obtr8
ADVANCING ENDODONTIC EDUCATION

WE'VE BEEN LOOKING AT CYCLIC FATIGUE RESISTANCE ALL WRONG

A broader perspective on endodontic file functionality

David Landwehr, D.D.S., M.S.

David Landwehr, D.D.S., M.S.

In the endodontic literature, significant attention has been devoted to and much has been written about cyclic fatigue — undoubtedly because it has been reported to be the leading cause of file separation.[1] The sheer volume of rhetoric from file manufacturers seems to single out fatigue resistance as the strongest marker of a file's performance.

But is there more to the story of endodontic file functionality?

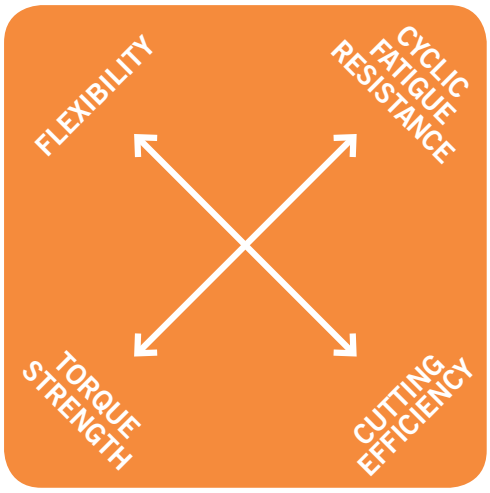
From my perspective, shaped by saving thousands of teeth over 18 years as a clinical endodontist, it is imperative that we look beyond the halo effect created by industry claims about cyclic fatigue. The reasons are clear. To date, no standard model exists for measuring cyclic fatigue resistance in a clinically relevant setting. Different testing modalities created to quantify cyclic fatigue resistance in the laboratory yield varying results. In fact, slightly tweaking the measurement of fatigue resistance with the exact same instrument can drastically change the numbers. As a result, the laboratory numbers reported about cyclic fatigue resistance may have very little correlation to the safety or performance of a file in the root canal system.

Moreover, in actual clinical use — the one place where file performance truly matters — fatigue resistance cannot be divorced from other related file traits as a sole measure of performance. If an instrument lacks torque strength and unwinds, but it is highly resistant to cyclic fatigue, its cutting efficiency and ability to clean the canal in three dimensions will potentially diminish. To put it more plainly, a fatigue resistant but unwound file that lacks cutting efficiency will require more time to achieve the ideal root canal shape and would have no added benefit to my clinical practice. Given these disconnects, a broader approach to file evaluation is recommended.

THE FOUR INTERRELATED TRAITS OF AN IDEAL FILE

As a clinician, my ideal file would not be one thing, but four. It would exhibit:

- *cyclic fatigue resistance,*
- *torque strength,*
- *flexibility,*
- *and cutting efficiency.*



The four interrelated characteristics of the ideal file.

Imagine using these four points to create a square, with fatigue resistance and torque strength diagonally at opposite corners, and flexibility and cutting efficiency at the other diagonal corners, to represent their give-and-take relationships. The ideal file would cover the entire square.

The problem? That ideal file does not exist.

Historically, advancements in torque strength were made at the sacrifice of fatigue resistance. Likewise, if a file was made extremely flexible it likely lost cutting efficiency. However, with the development of new and improved Nickel Titanium (NiTi)

alloys, these relationships are not as closely linked as they once were. Industry leaders have come closer to hitting all four marks, but several manufacturers would want the clinician to believe that cyclic fatigue resistance is the only measure of significance.

THE PHYSICS OF NITI AND THE INFLUENCE ON CLINICAL OUTCOMES

NiTi files have both superelasticity and shape memory and these physical properties influence how an endodontic file performs. First generation rotary NiTi files were manufactured exclusively in the more brittle austenite phase. However, when stressed during the shaping of a canal there is a non-proportional strain referred to as the martensitic transformation. In the martensitic phase, NiTi files exhibit more flexibility and fatigue resistance. This austenite to martensite transformation is referred to as superelasticity.

Shape memory is the ability of a NiTi file to be deformed in the martensitic phase, but heating above a transformation temperature will allow the instrument to recover its original shape. By this engineering definition, this physical property of NiTi files has very little to do with performance. However, a more clinically relevant definition of shape memory relates to the file's desire to remain in the more stable austenitic form. In essence, a straight file wants to remain straight. The larger and stiffer the file, the more it desires to remain straight and the less likely it will be able to follow the subtleties of a curved root canal system.

With the evolution of heat-treated metals such as those in Dentsply Sirona's WaveOne Gold, Vortex Blue, or ProTaper Gold there can be a simultaneous increase in flexibility and fatigue resistance with very little or no loss in torque strength or cutting efficiency.[2] The engineering and manufacturing process of these files results in stable martensitic nanostructure with little or no shape memory. This allows these files to efficiently shape the root canal system in three dimensions, with very little or no risk of file separation.

