

Topographic Analysis of HyFlex® Controlled Memory Nickel–Titanium Files

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Abstract:

Background: The multiple uses of HyFlex® controlled memory (CM) rotary instruments (Coltene-Whaledent, Allstetten, Switzerland) have been recommended after sterilization. The purpose of this study was to analyze the surface defects on HyFlex® instruments after use and to determine their ability to return to their original shape after autoclaving.

Materials and Methods: Twenty-four new HyFlex® files were scanned using micro-computed tomography before the initial use, after use until defects were visible and after autoclaving. Surface analysis was performed on each file to determine the changes in the files after deformation; defects were recorded as unwinding and curving. These changes were categorized according to the severity, and the initial and final scans of the files were superimposed to illustrate the recovery of the files to their original shape. The data were analyzed using Chi-square and *t*-test.

Results: The *t*-test of Student's Newman–Keuls revealed a significant difference ($P < 0.05$) between unused and used files, almost all files exhibited visible defects without fractures, including unwinding and curving associated with unwinding. The most frequently observed defect was unwinding of the spirals (100%), whereas curving associated with unwinding was infrequently observed. A Chi-square test showed that the deformation (curve: $P = 0.000$, and unwinding: $P = 0.011$, incidence depended on the size of the files. The greatest frequency of curving occurred in the small files #20/0.04 and #20/0.06, the difference was statistically significant from all file sizes ($P < 0.05$). The majority of the files (79%) were able to restore the unwinding and regain their original shape after autoclaving. The highest rate of unrestored files was observed on #20/0.04 and #20/0.06 instruments, and the difference was statistically significant from all file sizes ($P < 0.05$).

Conclusion: HyFlex® CM nickel-titanium files appear to regain their original shape after sterilization.

Key Words: Controlled memory alloy, endodontics, HyFlex® controlled memory, nickel titanium alloy

Introduction

A major innovation in endodontics has been the introduction of nickel-titanium (NiTi) alloy to manufacture root canal

instruments, mainly due to the superelasticity of the NiTi alloy, which provides increased flexibility and allows the instruments to effectively follow the original path of the root canal.¹⁻⁵ Thermal treatment of the alloy is known to produce a better arrangement of the crystal structure, thereby leading to improved flexibility (superelastic behavior) as well as changes in the phase percentages (different grain structure) of the alloy, leading to improved resistance or plastic behavior. Proprietary processes are highly influenced by temperature and time intervals, and each small change makes every manufacturing process unique.²

HyFlex® CM rotary instruments (Coltene-Whaledent, Allstetten, Switzerland) are made from a new type of NiTi wire, namely CM wire that has been subjected to proprietary thermomechanical processing. It is manufactured by a unique process that controls the material's memory, making the files extremely flexible but unlike conventional files, which exhibit a stress-induced phase transformation.^{6,7}

Micro-computed tomography (μ CT) has been shown to be accurate for experimental endodontology and allows nondestructive quantitative analyses of different variables such as volume, surface area, cross-sectional shape, taper, and the proportion of the prepared surface.⁸⁻¹⁰

The manufacturer reports that the shape and strength of files with straightened spirals can be restored during autoclaving,¹¹ meaning that the files appear to regain their shape after sterilization and reuse. The purpose of this study was to analyze the surface defects of HyFlex® instruments after use and to use μ CT to determine their ability to return to their original shape after autoclaving.¹¹

Materials and Methods

Twenty-four new HyFlex® files with different size and taper (0.8/25, 0.4/20, 0.4/25, 0.6/20, 0.4/30, 0.4/40) were scanned before use, after use, and after autoclaving. Before the initial scans were performed, a customized jig was fabricated, and each file was mounted such that it could be placed in the same position before and after use. The new files were scanned (Figure 1) using a μ CT scanner (1172 scanner; SKYSCAN, Kontich, Belgium) at 100 kV and 100 μ A, with a resolution of 57 μ m and using an AL + 0.5 mm thick aluminum filter and 54% beam-hardening reduction. The acquired images were reconstructed using NRecon® software (SKYSCAN, Kontich, Belgium), producing two-dimensional cross-sectional slices of the file structure.

Access cavities were prepared on 12 plastic teeth using #2 and #4 high-speed round carbide burs (Dentsply-Maillefer, Ballaigues, Switzerland). The working length was determined for each of the 24 canals, and a new HyFlex® file was used for each canal preparation (Dentsply-Maillefer, Ballaigues, Switzerland), using a handpiece at 500 rpm with a torque of 2.5 N/cm. Irrigation with distilled water was performed frequently when using the files. Each file was used until visible defects were observed. The files were scanned (Figure 2) after deformation using the same protocol as described above, μ CT analyzer software (SKYSCAN, Kontich, Belgium) was used to obtain all variables. Surface analysis was performed for each file to determine the changes in the files after deformation; defects were recorded as unwinding and curving associated with unwinding (Figure 2). These changes were categorized according to the severity as follows:

Severe: More than 2 flutes showed unwinding, with or without curving

Moderate: Only 2 flutes showed unwinding, no curving

Minor: Only one flute showed unwinding, no curving.

Used files were wiped and placed in file blocks, to avoid any contact between instruments. All file blocks were placed in a sterilization wrap and steam sterilized at 134°C/273°F for 6 min and 18 min for inactivation.

All files were scanned (Figure 3) again using the same protocol as described above, and the initial and final scans of the files were superimposed using NRecon software (SKYSCAN,



Figure 1: File scanned image before the initial use.



