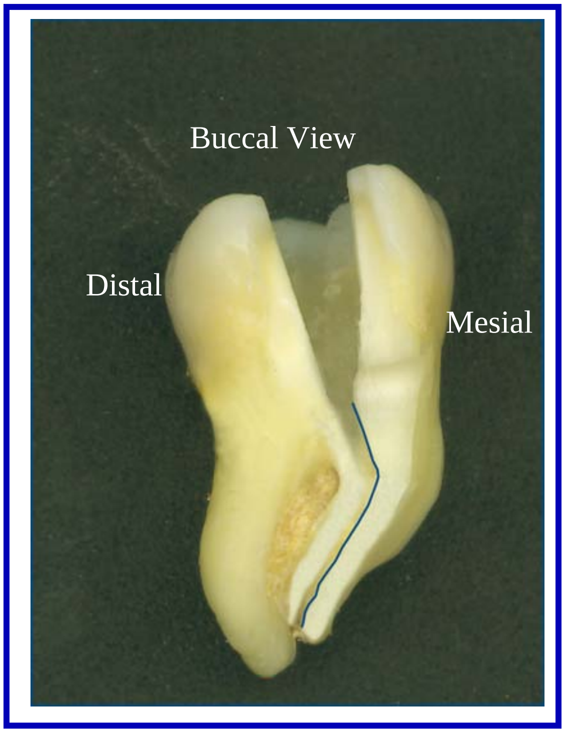
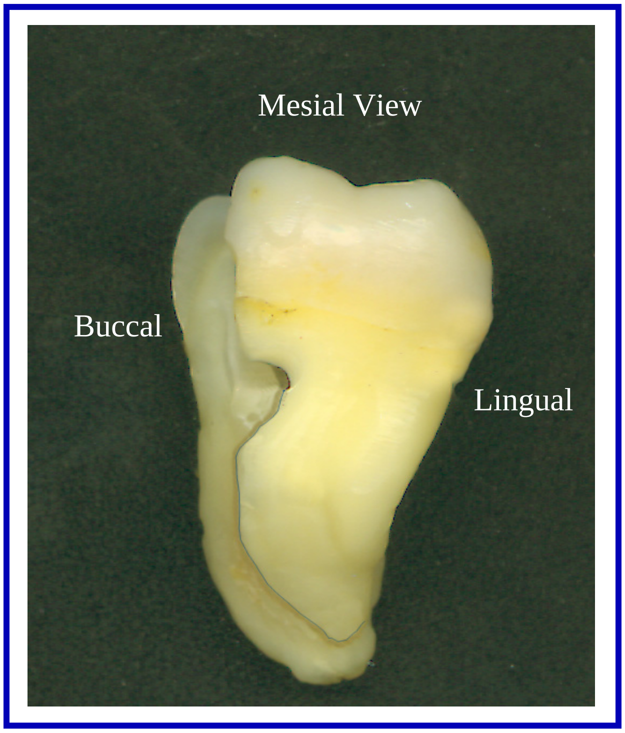
26. How important is file flexibility?

Successful endodontic treatment requires considerable knowledge of root canal anatomy and instrument limitations. The current literature is replete in illustrating that the root canal system is rarely composed of straight cylindrical canals but rather is comprised of frequent curvatures and aberrations. The phenomenal benefits, particularly the flexibility, of rotary nickel titanium files for negotiating difficult anatomies while enhancing the quality of canal enlargement and debridement can prove invaluable and outweigh most risks encountered during canal preparation.

The rotation of flexible instruments around curvatures can certainly facilitate one's ability to accomplish 360-degree canal enlargement while maintaining the central axis of the canal and preserving more tooth structure. Although canal curvatures in the mesial-distal plane may be apparent on x-ray examination, the severity of curvatures, due to angulations and location in the facial-lingual plane, may not be so apparent. In this case, flexibility can often be a benefit without our awareness of it.





Tooth structure has been removed to expose and outline the pathway of the canals. Note that the buccal view gives no indication of the buccal-lingual curvature and especially its abrupt curvature at the apex.