UNWINDING THE MYTH: CYCLIC FATIGUE, TORQUE OR BOTH

Compression and elongation cycles lead to undetectable microcracks in the file and ultimately to cyclic fatigue failure. Like a paper clip, after enough bends breakage will occur. Torque failure occurs when the file tip becomes locked in the canal and continues to rotate. As stated previously, there is no standard by which cyclic fatigue is evaluated. This results in significant confusion for clinicians, because multiple file systems make claims of superiority. There is a standard to measure torque strength, but this may not matter if we only evaluate each of these performance indicators as a stand-alone feature of file engineering. For example, if a NiTi instrument has been torqued and is close to failure, it is more likely to break because of fatigue issues as well.[3] Several studies show this, and it's been looked at from both sides. Meaning, the converse is also true: instruments that have been fatigued are more susceptible to torque failure.[4]

An "unwind" may be the first step in the failure of an endodontic file, but just as important as what happens when a file unwinds is what doesn't happen. Manufacturers can engineer extremely cyclic fatigue-resistant files that unwind and have very limited cutting efficiency. The file doesn't break, but it doesn't have the ability to cut dentin either. In this scenario, there is added chair time and additional cost for every deformed file that needs to be switched out for a new one.

FILE INTEGRITY AND 3D ENDODONTICS

The goal in cleaning and shaping the root canal is to contact as much of the canal wall as possible to facilitate the removal of a polymicrobial biofilm while preserving the natural three dimensional anatomy from orifice to apex. This enables the safe delivery of irrigants deep within the root canal system and ultimately allows a three dimensional seal.

Unwinding impacts a file's ability to contact and clean the maximum amount of canal wall surface area. Moreover, deformed or flat spots in the file's flutes simply can't remove biofilm as efficiently and potentially leave bacteria in the root canal or push debris through the apex.

Reduced file performance and efficiency can take a toll on the patient experience. For these reasons, the overstated importance of fatigue resistance should not overshadow other aspects of file design important to astute clinicians.

OVERLOOKED FACTORS IN PREVENTING FILE SEPARATION

The instrumentation protocol I follow is designed to be simple yet efficient. The number of files and the design used is determined by the anatomical complexity of the roots and the length and shape of the canals to be treated. Fortunately, I have multiple file systems to choose from and can match both the

movement and the taper of the instrument to the desired shape necessary to clean the root canal system. All of this is designed to avoid the one outcome that is completely unacceptable to me: file separation. In addition to fatigue resistance and torque strength in my instruments, I recommend three usage tips to eliminate file separations.

1. *The power of a great glide path: With the orifice open and a reproducible glide path, final shaping instruments have to do less than they are designed to do. This enhances clinical efficiency because the files will be in the canals for less time, limiting the likelihood of crack initiation in the instrument.*

2. *The appropriate file, used once: By using a file one time, the file will cut efficiently and have the same feel each and every time. Single patient use also limits both the accumulated cyclic fatigue and torque loads placed on the file which has resulted in the virtual elimination of file separation from my clinical practice.*

3. *Consistent quality for predictability: I pay close attention to the uniform length and appearance of my files and choose a source whose internal testing data and performance claims are consistently validated by independent, peer-reviewed research.*

The key to safely and efficiently instrumenting the root canal system is to get away from looking at one parameter, cyclic fatigue resistance, while viewing file functionality as a whole. Doing this, while asking the file to perform as designed, will enhance the clinician's experience by making endodontic treatment more efficient and enjoyable while also enhancing the patient's experience with a better and safer outcome.

[1] *Plotino G, Grande NM, Cordaro M, Testarelli L, Gambarini G. A review of cyclic fatigue testing of nickel–titanium rotary instruments. J Endod 2009: 35: 1469–1476.*

[2] *Gao Y, Gutmann JL, Wilkinson K, Maxwell R, Ammon D. Evaluation of the Impact of Raw Materials on the Fatigue and Mechanical Properties of ProFile Vortex Rotary Instruments. J Endod 2012: 38: 398-401.*

[3] *Galvão Barbosa FO, Ponciano Gomes JA, Pimenta de Araújo MC. Influence of previous angular deformation on flexural fatigue resistance of K3 nickel–titanium rotary instruments. J Endod 2007: 33: 1477–1480.*

[4] *Ullmann CJ, Peters OA. Effect of cyclic fatigue on static fracture loads in ProTaper nickel–titanium rotary instruments. J Endod 2005: 31: 183–186.*

David Landwehr, D.D.S., M.S.

As a leading practitioner and educator, David Landwehr, D.D.S., M.S. serves as a frequent lecturer for a variety of organizations at dozens of events each year focusing on Endodontics and Oral Pathology.

A Wisconsin native, Dr. Landwehr studied as an undergraduate at the University of Wisconsin-Madison and went on to earn his D.D.S. at the University of Minnesota in 1994. From there, he earned an M.S. degree and certificate in Oral and Maxillofacial Pathology at The Ohio State University followed by specialty training in Endodontics at the University of Michigan.

Since returning to Wisconsin in 1999, Dr. Landwehr has provided exemplary care to patients and currently maintains a full-time private practice at Capital Endodontics in Madison. He has presented case studies both nationally and internationally, published research findings in peer-reviewed journals and served as an evidence reviewer for the American Dental Association.