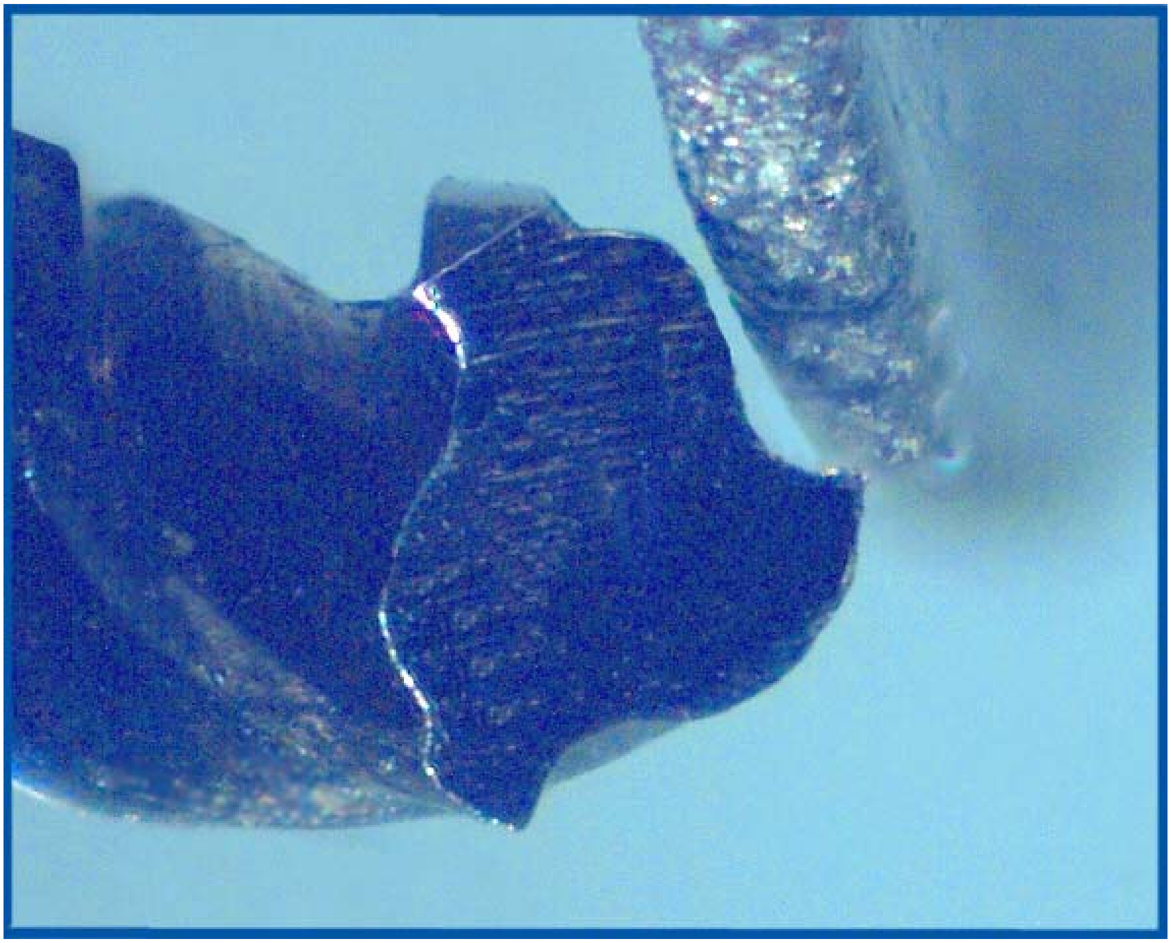
11. Why are the rake angles and cutting angles the same on some files and not on others?

