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Wear analysis and cyclic fatigue resistance of electro discharge machined NiTi rotary instruments

HyFlex EDM: caratteristiche superficiali e resistenza alla fatica ciclica di innovativi strumenti rotanti NiTi prodotti per elettroerosione

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CM-wire;
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SEM analysis;
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Abstract
Aim: To evaluate the wear of new rotary instruments produced via electro discharge machining and to test their fatigue resistance.
Methodology: Twenty-one HyFlex EDM (Coltène/Whaledent, Switzerland) files were used for laboratory instrumentation of curved root canals of extracted teeth. Superficial characteristics were analyzed pre- and postoperatively by scanning electron microscopy (SEM) (JSM-5200, JEOL, Tokyo, Japan) at same points and with same angulations to identify the wear features. Number of fractures, microcracks blunt/disruption of cutting edge and tip deformations were reported.

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Twenty HyFlex EDM and 20 HyFlex CM (Coltène/Whaledent, Switzerland) were subjected to cyclic fatigue test in a 70° artificial metal canal. Results were statistically analyzed using Mann–Whitney tests.
Results: No fractures were registered during laboratory canal instrumentation. No wear and no degradation of the 25.12 and 25.08 files were reported. Slight plastic deformations were only observed in three 10.05 files. The cyclic fatigue test revealed a significant increase of fatigue resistance of EDM files compared to CM ($p = 0.0001$).
Conclusions: The typical irregular surface of HyFlex EDM remained unaffected after multiple uses, confirming a high wear resistance. The new manufacturing process of electrical discharge machining had a substantial impact on fatigue lifetime of EDM files when compared with HyFlex CM. Within limitations of the present *in vitro* results, EDM files appeared suitable in shaping severely curved canals.

PAROLE CHIAVE
Strumenti endodontici;
Nichel Titanio;
Elettroerosione;
Analisi superficiale;
Fatica ciclica.

Riassunto
Obiettivo: Esaminare la morfologia superficiale e l'usura di strumenti HyFlex EDM usati *in vitro* e testare la loro resistenza in fatica ciclica.
Materiali e Metodi: Ventuno strumenti HyFlex EDM sono stati utilizzati per la strumentazione *in vitro* di canali curvi. La morfologia di superficie e i fenomeni di usura sono stati investigati pre e post operativamente con un Microscopio Elettronico a Scansione (SEM) (JSM-5200, JEOL, Tokyo, Japan). Ulteriori 20 HyFlex EDM sono stati poi testati in fatica ciclica in un canale artificiale con angolo di curvatura di 70° e comparati con strumenti HyFlex CM. I dati ottenuti sono stati validati con il test di Mann-Whitney.
Risultati: Le indagini al SEM hanno rivelato una specifica struttura irregolare caratterizzata da una superficie con morfologia a "cratere" legata alla capacità erosiva generata dalle scariche elettriche del processo produttivo. Tutti gli strumenti, dopo diversi utilizzi, hanno preservato il loro peculiare aspetto crateriforme e non hanno mostrato appiattimento dell'angolo di taglio delle lame. Non si è verificata nessuna frattura. I test di fatica ciclica hanno evidenziato una resistenza statisticamente significativa degli HyFlex EDM rispetto agli HyFlex CM ($p = 0.0001$).
Conclusioni: Gli HyFlex EDM hanno dimostrato un affidabile comportamento *in vitro* quando sottoposti a strumentazione di canali molto curvi. La superficie crateriforme si è ben conservata dopo ripetuti utilizzi. Gli strumenti di diametro minore sono apparsi quelli maggiormente stressati. La resistenza in fatica ciclica di strumenti della stessa lega sembra essere notevolmente aumentata dal differente processo di produzione.

Introduction

Introduction of nickel titanium (NiTi) rotary instruments has favored endodontic procedures by minimizing procedural errors associated with hand instrumentation and reducing time for chemo-mechanical preparation.[1,2] Despite many advantages of the NiTi instruments, unexpected intracanal separation due to torsion or flexural fatigue of the instruments is still a major concern.[3,4] In recent years, several novel thermo-mechanical processing and manufacturing technologies have been developed to optimize the microstructure of NiTi alloys.[5] In 2010, CM (controlled memory) NiTi files have been introduced using a special thermo-mechanical process of the alloy that controls the memory of the material, making the files extremely flexible but without the shape memory of other NiTi files, as opposed to what is found with conventional NiTi instruments. This imparts to the HyFlex CM (Coltene/Whaledent, Switzerland) a high fatigue resistance[6,7] and the possibility to be easily bended during use, recovering its original shape heating above the transformation temperature.[8] Recently a patented fabrication process was introduced in the manufacturing of new files obtained by the same CM wire. In fact, HyFlex EDM (Coltene/Whaledent, Switzerland) instruments are manufactured via electro discharge machining (EDM) process. In the EDM process an electric spark is used to cut the workpiece, which takes the shape opposite to that of the cutting tool or electrode. The electrode and the workpiece are both submerged in a dielectric fluid, which is generally light lubricating oil.[9] The electrical sparks causes a local melting and partially evaporation of small portion of material that is removed from this local area living a typical crater-like surface finishing.[10] Despite EDM is a common fabrication process for miniaturized components in medical technology,[11–13] HyFlex EDM files are the first endodontic instruments manufactured with this process.

The aim of this study was to evaluate the wear of new rotary instruments produced via electro discharge machining and to test their fatigue resistance in comparison with the conventionally manufactured HyFlex CM.