On the other hand, most dentists resort to stainless steel files when using the smallest sizes for establishing the working length and the patency of the apical foramen. Having the flexibility needed but lacking the toughness of nickel titanium, these smaller sizes of stainless steel files are used manually and have the advantage of being more easily pre-bent without excessive stress in order to negotiate curvatures. Bending a nickel titanium file can be accomplished; however, the property of shape memory causes the file to return to its original shape unless unusual force is used. Although shape memory provides the advantage of usually having a straight file after being used, this property offers no advantage in the canal unless one is attempting to straighten the canal.

One must keep in mind that continuous rotation of even flexible instruments can eventually lead to cyclic fatigue failure. The rotation of larger diameter instruments that lack adequate flexibility may often be the cause of treatment complications due to canal transportation or instrument breakage when other factors receive the blame. The frequency of curvatures in each plane of tooth anatomies dictates that we assume their presence. Understanding the limitations of flexibility or the lack of it and the complexities of anatomies is essential for maximizing the benefits of rotary instrumentation.

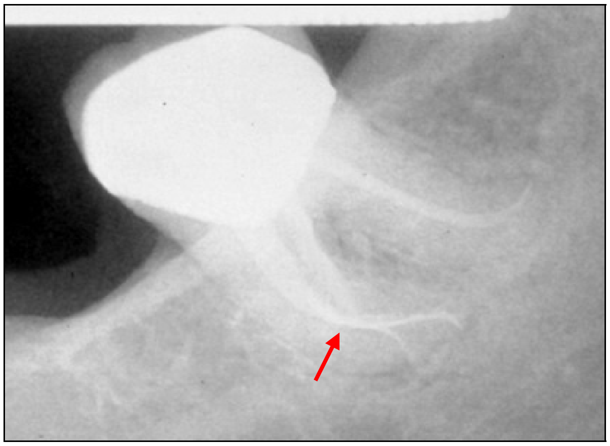
27. *What is fatigue?*

File fatigue is the result of any repetitive stress that occurs, predominantly during flexion while rotating around a canal curvature and is closely related to the inverse of the square of the file's diameter. A file can withstand more stress during a single rotation around a curvature than it can after numerous rotations. Metal fatigue usually begins at minute defects on the surface or at stress concentration points in the design that result in the formation of stress cracks. Since substantially less stress may be required to propagate a crack than is required for its formation, a fatigue failure is particularly insidious and can occur without any obvious warning. Any prediction of fatigue failure is complicated by stresses that result from geometrical discontinuities, porosities, inclusions and overheating that occurred during manufacturing.

Knowledge of the relationships of file sizes and canal anatomy is especially important when dealing with the combined stresses of torque and fatigue. Computerized handpieces are being developed to address the problems of fatigue as well as torque but the judgments for determining appropriate technique should always be the role of the dentist and mechanical technology should not be an excuse for a lack of understanding.