All nickel-titanium files begin as round wires. When files are manufactured with conventional grinding processes the wire transverses a grinding wheel to form a flute (groove) in the side of the wire. If the wire is rotated as it is fed across the grinding wheel a spiraled flute is formed having a helix angle (the angle of the flute with the long axis of the file), and the shape of the flute is formed by the shape and angulations of the grinding wheel. Positive ***rake*** angles are difficult to accomplish due to the size of the grinding wheel relative to the file diameter. However, by adjusting its angulations, positive ***cutting*** angles are more easily accomplished. Of the current spiraled instruments, positive rake angles of at least one blade exist only on K3 files. However, it is conceivable that other H-type (Hedstrom) instruments could incorporate positive rake angles.

Files that have ***symmetrical*** flutes will not have positive rake or cutting angles and both angles will be essentially the same. Any positive cutting angle is the result of the flute having a smaller radius ***(asymmetrical***) adjacent to its cutting edge as compared to the radius of the remaining portion of the flute. By varying the depth and/or asymmetry of the flute, the cutting edge of the file can be adjusted to become more or less positive along its working length in order to enhance its effectiveness.

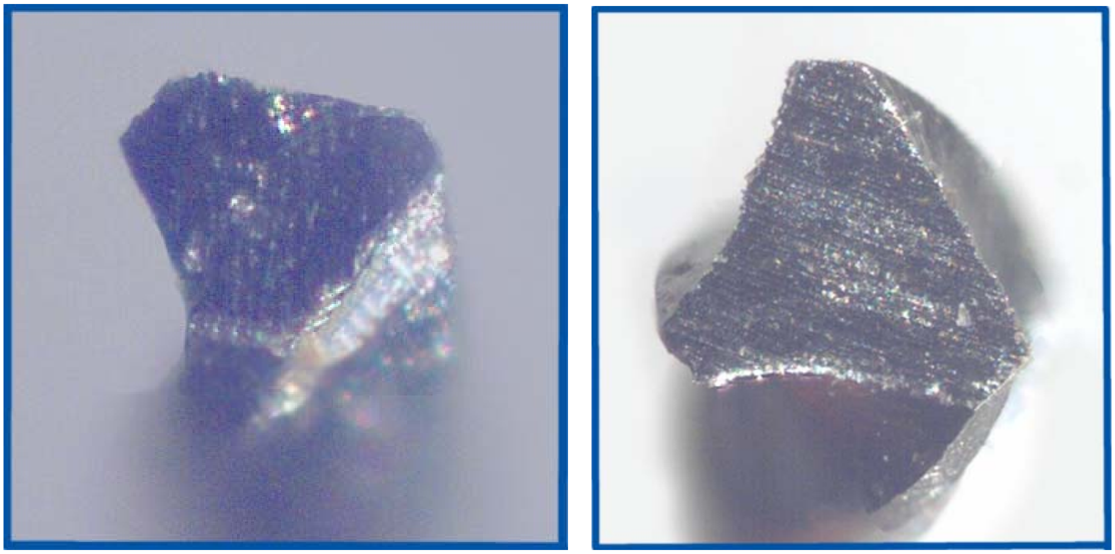


Grinding angle for asymmetrical flute

The grinding wheel during fabrication of the ***K-3*** *file forms a positive cutting angle by grinding a smaller radius on one side of the flute (asymmetrical).*

12. Do cutting angles change along the working surface of a file?

If the flute design of a file has no radius when viewed in its cross-section, the cutting angle will remain the same along its working surface from D1 to D max. Without a radius, the depth of flute in cross-section will be outlined as a straight line and the only files having that design are the K-type file and reamer and the RaCe file. Although there are exceptions, as is the Hero file, any file that has a cross-sectional design with a radius may likely have a cutting angle that changes along its working surface. The flutes of these files usually occupy proportionately less of the cross-sectional area at their tips than at their largest diameters for two reasons. One reason is the intentional design to provide a more rigid tip and the other reason is the limitation of manufacturing capabilities. Consequently, the cutting angles near the tips would be less positive than at their larger diameters and the tips of these files have comparatively less flexibility but more resistance to torsion stress. If one attempts to mentally determine the cutting action of a file by viewing its cross-section, it is important to keep in mind that the cross-section design may change along the working surface and may be substantially different from the manufacturer's representations.



