

## Hyflex EDM: innovative electro discharge machined rotary instruments. Fatigue testing, superficial and microstructural characterization



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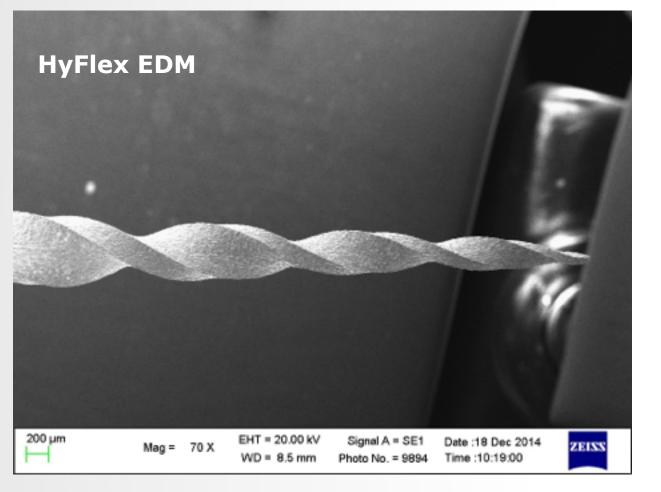
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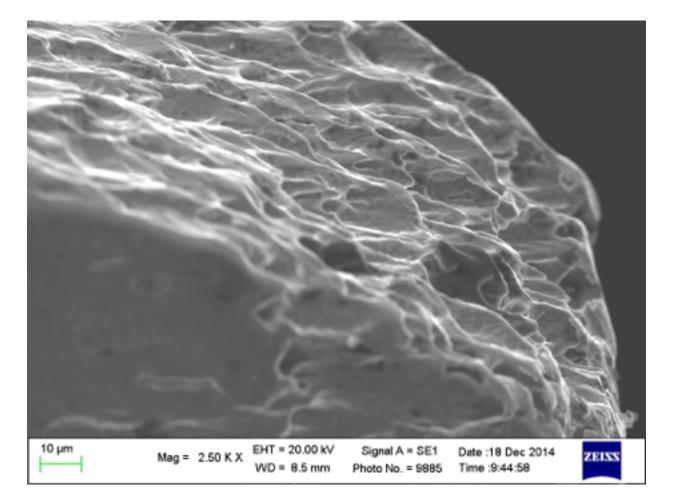
**Aim** A patented fabrication process was recently introduced in the manufacturing of new files obtained by CM NiTi wire. HyFlex EDM (Coltene/Whaledent, Switzerland) instruments are produced via electro discharge machining. Aim of this study was to test the fatigue resistance and to evaluate the surface and microstructural alterations of new and *in vitro* used HyFlex EDM NiTi rotary prototypes.

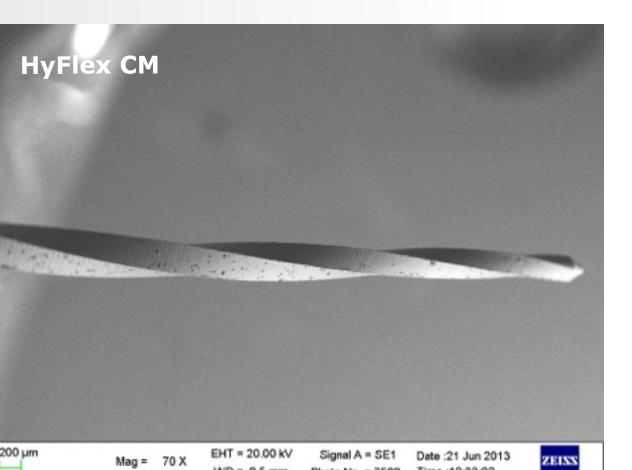
**Methodology** Thirty electro discharge machined HyFlex EDM (Coltène/Whaledent, Switzerland) prototypes, and 20 HyFlex CM (Coltène/Whaledent, Switzerland) files were subjected to cyclic fatigue test in a standardized 70° artificial metal canal. Results were validated using Mann-Whitney tests (a-level 0.05). Fractographic analysis on broken samples was conducted using environmental scanning electron microscopy (ESEM) imaging. Fifteen new HyFlex EDM prototypes were used for *in vitro* instrumentation of severely curved root canals of extracted multi-rooted teeth (curvatures ranging between 50° and 70°). Each HyFlex EDM file was used in 10 curved canals with a 16:1 reduction handpiece X-Smart (Dentsply Maillefer, Baillagues, Switzerland) following the manufacture's direction, at 500 rpm and 2.5Ncm, with slightly apical pressure and pecking motion. The operative sequence was: 25/12 at 2/3 of the WL, 10/05 and 25/08 at WL.