Figure 2: File scanned image after use showed visible defects, combined defects (unwinding and curving).

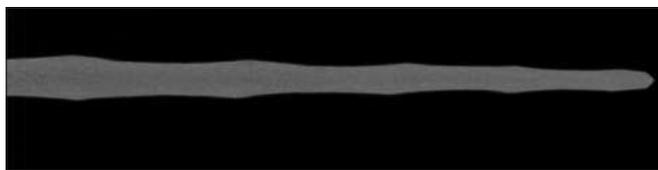


Figure 3: File scanned image after autoclaving (restored the original shape).

Kontich, Belgium) to, illustrate the recovery of the files to their original shape.

The defects for each file after use and after autoclaving were recorded. Data were analyzed by using chi-square and student test, where appropriate, in software (SPSS for windows 8; SPSS, Chicago, IL, USA).

Results

The *t*-test of Student's Newman-Keuls revealed a significant difference ($P < 0.05$) between unused and used files. Almost all of the used files exhibited significant visible defects without fractures, including unwinding and curving associated with unwinding. The most frequently observed defect was unwinding of the spirals (100%), whereas curving associated with unwinding was infrequent and combined with unwinding, it was observed with 20% of the samples (Figure 2). A Chi-square test showed that the deformation (curve: $P = 0.000$ and unwinding: $P = 0.011$), incidence depended on the size of the files. The greatest frequency of curving occurred in the small files #20/0.04 and #20/0.06; the difference was statistically significant from all file sizes ($P < 0.05$). Only 4 files showed slight defects at the tips of the files. The majority of the files (79%) were able to restore the unwinding and regain their original shape after autoclaving (Figure 3). Among these, the files with minimum to moderate changes could be restored, whereas the files with severe changes (25%) could not be restored. The highest rate of unrestored files was observed in the small files #20/0.04 and #20/0.06 instruments, and the difference was statistically significant from all file sizes ($P < 0.05$). All files that exhibited changes at the tip were able to be restored after autoclaving.

Discussion

At the beginning of 2000, a series of studies¹²⁻¹⁵ found that changes in the transformation behavior via heat treatment were effective in increasing the flexibility of NiTi endodontic instruments. Since then, heat-induced or heat-altering manipulations were used to influence or alter the properties of NiTi endodontic instruments.

A series of proprietary thermomechanical processing procedures has been developed with the objective of producing SE NiTi wire blanks that contain substantially stable martensite phase under clinical conditions.¹⁶ Enhancements in these areas of material management have led to the development of the next generation of endodontic instruments. CM wire (DS Dental, Johnson City, TN) is a novel NiTi alloy with flexible properties that was introduced in 2010. CM NiTi files have been manufactured using a special thermomechanical process that controls the memory of the material, making the files extremely flexible but without the shape memory of other NiTi. CM NiTi files are unlike conventional files that exhibit a stress-induced phase transformation; instead, these files show

behavior that is similar to what is termed martensitic-active or shape memory, which produces remarkable fatigue resistance.¹⁶

It was observed that most of the files showed defects that appeared as lengthening of the spirals due to the unwinding without fractures. This occurrence was explained by the manufacturer: These files respond to pressure, torque, and resistance with a lengthening of the spirals, and, therefore, increases the fracture resistance. This could be explained by the fact that instruments made from CM were nearly 300-800% more resistant to fatigue failure than instruments made from conventional NiTi wire with the same design.^{4,17} A majority (79%) of the files were able to be restored after sterilization, which supports the company's claim that a characteristic of HyFlex® is its ability to return back to the original shape after autoclaving. This is consistent with the view that NiTi files do not present the rebound effect after unloading, and their original shape is restored only after autoclaving.¹⁸ This phenomenon was explained in a previous study, which showed that instrument in the stable martensite phase is known for exhibiting the shape memory effect, where it can easily be deformed, yet they have the capacity to recover its shape with heating above the transformation temperature. The explanation for this phenomenon may be that heating transforms the metal temporarily into the austenitic phase, which makes it possible for the file to regain its original shape before cooling down again.^{4,17} Although the exact thermomechanical treatment of CM wires remains unknown, the mechanical deformation behavior is closely related to the phase transformation temperature, which is sensitive to the material's thermomechanical history.¹⁹

Most of the unrestored files were the small files size (20/0.04 or 20/0.06), this trend of the inability of small files to recover corroborated the findings of other studies, which showed a trend toward a high incidence of distortion and separation in small NiTi instruments.²⁰⁻²³ An analysis of used HyFlex® instruments indicated that most of the files showed visible plastic deformation such as unwinding and curving. However, the majority of these files could be restored after autoclaving. In addition, a recent study by Capar *et al.*²⁴ revealed that the HyFlex® files had the highest fatigue resistance compared to ProTaper Next and Revo-S. Furthermore, many studies showed the new CM-wire manufacturing process to produce NiTi rotary instruments that were more flexible and more resistant to cyclic fatigue than instruments produced by a traditional manufacturing process or a thermally treated NiTi alloy (M-wire).^{4,16-18}

Therefore, with the limitations of this study, it can be concluded that the shape of files with unwound spirals can be restored during autoclaving. This finding means that HyFlex® CM NiTi files appear to regain their shape after sterilization and reuse. However, the finding of this study suggest that HyFlex® size 20

files should be considered as single-use, disposable instruments because of the likelihood of being distorted.

Conclusion

HyFlex® CM NiTi files appear to regain their shape after sterilization and can be reused, however, further studies are needed to determine the properties of these restored files.

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