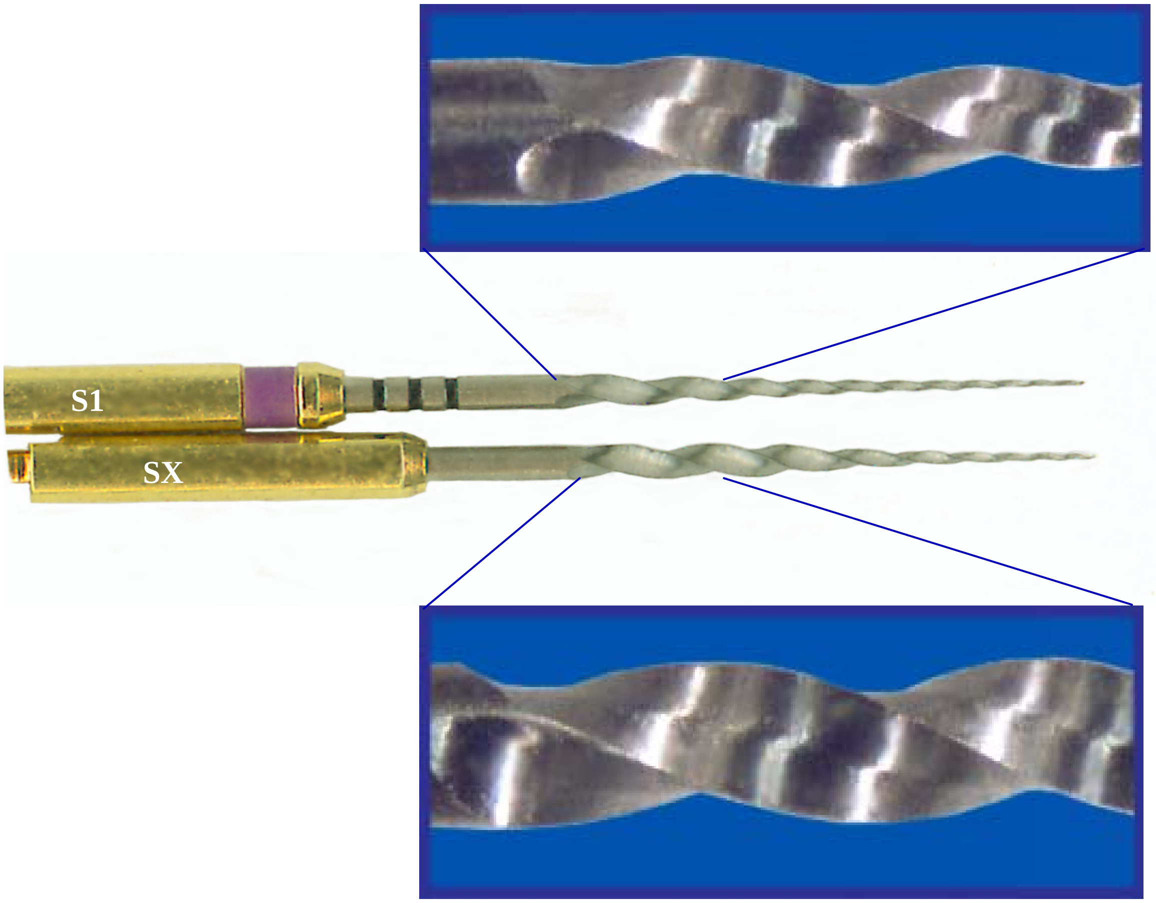
ProFile GT sectioned at .25 mm. diameter *Profile GT sectioned at .90 mm diameter*
Although the ProFile and ProFile GT series of files are usually portrayed as having a flute with a radius, diameters smaller than .6 mm have flutes that are essentially straight in cross section. The radius of the flute is limited by the radius of the grinding wheel during the manufacturing process.