28. What causes fatigue?

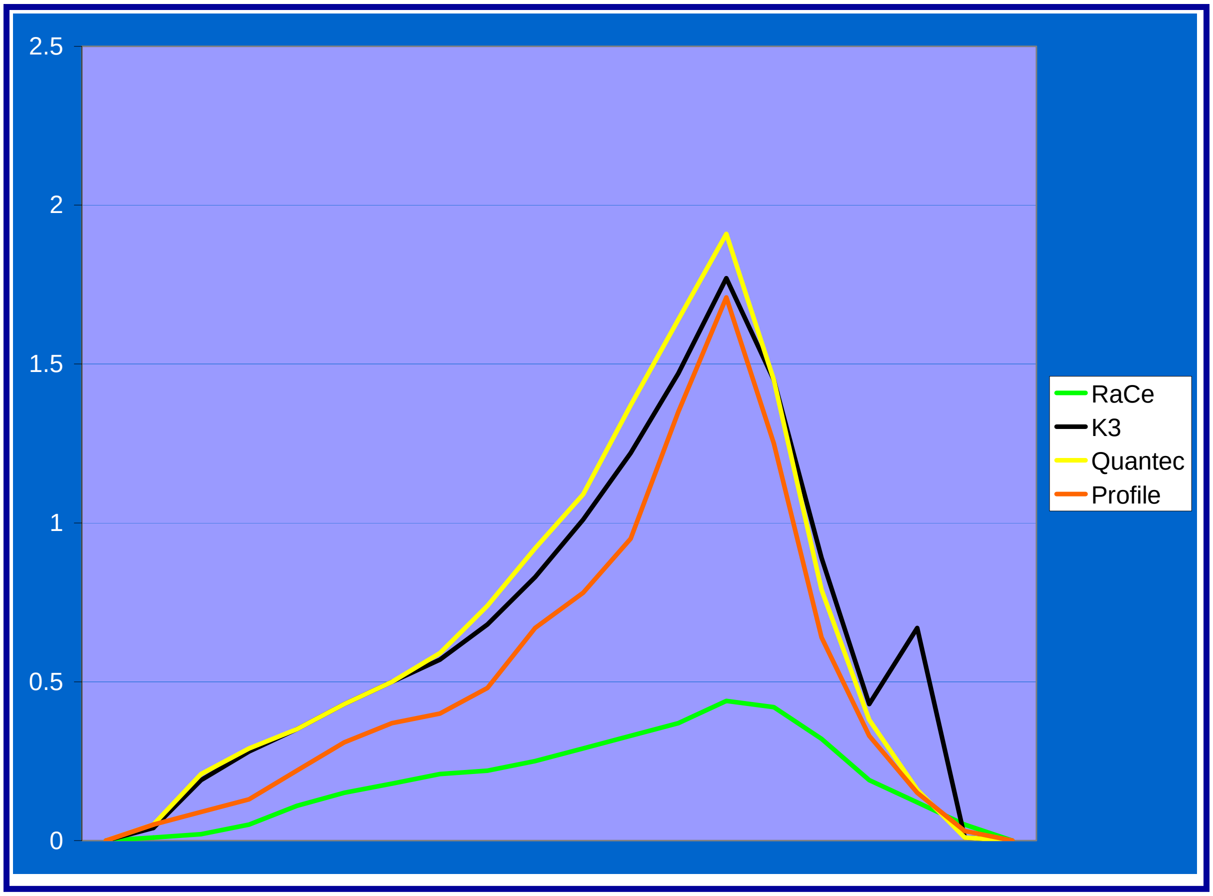
On the inside of the curvature of a canal a rotating file is compressed. On the outside of the curvature the file undergoes tension. During continuous rotation around a curvature each surface of the file undergoes compression and tension until faults in the file propagate and the file fatigues. Generally, the greater the distance between the stress of tension and the stress of compression the greater the total stress on the instrument is. The smaller the diameter that a file has, the longer it can rotate around a curvature without fatigue failure. The file's resistance to fatigue has a close inverse relationship with the square of the diameter. Therefore, a size .20 mm diameter resists fatigue approximately 50% more than a size .25 mm diameter even though the difference in the diameters is only .05 mm. As the diameter of a tapered file increases as it progresses through a curvature, the stress on the file eventually reaches the point of potential failure and the use of the file should be terminated in favor of a smaller diameter or smaller tapered file. The dentist must consider the number of rotations, the file diameter, the file design and the degree of curvature in order to determine how to avoid fatigue.

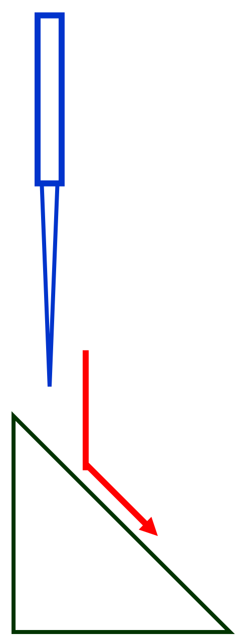


Dr. William Watson

Larger tapered files commonly used in minor mid-root or coronal curvatures have diameters that can cause severe compression and tension stresses that can lead to fatigue failure. The file diameter at the point of curvature and the number of file rotations are important considerations during canal instrumentation.