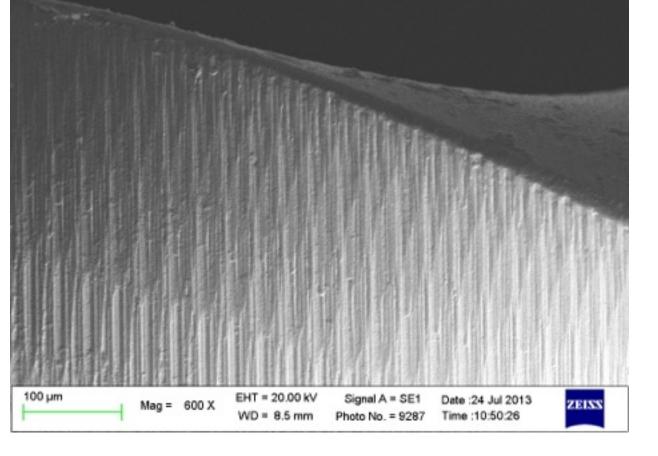


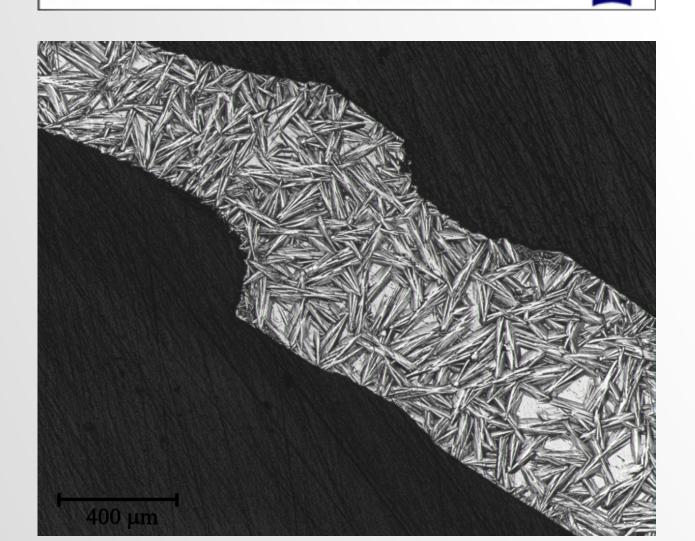
Surface and microstructural characteristics of files were analyzed by ESEM equipped with energy dispersive x-ray spectrophotometry (EDS) and optical metallographic imaging. The same analysis was conducted on new and used instruments to assess the usage-induced degradation. Pre- and post-operative micrographs were examined in order to verify the appearance of fractures, unwinding, microcracks, blade disruption and tip deformation.

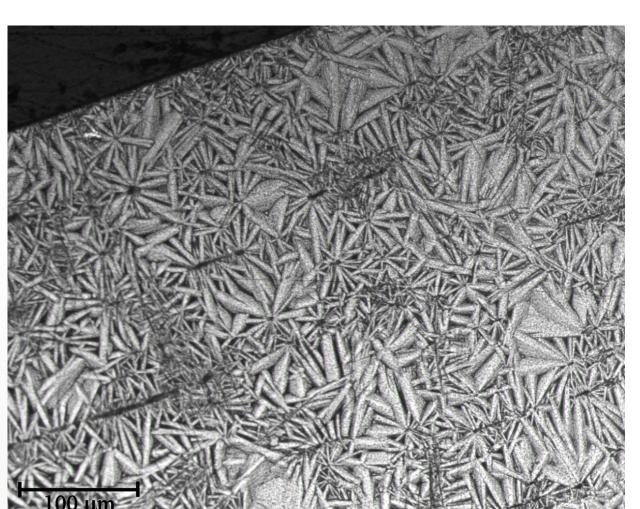












**Results** The cyclic fatigue test revealed a superior fatigue resistance of the EDM files when compared to CM (p= 0.0001). When 40.04 EDM was compared with 40.04 CM, an increase of about 683% was observed (p= 0.0001). When 25.08 EDM and 25.04 CM were compared an increase of 41% was observed (p>0.05). Fractographic analysis of fatigued EDM instruments disclosed multiple crack origins in correspondence of the cutting edges, with a limited fatigue striations zone and a noteworthy dimpled area.

Instruments	25.04 CM	25.08 EDM	40.04 CM	40.04 EDM	50.03 CM
Fatigue life (NCF)	696 ± 271 <sup>a</sup>	981 ± 329 <sup>a</sup>	$257 \pm 100^{\text{b}}$	2013 ± 425°,A	1682 ± 241 d,A

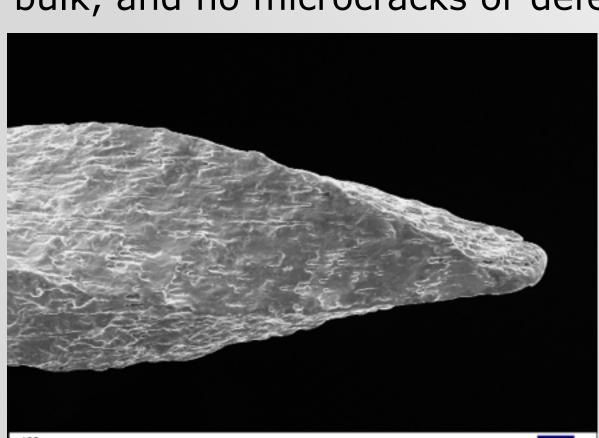
Table 1. Mean fatigue life ( $\pm$ SD) expressed as numbers of cycle to failure (NCF), for HyFlex EDM and CM of various sizes rotating in a 70° curvature with 5-mm radius (n = 10). Different superscript letters indicate significant differences.