13. ***What is an aggressive file?***

An efficient file, a file having greater cutting ability, requires less time, torque and/or pressure to accomplish canal preparation. The less pressure, torque and time required, the more likely file failure can be prevented. The *concept* is often confused, however, by describing a more efficient file as a more aggressive file, a term that seems to be used with a negative connotation. Aggressive forces of the operator on an efficient file are unnecessary and can be counter-productive. For example, if one pushes with excessive pressure on an efficient file the chips that are formed on the wall of the canal can be larger than can be removed without requiring significantly more torque than would have been required for forming and removing smaller chips with less pressure. Clinicians who change file systems and begin working with more efficient files often have a tendency to apply the same time or force as was required with less efficient files. The excessive (aggressive) force on the more efficient file should be avoided and the clinician will enhance the quality of preparation and reduce the threat of failure by learning to match the file's efficiency with the level of force required. Without the benefit of efficiency data, clinicians often choose less efficient files because of the tactile sensations perceived**.** A file that enlarges a canal with inefficient scraping actions, for instance, can "feel" smoother than a file that uses cutting actions. ***How an instrument feels during use is not a reliable indication of its efficiency.***

The major concern for an efficient instrument is its ability to transport the canal. It should be remembered that ***time*** as well as ***force*** are functions of efficiency and less time will be required to transport as well as to enlarge a canal with an efficient file. On the other hand, the less efficient file requires more time that results in more rotations and greater fatigue, and/or more force that results in greater torsion. The additional fatigue and torsion, of course, increase the possibilities of breakage.

One should also keep in mind that a file cannot transport unless it was at first where it should be and only the excessive time it remains in that position results in transportation. Once a file has rotated one time in one position the canal will be enlarged to the file's diameter and to avoid transportation the file should not remain in that position once the canal is enlarged. Even very minor differences in file design dimensions can affect the cutting efficiency of files and their propensity for transporting canals.

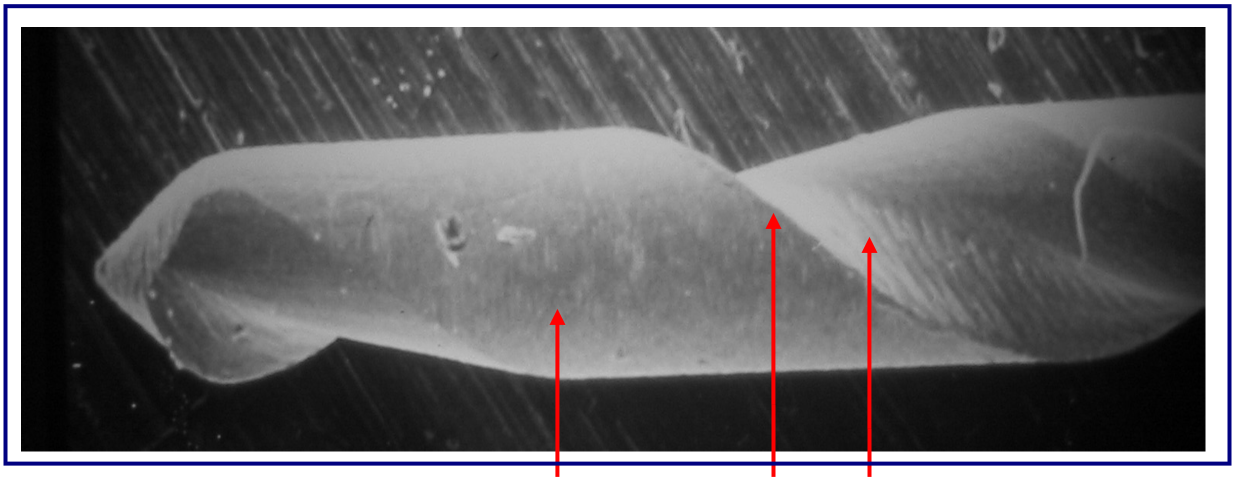


The S1 and the SX ProTaper files have the same cross-section design and maximum diameter. However, slight dimensional differences of the S1 enable it to have more side cutting ability when only engaged at its maximum diameter.