The pressure at the more flexible tip end of a file will result in substantially more bending than at the more rigid larger diameter handle end. As a file progresses into a curved canal, the diameter that transverses curvatures increases and the file's resistance to fatigue failure decreases. *Therefore, the length of a file that extends beyond a curvature becomes a very important consideration and one that is ignored in many recommended instrumentation techniques.*

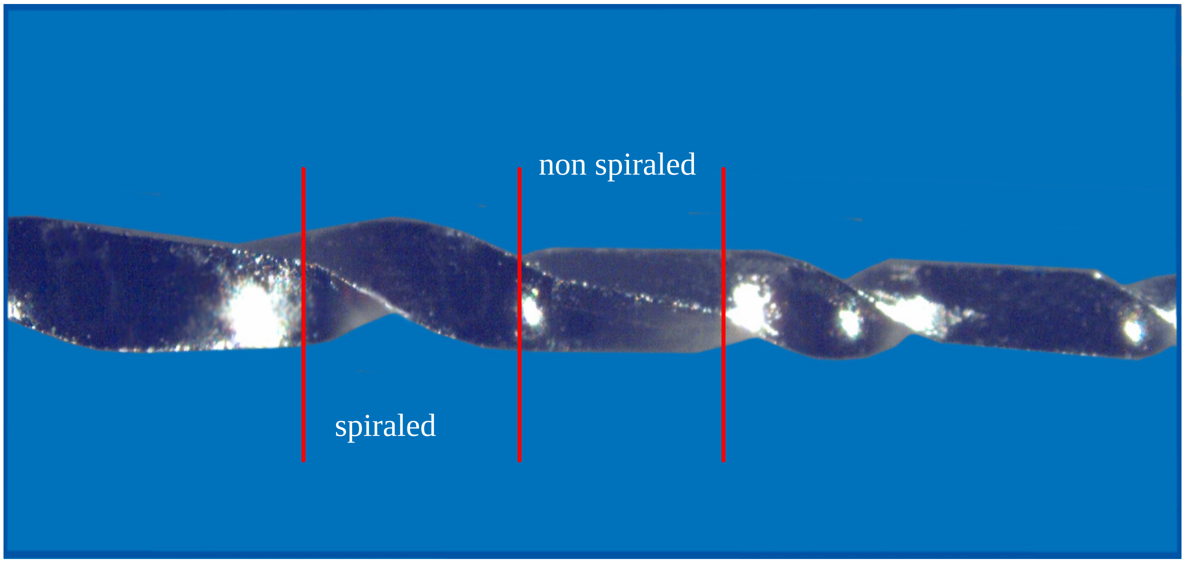




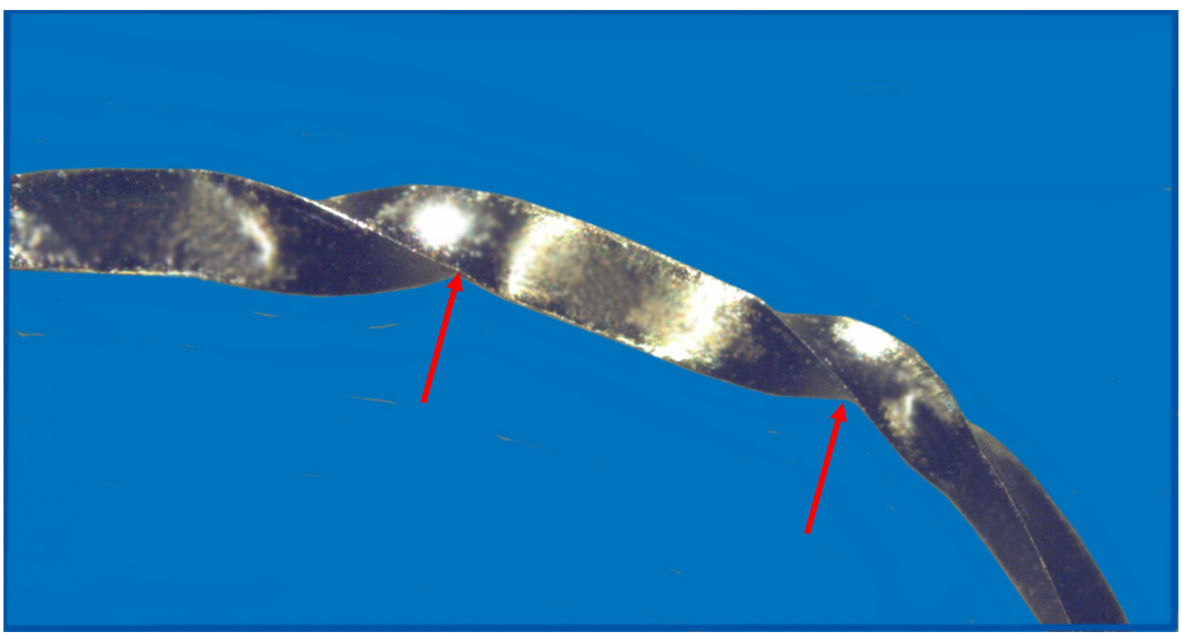
Rotating at 300 rpm each 25/.06 files progressed onto a 45 degree inclined plane with an open canal, the file's resistance to deflection or the force exerted on the incline was measured. The resulting measurements plotted each file's change in flexibility as its diameter increased. The RaCe file's greater flexibility is due to less cross-section area and its unique design of incorporating spiraled and non-spiraled segments along its working surface. However, most of the deflection occurs at specific areas of stress concentration points rather than being more evenly distributed over the length of the working surface. Note the flexibility of the RaCe file.