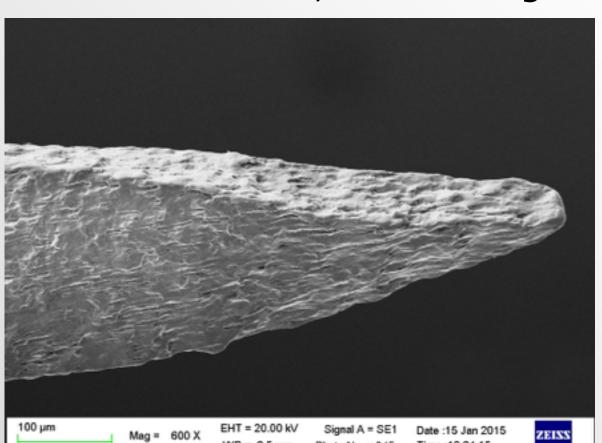
HyFlex EDM	Fractures	Unwinding	Microcracks	Tip deformation	Blade disruption
25.12 (n=5)	0	0	0	0	0
10.05 (n=5)	0	1	2	1	0
25.08 (n=5)	0	0	0	0	0

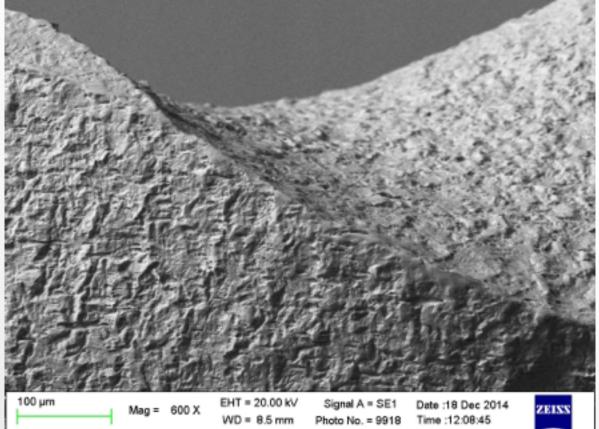
Table 2. Incidence of wear and superficial defects after 10 canals instrumentation.

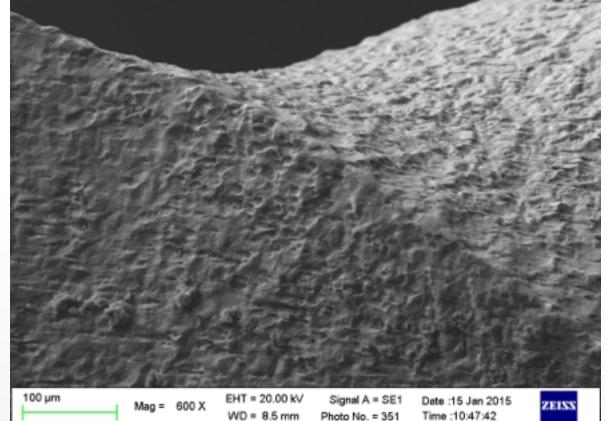
Representative optical metallographic micrographs at different magnifications of a new HyFlex EDM.

Surface and microstructural characterization of new instruments revealed the typical features of a NiTi ED-Machined alloy with a "craters-like" surface (Fig. 1a.b). No fractures were registered during instrumentation of curved canals. Surface and microstructural characterization of used files revealed no wear and no degradation of the 25.12 and 25.08 files. The tip segment was confirmed as the most mechanically stressed portion of 10.05 files. The metallographic inspection on the cross section of brand new HyFlex EDM files showed an homogeneous martensitic phase. The microstructure appeared uniform from the surface to the bulk, and no microcracks or defect were identified, even at high optical magnification (1000X).









Comparison of the same HyFlex EDM file (tip and 5 mm from the tip) before and after 10 uses. The outline was not altered. No deformations, blade disruptions or microcracks were identified. Tiny traces of debris were observed on the surface of the used file.

**Conclusions** Instruments exhibited surprising high values of cyclic fatigue resistance and a safe *in vitro* use in presence of severely curved canals. Unaltered spark-machined surface and low microstructural degradation are the main features of HyFlex EDM.

## References

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