A, while 20 K files brought from London, UK were named as Group B. The description about the files used for the testing purpose is given in Table 1.

Chemical composition of the files belonging to both the groups was determined using Energy Dispersive X-ray analysis. Emphasis was based on the nickel and chromium contents of the samples, since these two elements constitute the major portion of the alloying elements in austenitic stainless steels[13].

RESULTS

Nickel and chromium contents of the samples were statistically analyzed by independent sample T test and compared with AISI 304 and 316[13,16]. Nickel and chromium contents of the tested samples of Group A, as estimated with energy dispersive spectrometer analysis are given in Table 2, while those of Group B are given in Table 3.

Table No.1: Material used for testing

Sources (countries)	**Type of files**	**No. of Files**	**Manufacturer**	**Lot Number**	**Grou PS Assigned**
Pakistan (Rawalpindi/ Islamabad)	Stainless steel K files, 21mm #25	20	MANI, INC. 8-3Kiyohara industrial park. Utsunomiya, Tochigi, Japan.	R151412100	Group A
United Kingdom (London)	Stainless steel K files, 21mm #25	20	MANI, INC. 8-3Kiyohara industrial park. Utsunomiya, Tochigi. Japan	R110868200	Group B

The average means and standard deviations of nickel and chromium contents of the tested samples are given in Table 4. No significant difference between Groups A and B was found (p>0.05).

Table No.2: Nickel and Chromium contents by weight % of Group A files:

Sample Number	Chromium Content	Nickel Content
1.	19.57	8.27
2.	19.77	7.90
3.	19.03	7.52
4.	19.68	8.08
5.	19.03	5.97
6.	18.50	8.07
7.	19.50	8.11
8.	19.42	7.99
9.	17.88	7.24
10.	18.96	7.47
11.	18.38	7.41
12.	17.25	8.05
13.	17.29	6.87
14.	15.19	8.44
15.	18.44	8.47
16.	18.43	8.58
17.	18.88	8.63
18.	18.24	8.33
19.	19.20	8.61
20.	19.16	7.93

Table No.3: Nickel and Chromium contents by weight % of Group B files:

Sample Number	**Chromium Content**	**Nickel Content**
1.	18.73	7.69
2.	18.48	7.65
3.	17.43	8.36
4.	19.36	7.41
5.	19.44	8.31
6.	18.66	7.68
7.	18.32	7.45
8.	19.47	8.02
9.	18.18	7.88
10.	18.86	8.74
11.	19.51	8.54
12.	17.54	7.43
13.	17.93	7.56
14.	18.56	8.49
15.	18.83	7.80
16.	19.42	8.19
17.	19.31	7.33
18.	19.39	8.39
19.	17.33	8.46
20.	19.55	8.13

Nickel and chromium contents of the tested samples in both the groups fell within AISI 304. Nickel content however, was found to be in lower range of the specified limit. The absence of molybdenum in the chemical composition of the files showed that the files were not made from auestenitic type 316 stainless steel.

Table No.4: Means and standard deviations of Ni and Cr contents of Groups A & B:

Groups	N	**Composition** (%)	P **Value**
Nickel			
Group A	20	7.89 ± 0.66	0.66
Group B	20	7.97 ±0.44	0.66
Chromium			
Group A	20	18.59 ±1.07	0.67
Group B	20	18.71 ±0.73	0.67

DISCUSSION

The results of this study in terms of metallic composition of the files are consistent with a previous study[13]. Both the groups of files examined fell into one of the most commonly used austenitic type 304 stainless steel grades, which are easily recognized by the absence of molybdenum and percentage weight of nickel (8-10%) and chromium in their chemical composition (18-20%). It was however observed that nickel content of files in both the groups was in the lower range of the specified limit.

The price of stainless steel in general is markedly governed by the cost of alloying elements. The price of chromium which is the vital stainless steel element is not high, but incorporation of ingredients which enhance the corrosion resistance (mainly molybdenum) or which alter the manufacture properties (particularly nickel) add significantly to the overall cost[17]. These costs have a direct influence on the two most widely used grades: 304 (18%Cr, 8%Ni) and 316 (16%Cr, 10%Ni, and 2% Mo)[17]. Considering these facts, it was postulated that variations might exist in the chemical composition of stainless steel endodontic files, particularly the nickel contents.

Basically, stability between austenite former and ferrite former elements governs the microstructure of steel. Carbon, manganese, nitrogen and copper are all austenite former lower cost potential substitutes to nickel[18]. However, each element has a different function, and it is not likely to completely eliminate nickel and substitute it with either of these elements[19]. For example, manganese acts as an austenite former but is not as effectual as nickel, and Cr-Mn steels have greater strain hardening rates than do seemingly corresponding Cr-Ni steels. Similarly, carbon is a very effective austenite former, but has only partial solubility in austenite, so it is of limited significance in steel designed to be totally austenitic.

Similarly, limited solubility of nitrogen (<0.2%) does not have a very substantial influence on corrosion resistance of the alloy[18,20].

Mechanical integrity of an endodontic file depends to a great deal upon its chemical stability[14]. Lower amounts of nickel in an alloy may reduce its overall cost as well as its toxic potential, however, care must be taken to ensure a balance between the corrosion and strength properties[16]. Addition of nickel in stainless steel files improve their flexibility, so as to allow maneuvering of the curved / constricted canals relatively easier. Therefore, alteration in the alloy composition of nickel may compromise the clinical efficacy of a file, resulting in its sudden catastrophic failure at any point, during the course of clinical use[13].

In our study none of the low cost substitutes for nickel were found in composition of the endodontic files. Nevertheless, from lower range of nickel, it could be well postulated that to control and reduce cost of the instruments, manufacturers may be focused on reducing the cost of the raw material by employing the lowest applicable tolerance of expensive alloying elements. It should however be considered that the current study involved only one type of several files systems available on the market. Hence, to draw a more decisive inference on this matter, further research is required with several brands of files in multiple sizes.

CONCLUSION

No significant difference was found between locally and internationally acquired files and the alloy composition fell within AISI 304. Nickel content, however, was found to be in lower range of the specified limit in both the groups. Further investigation to evaluate the corrosion properties of these files is required for future research. Furthermore, studies on identifying the nickel contents in stainless steel endodontic files in general is required since the results of this study indicate towards a general inclination of manufacturers towards using lower amounts of nickel in the manufacture of stainless steel files. Evaluation of in-vivo performance of the files may add significantly to the data available on the importance of chemical composition in maintaining the integrity of stainless endodontic files.

Author's Contribution:

Concept & Design of Study:	Maryam Saeedullah
Drafting:	Syed Wilayat Husain
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Conflict of Interest: The study has no conflict of interest to declare by any author.

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