29. What is the relationship of the resistance to fatigue and flexibility?

Generally, the file that is more flexible is also more resistant to fatigue. This is certainly true of files having the same or similar designs. However, as with resistance to torsion failure, resistance to fatigue is dependent not only on diameter and mass but also on design and quality of manufacturing. The RaCe file has considerably more flexibility than the other files of the same size tested.

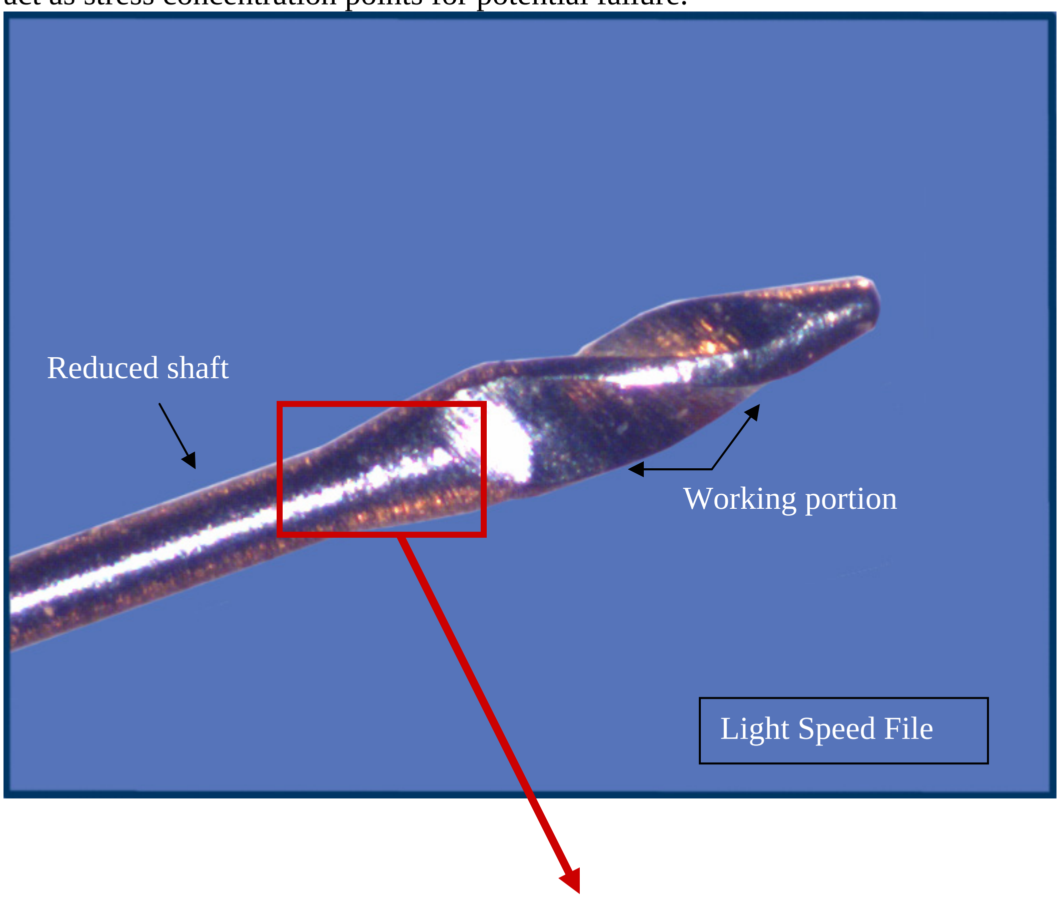


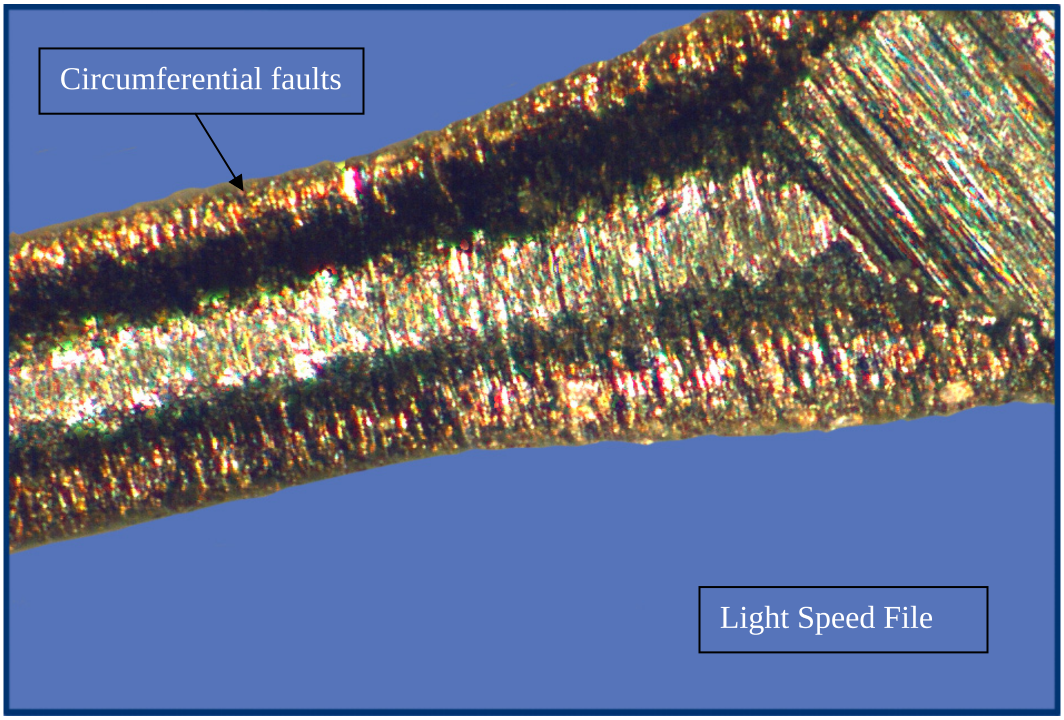
The spiraled and non-spiraled segments incorporated in the RaCe design and its smaller cross-sectional mass results in high flexibility. The configuration of the RaCe file offers a unique opportunity to study the different stress characteristics of its spiraled and non-spiraled segments along its working surface.



Note that essentially all bending occurs at the junction of the spiraled and non-spiraled segments where stress concentration also occurs. Since flexion is confined to the spiraled portion of the working area rather than being distributed more evenly over the entire area, fatigue will occur more quickly. The recommended speed of 500 RPM