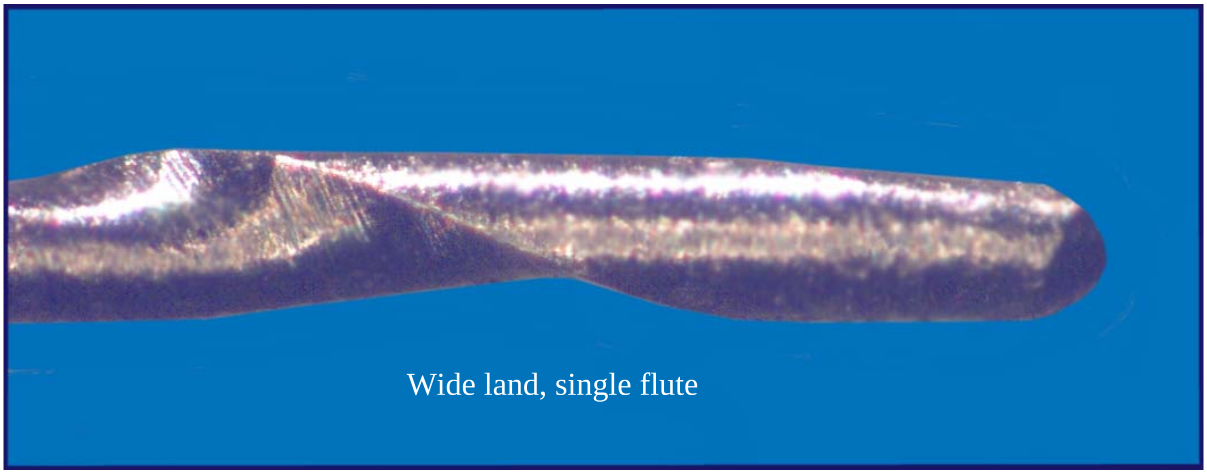
14. What do lands do?

Lands, the surfaces of files that extend as far axially from the center as the cutting edges that define the file's circumference, are used to reduce screwing-in forces, support the cutting edge, reduce transportation, and limit the depth of cut in much the same manner that a safety razor functions. The wider surface of a land reduces the tendency of faults caused by stress or manufacturing imperfections in the metal to propagate along its cutting edge or circumference. Lands need not be very wide to function.

The force of abrasion is a direct result of the surface area of a land that rotates against the wall of the canal. Wide lands can result in excessive abrasion forces that increase the torque requirements for rotation. In addition, faster rotations of a file cause the lands to further limit the depth of cut, and wide lands on larger files can prevent the blades from engaging an adequate depth into the canal. Wide lands can be very useful in small diameter files by adding rigidity and by enabling the file to negotiate curvatures when canal enlargement is minimal. When lands are too wide for effective canal enlargement the files can be used very effectively for removing gutta percha from the canal and for circulating irrigation in the canal.

