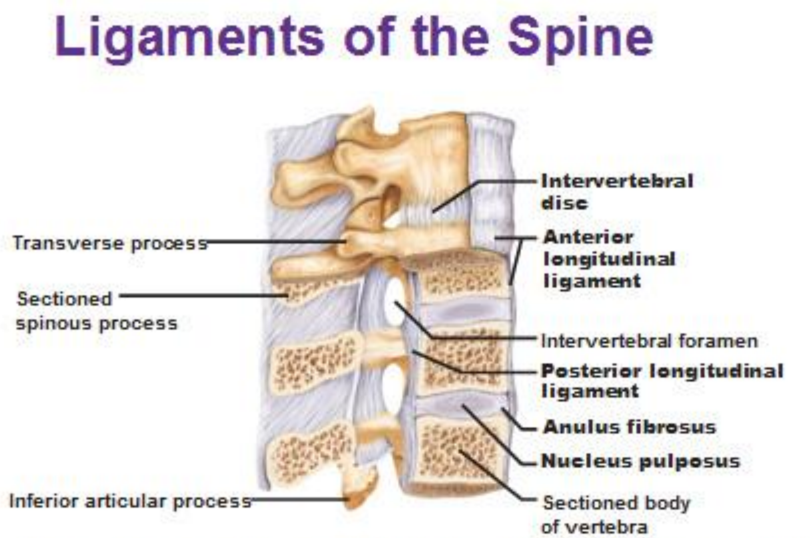

(a) Median section of three vertebrae, illustrating the composition of the discs and the ligaments

Function and Properties of Discs & Ligaments during whiplash

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Function and Properties of Discs

Cervical discs have the highest proportional height and their nuclei have the greatest capacity to swell. This allows greater range of motion and shock attenuation. The outer portion of the anulus is attached by Sharpey's fibers which may be torn in cervical acceleration/deceleration (CAD) injuries. Discs, longitudinal ligaments and other adjacent paraspinal soft tissues can be torn during whiplash trauma (1-19,1137,1138). [Anulus, by the way, is the correct spelling.]

Discs, like all soft tissues in the body, are viscoelastic structures. They display properties of anisotropy, creep and hysteresis.

1) Anisotropy--the disc's strength and stiffness vary depending on the type and direction of forces applied. Speed or acceleration to ligaments and disc is problematic.

2) Creep--the disc deforms gradually under a constant load.

3) Hysteresis--the tissue loses energy after repetitive loading and unloading cycles.

The fluid dynamics of the nucleus in a healthy disc allows for an even distribution of load over the end plate (20).

Function and Properties of Ligaments

Ligaments are uniaxial, able to resist loads in only one direction. They provide strength and stability by allowing a finite amount of displacement in each spinal segment. Recent research by Miyamoto et al. (21) suggest a new model for the development of osteophytes secondary to spinal instability wherein proliferation of fibroblastic cells in the anulus undergo metaplasia into chondrocytes and then form osteophytes via a process of enchondral ossification. This differs from Schmorl and Junghanns' classic theories (22).

Ligament strength increases with the amount of loading but little resistance is offered within normal physiologic ranges of motion (ROM). During whiplash this resistance increases many fold. In a latter section I'll discuss the results of specific tests to ligaments under loading conditions.

Stress Characteristics of Ligaments

Understanding strain characteristics of ligament is crucial for the understanding of the types of injuries seen clinically (25). Tensile failure loads and maximal deflection at failure of all cervical ligaments (1402). In isolated collagen fibers, normal loading results in 2-5% strain with return to resting length following release of tension.

$$\text{Strain} = \frac{\text{Increase in length}}{\text{Original length}} \times 100$$

This describes elastic deformation. In isolated collagen fibers, failure occurs at 7-8% strain. Beyond this 7-8% strain, ligaments may undergo plastic deformation (i.e., failure to return to normal resting length). Strain levels of up to 20-40% may be tolerated in whole ligaments before failure occurs. Even higher strains have been measured in facet capsules experimentally. Very high velocity stretching (as is seen uniquely with CAD trauma) may preclude the ligament's viscoelastic properties from protecting it and thus result in plastic deformation and/or rupture of fiber bundles at lower strain levels.

It was demonstrated in an animal model that ligaments can be loaded to a sub-failure level and be grossly intact, yet functionally deficient (1139).

Ligamentous injuries of peripheral joints (i.e., outside of the spine) are graded in terms of severity (23).

1) Grade 1 (1st degree)--mild pain developing at the time of injury or within 24 hours. Local tenderness may or may not be present. Pain usually only when stress is applied.

2) Grade 2 (2nd degree)--pain causing handicap of activity with local tenderness. Moderate to severe pain when stress is applied.

3) Grade 3 (3rd degree)--complete or nearly complete rupture or avulsion of at least a portion of ligament. Paradoxically, loss of continuity may result in painless stressing of the joint.

A 3rd degree sprain is best defined by its lack of load carrying capacity since a ligament may appear macroscopically intact and yet fail completely under a load (24).

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