FLEXURAL STRENGTH AND FLEXURAL MODULUS VERSUS FRACTURE TOUGHNESS
(The making of a fracture tough fiber reinforcement)

If you want to understand why and how dental materials fracture and break, traditional flexural strength and flexural modulus tests will not provide you with the facts you need to know. These particular types of "strength" tests are greatly misleading and provide a false understanding of how much energy, load, and work of fracture it takes to break a dental material.

This factual understanding of why and how materials fracture was best described by Professor J.E. Gordon (www.en.wikipedia.org/wiki/J.E._Gordon) who is one of the founding fathers of modern material science. Professor Gordon stated that materials tend to fail not due to a lack of flexural strength or lack of flexural modulus but rather due to a lack of fracture toughness. Fracture toughness is a material's ability to resist the rapid propagation of a crack and prevent fracturing. Flexural strength and flexural modulus are qualities of stiffness.


Prof J.E. Gordon

Materials that possess high flexural strength and high flexural modulus are brittle and fracture relatively easily. Glass is a classic example of a material that has relatively high flexural strength and high flexural modulus but is brittle and is not fracture tough.


Glass has high flexural strength but is brittle.

Prof. Gordon wrote that it is much easier to design a structure for stiffness using non-stiff materials than it is to design a structure for fracture toughness using non- fracture tough materials. It is much more difficult to design a structure to overcome a material's lack of fracture toughness.

Applying Professor Gordon's work to dental fiber reinforcements, the quality we should be concerned about should be fracture toughness instead of flexural strength or flexural modulus. **There are three elements to Ribbond that make it the most fracture tough dental fiber reinforcement**:

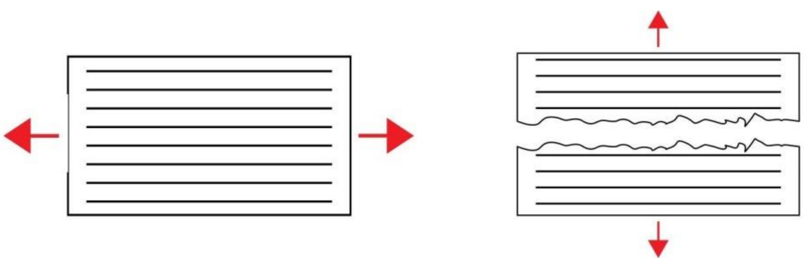
TYPE OF FIBERS

The same super tough Ultra-High Molecular Weight Polyethylene (UHMWP) fibers used to make Ribbond are used to make bullet proof vests. Glass fibers are strong in the sense that they have relatively high flexural strength and high flexural modulus, but glass fibers are brittle and are not fracture tough and are therefore not used to make bullet proof vests.

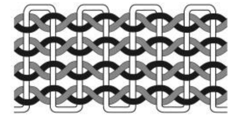
Tough enough to stop a bullet.

FIBER ORIENTATION

Unidirectional orientations are very effective in providing flexural strength and flexural modulus for in-vitro test bars when the test bars are stressed only in a direction parallel to the unidirectional fibers. However, multidirectional forces are the norm in clinical cases and the effectiveness of unidirectional fibers is greatly compromised when loads are applied perpendicular to the direction of the unidirectional fibers. Unidirectional fibers do not provide mechanical connections from one thread to the next and do not preventing crack propagation in the resin matrix due to multidirectional stresses.


Unidirectional fibers are strong in one direction but week in the other direction.

Ribbond is woven using a patented multi-directional leno weave that provides mechanical interlockings of one thread to the next. These mechanically interlocked fibers prevent crack propagation within the resin matrix and provide fracture toughness.



Interlocked leno weave

BOND STRENGTH

The manufacturers of glass fiber reinforcements market their materials by suggesting that glass fibers have higher-bond strength to resin than UHMWP, and are therefore "stronger". Dentists assume that a high-bond strength of the fibers to the resin is desirable since a high bond strength of resin to tooth structure is desirable.

This assumption is incorrect. J.E Gordon explained that a relatively high-bond of fibers to resin makes a material act like a brittle material. The higher the bond strength between resin and fibers, the more efficient the crack energy transfers from the resin to the fiber. This results in a higher chance of fibers breaking and increased brittleness.

Counter-intuitively, a moderate-bond strength between resin and fibers creates more fracture toughness than a higher-bond strength. A moderate strength resin-fiber interface deflects the crack's energy and it takes even more energy to continue the propagation of the crack.

In recognition of this phenomenon, high-tech industries such as those that make airplane body components and boat hulls contaminate glass fibers to compromise the bond strength to the resin.

A good example of this phenomenon is safety glass in windshields. A thin film of plastic is placed between two panes of glass to act as a weak interface and redirects and blunts the energy of the crack from transferring from one sheet of glass to the other.

Fracture tough safety glass

An even more appropriate example is tooth enamel. The protein sheathes in tooth enamel have relatively low bonds to the enamel prisms. This lower bond interface is a stress breaking mechanism that prevents the rapid propagation of cracks and makes the tooth enamel fracture tough.

Fracture tough tooth enamel

If the term "strength" means the ability to resist clinical failure, we argue that Ribbond is the strongest dental fiber reinforcement.