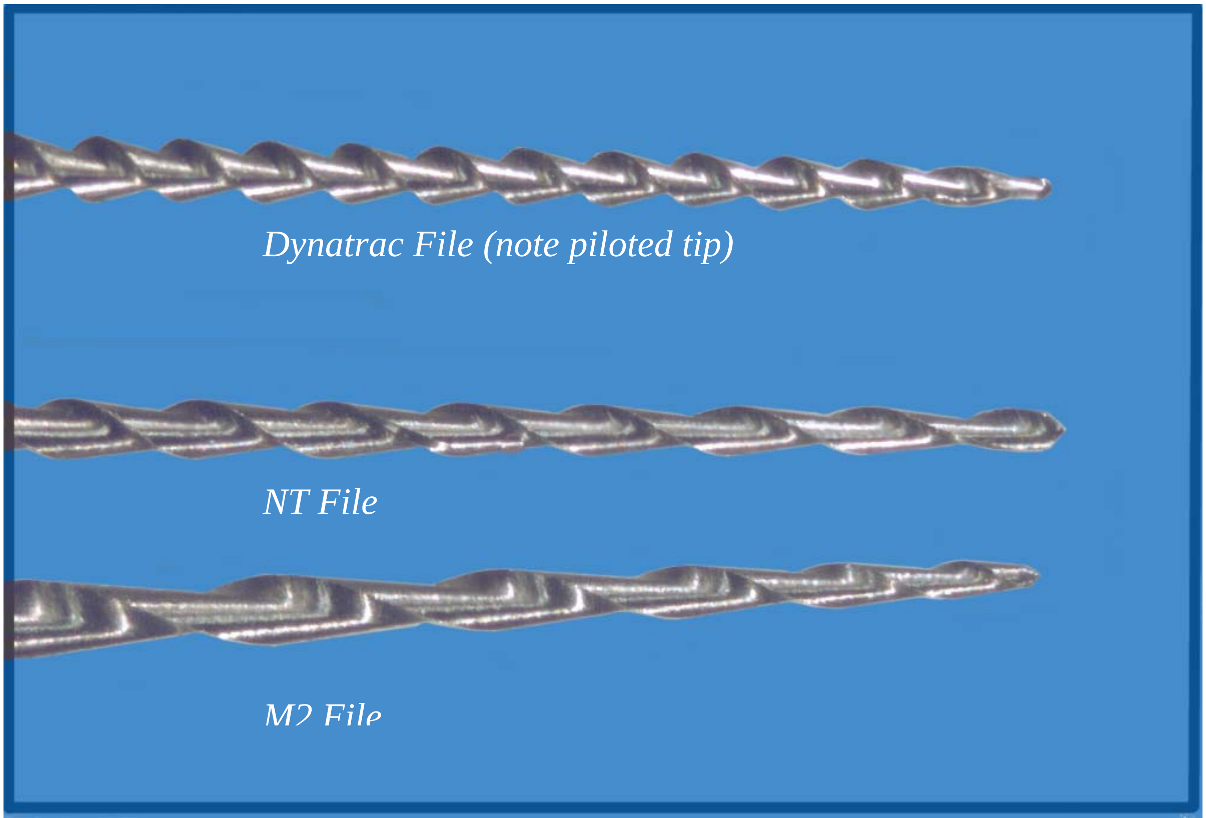


The GPX *instrument, Brasseler USA, is used for removing gutta percha from the canal. The friction of the wide land rotating against gutta percha causes it to plasticize while the spirals auger it from the canal. The instrument is very effective for removing gutta percha but is ineffective as a larger size file because the land occupies most of the working surface and keeps the leading edge from engaging into the canal surface.*



*The **Endomagic** file (size 15) utilizes wide lands for smaller size files to facilitate negotiating curvatures.*

