Detection of Altered Collagen Fiber Alignment in the Cervical Facet Capsule After Whiplash-Like Joint Retraction

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Kyle P. Quinn and Beth A. Winkelstein
From the Department of Bioengineering and the Department of Neurosurgery, University of Pennsylvania

FROM ABSTRACT

The cervical facet joint has been identified as the source of pain in patients with whiplash-associated disorders, but most clinical studies report no radiographic evidence of tissue injury in these disorders.

The goal of this study was to utilize quantitative polarized light imaging to assess the potential for altered collagen fiber alignment in human cadaveric cervical facet capsule specimens (n = 8) during and after a joint retraction simulating whiplash exposure.

Although no evidence of ligament damage was detected during whiplash-like retraction, mechanical and microstructural changes were identified after loading.

Retraction produced significant decreases in ligament stiffness and increases in laxity.

In addition, image analysis indicated that 21.1 ± 17.1% of the capsule sustained principal strains that were unrecovered immediately after retraction [this means they were injured].

Altered collagen fiber alignment was detected in 32.7 ± 22.9% of the capsule after retraction.

The capsule regions with unrecovered strain and altered fiber alignment after retraction were significantly co-localized with each other, suggesting the altered mechanical function may relate to a change in the tissue's fiber organization.

The identification of altered fiber alignment in this ligament following retraction without any tears implicates the whiplash kinematic as a potential cause of microstructural damage that is not detectable using standard clinical imaging techniques.

KEY POINTS FROM THIS ARTICLE

1) This is the first study that has assessed changes in tissue microstructural organization of the facet capsule following whiplash-like loading.

2) "Whiplash is a common cause of chronic neck pain, and the cervical facet joint has been identified as the site of pain in the majority of these cases."

3) "Up to 62% of people affected by whiplash injuries report pain lasting 2 years or more after injury."

4) Facet joint injuries cannot be imaged in most whiplash patients with x-rays or magnetic resonance imaging (MRI).

5) "The lack of any definitive evidence of facet capsular ligament damage following whiplash, despite the high incidence of facet-mediated pain, suggests radiographic and MRI techniques may lack the resolution or contrast to identify these subtle injuries."

6) Atypical cervical spine and facet joint motions occur during the whiplash mechanism.

7) Low-speed rear-end impact collision causes the lower cervical spine to undergo a combination of compression, posterior shear, and extension. "This combination of forces and moments primarily induces a retraction of each vertebra in the posterior direction relative to its adjacent inferior vertebra in the lower cervical spine prior to head-headrest contact."

8) The facet capsular ligaments are at risk for excessive motion during this vertebral retraction, creating subfailure injuries to the facet capsule. "The facet capsular ligament may sustain partial failures and/or unrecovered deformation during whiplash."

9) Facet joint injury causes altered collagen fiber organization and facet capsular ligament laxity that may produce persistent pain. "Neither partial failure nor capsule rupture is required to initiate facet-mediated pain, suggesting painful facet joint injuries cannot be identified through traditional load-based or medical imaging techniques."

10) Polarized light can characterize the microstructural organization of the collagen fibers in soft tissue.

11) Prior to ligament visible rupture or mechanical failure, there is an anomalous fiber realignment, which may be used as a marker for subfailure capsule injury.

12) These authors evaluated the collagen fiber kinematics during a whiplash-like retraction of cadaveric C6/C7 facet joints and determined that facet joint retraction produces anomalous realignment that results in unrecovered strain and altered fiber alignment after loading.

13) They used 8 C6/C7 cervical facet joints from fresh, unembalmed human cadavers, 46-70 years of age. The C6 vertebra underwent 2.5 mm posterior displacement (retraction) to simulate the magnitude of that joint's motion during the whiplash kinematic. "Previous whiplash simulation studies using human cadaveric specimens have estimated the magnitude of retraction of the lower cervical facet joint to range from 1 to 4.3 mm. The 2.5-mm magnitude was chosen for this study as a midpoint in that range; this magnitude of facet retraction does not produce mechanical failure or visible rupture."

14) "This study used quantitative polarized light imaging to demonstrate that whiplash-like vertebral retraction can produce altered collagen fiber alignment in the facet capsular ligament, which is associated with significant laxity and reduced ligament stiffness."

15) The changes in the microstructural organization after retraction may contribute to the altered mechanical function.

16) The retraction caused permanent deformation of ground substance materials of the ligament, leading to altered collagen fiber organization. This tissue damage may be sufficient to induce an inflammatory response or nociceptor firing in the ligament.

17) "The optical imaging findings documented here do provide the first evidence of a change in the facet capsule microstructure following a whiplash-like joint retraction."

18) The retraction also produced joint laxity which is consistent with modifications to the facet joint spacing or the cervical spine angulation that has been documented following whiplash trauma.

19) "The majority of radiographic or MRI studies involving whiplash patients identify little, if any, direct evidence of structural damage to the soft tissues in the neck."

20) "In contrast, polarized light imaging demonstrated changes in the collagen fiber alignment of every capsular ligament specimen in this study following whiplash-like loading." "These findings would suggest that radiographic or MRI diagnostic approaches may lack the resolution to detect the microstructural changes that can occur in the facet capsule without overt capsule rupture after a whiplash exposure."

21) "Facet joint displacements that produce persistent pain symptoms also induce laxity in the capsular ligament and collagen fiber disorganization."

22) "The detection of altered fiber alignment and unrecovered strain observed after facet retraction in the current study would suggest that whiplash-like loading may be sufficient to generate facet-mediated pain."

23) This "study demonstrates that microstructural changes to the facet capsule can be produced by whiplash-like loading."

24) The "unrecovered strain and altered fiber alignment in the current study suggests that the development of laxity in this and other simulations of whiplash may be the result of microstructural damage."

25) "The development of whiplash-induced laxity or altered fiber alignment may not be detectable in a clinical setting using current approaches."

COMMENTS FROM DAN MURPHY

Whiplash injury causes microstructural changes, anomalous fiber realignment and laxity of the facet capsular ligaments. These injuries may cause permanent deformation of ground substance of the ligament, leading to altered collagen fiber organization. These injuries are subfailure in magnitude, but are capable of causing pain and permanent alterations in capsular mechanics. These injuries are not identifiable clinically, with x-ray, or MRI imaging. The tissue damage may be sufficient to induce an inflammatory response and/or nociceptor firing.