is another factor that increases fatigue. On the other hand, the torsion generated by the RaCe file is substantially less than most files because of the reduced tendency for screwing in due to the spiraled and non-spiraled configuration.

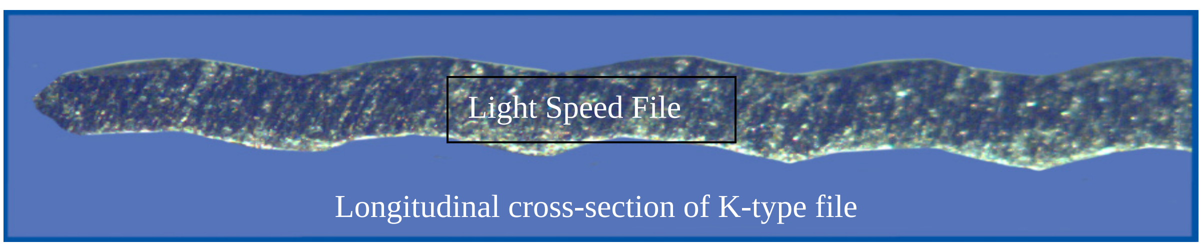
The unique Light Speed file design is comprised of a short working portion followed by a reduced diameter shaft similar to a Gates Glidden drill and has the greatest flexibility of all the files tested. A greater resistance to fatigue would be expected to accompany its flexibility when only the small diameter dimensions of its round shaft are considered, However, testing resulted in significantly shorter rotation times when rotated at the manufacturer's recommended speeds in curved canals when compared to other files having comparable tip sizes but larger working surface diameters. One contributing factor was the rotation speed of approximately 2,000 rpm recommended because of the minimum engagement of the working surface. A more plausible explanation might relate to the manufacturing process which results in circumscribed faults around the shaft of the file that act as stress concentration points for potential failure.