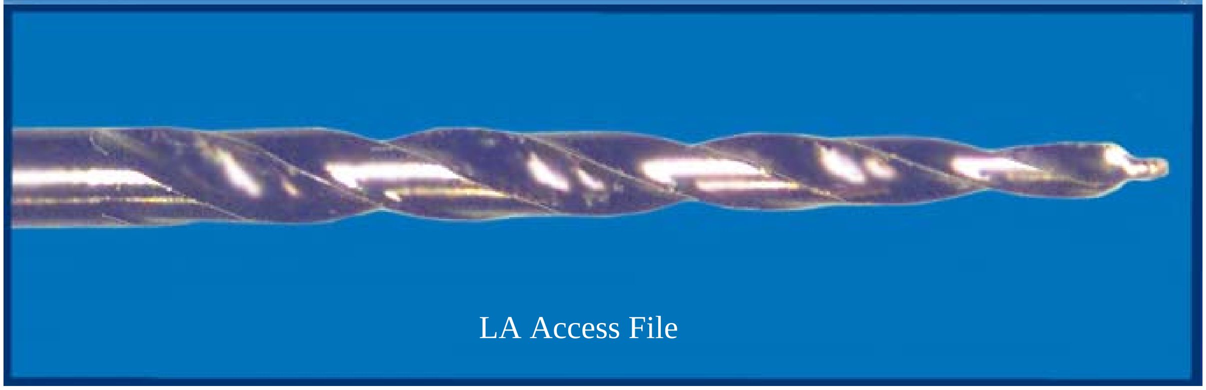
Although not technically lands, since the surface does not extend axially from the center of the file as far as the cutting edge, H-type files have surfaces that follow the blades that gradually retreat from the file's circumference. This design provides the support of the blade and reduces propagation of cracks along the blade in the same manner as lands but lacks some of the effectiveness in avoiding canal transportation. However, the force of abrasion is reduced. Rotary files having this design include the three-fluted Hero file (MicroMega) and the newly introduced two-fluted M2 file (Sweden Martina). The M2 file is essentially a modification of the Dynatrac file and NT file design having positive cutting angles but having fewer spirals. This modification is attributed to Dr. Vinio Malignino of Italy. Another modification is the LA Access file which has a surface that at first gradually retreats from the blade but becomes a flat recess or relief. This file is used primarily to intentionally transport the canal orifice and utilizes the piloted tip like the Dynatrac to minimize canal transportation at the tip. This design is attributed to Dr. Steve Buccanan.



Dynatrac File (note piloted tip)

NT File

M2 File



LA Access File

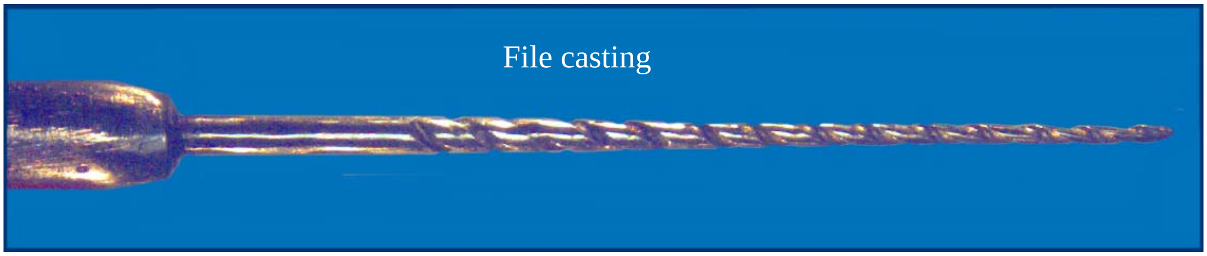
15. Do the designs of files have to be limited to a grinding process during manufacturing?

The capabilities for fabricating complex file designs have increased dramatically with computerized multi-axis grinding processes. However, any process of grinding limits the shape and strength of files. The size of the grinding wheel limits the file's shape, and cutting across the grain of the crystalline structure of the wire limits its strength. The process of ***electrical discharge machining, EDM,*** is a promising alternative means of manufacturing endodontic files. The shape of the file is formed by electric spark erosion of a wire. EDM manufacturing alters the molecular surface potentially strengthening the file without affecting its flexibility.

Another promising method for manufacturing nickel titanium files is using the ***process of twisting*** that was used for fabricating steel files for decades but was initially thought to be an impractical method for nickel titanium. Residual stress and the problem of shape memory for nickel titanium can be avoided during this process by heat-treating before, during or after twisting. The helix angle can be varied along the working surface by using a computerized twisting process. The rationale for using this manufacturing technique is that work hardening the metal by twisting might occur as it does during the twisting process of stainless steel files, and enhance its strength while maintaining greater integrity of the crystalline structure.

Alternative manufacturing also includes flute formation by forcibly pushing a blade into a tapered wire. The flute is formed as a furrow rather than being ground and the blade becomes projected from the shaft. Barbed broaches are manufactured in this manner.

The molecular structure of conventional metals is organized into grains or crystals. The boundaries between the crystals are the areas of weakness where failure occurs when undergoing excessive stress. Scientists have discovered that if some alloys are cooled very quickly during the process of casting, crystallization can be avoided. One of the most unique developments for the potential for fabricating complicated file designs incorporates this process of casting and avoids many of the limitations of grinding altogether. The resulting metal has an amorphous non-crystalline structure and the properties for accommodating stress are enhanced and the microscopic irregularities caused by the grinding wheel that result in stress concentration points are eliminated.

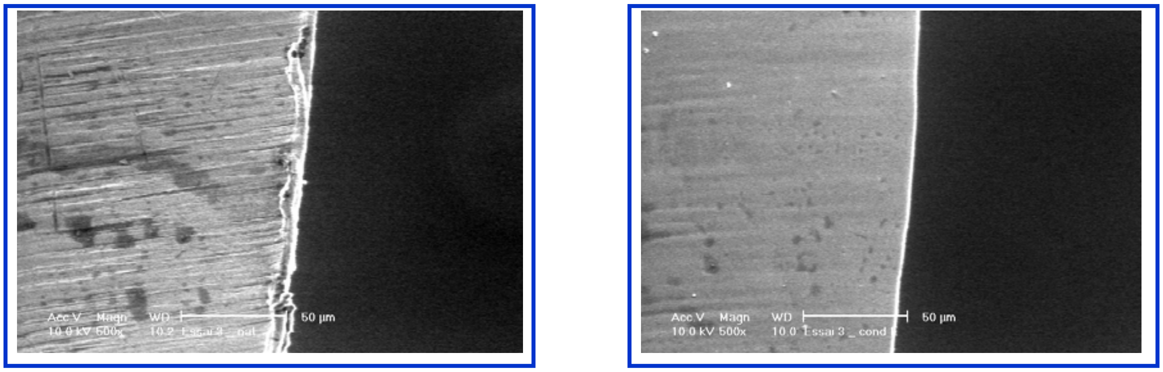


Liquidmetal *cast file (the handle and shaft are cast as one piece). Although castings lack precision at this time, continuous advancements in casting techniques can make it a viable manufacturing process in the near future.*

16. Does the quality of manufacturing make much difference?

Before different types of files are studied, it should be stressed that the quality of manufacturing is the most basic consideration for determining the success or failure of files independent of its composition or design. Less than ideal manufacturing quality controls result in the formation of micro-cracks and defects along the surface of a file.

Cracks can propagate to failure at a stress level lower than the stress ordinarily encountered during instrumentation and other defects can cause stress concentration points that lead to file failure and jeopardize endodontic success. It is not surprising to find that fatigue cracks in files usually start at geometrical irregularities on a macro- and micro-scale. If the defects are in a position of high stress, failure can occur quickly. The area of highest stress is along the blade or leading edge. Failure is the result of stress per unit area so a blade that is unsupported by a land, such as a file having a triangular cross-section, will have greater forces for failure than a blade supported by a land or regressing circumference.



The formation of micro-cracks (shown on the file’s cutting edge in the left photograph) during manufacturing was eliminated by a special process by FKG Co. (shown in the right photograph) and resulted in increasing the resistance to torque failure by as much as 1000% in some samples. Files were compared rotating in a glass tube (inside diameter 2 mm, 90 degree curvature and 8 mm radius) at a speed of 350 rpm until failure.