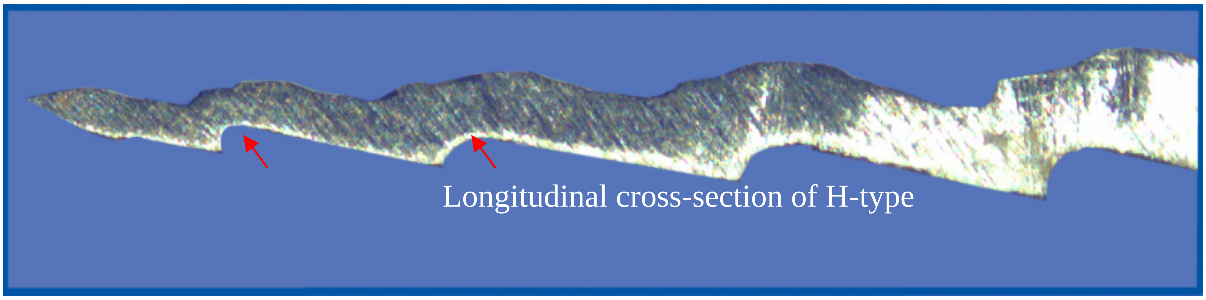


Fatigue is primarily the result of the propagation of faults. Unlike other files the faults of the Light Speed file can completely circumscribe its reduced shaft. The compression and tensile forces can act on the circumferential faults to accelerate failure.

Whereas torsion failure is more vulnerable to stress concentration points in the transverse cross-section design, fatigue is more dependent upon stress concentration points in the longitudinal cross-section. For instance, even though the core mass, total mass and diameter may be the same for a Hedstrom file and a conventional K-type file, the Hedstrom file has more abrupt changes in lines of design in transverse and longitudinal cross-sections that cause it to more likely fatigue.

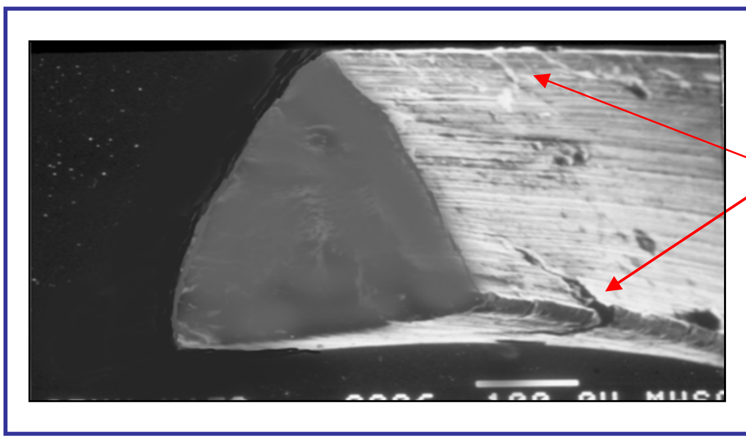


Longitudinal cross-section of a ***K-type*** *file. Abrupt changes in the lines of design are minimal.*



Longitudinal cross-section of ***H-type file****. The stress concentration points (red arrows) are more severe than those of K-type files when viewed in longitudinal cross-section.*

The shape of the file at its circumference also determines a file's resistance to fatigue. In basic terms the resistance to separation of molecular attraction provided by a greater mass of a rounded surface following a file's cutting edge at its circumference, such as a land, may be more resistant than an angular circumferential surface, i.e. a triangular cross-section in which the smallest surface mass is subjected to the greatest tension, but the prediction of failure becomes more difficult to compute.



An angular surface at the circumference of the file has more defects that can lead to failure under tension than the rounded surface of a land.