In Vivo Human Facet Joint Gapping During Cervical Spine Manipulation

[1]William Anderst PhD,[1]Tom Gale MS, [2]Kris Gongaware DC and [2]Michael Schneider DC, PhD

[1]Department of Orthopaedic Surgery and [2]Department of Physical Therapy

University of Pittsburgh, Pittsburgh, PA, USA (bdl.pitt.edu)

Introduction

Background

- Neck pain is one of the most commonly reported symptoms in primary care settings and a major contributor to increasing healthcare costs[1].
- Cervical manipulation is a common and clinically effective intervention for neck pain.
- Little is known about the biomechanics of spinal manipulation.
- The biological mechanisms underlying spinal manipulation remain unknown.

Scientific Basis for Assessing Facet Kinematics

- Previous research has documented pre- to post-manipulation changes in facet gapping[2].
- The cracking sound that is elicited during high-velocity low-amplitude manipulation (HVLA) is believed to be cavitation of the spinal facet joints.

Aim

- To characterize *in vivo* facet joint gapping during cervical spine manipulation.

Methods

Subjects

- Ten participants with acute mechanical neck pain provided informed consent and were enrolled in this IRB-approved study.

Manipulation

- Cervical manipulation was performed by a licensed chiropractor within a biplane radiography system (Figure 1).
- The manipulation was performed using the thumb cervical extension technique:
  - Patient supine
  - Head rotated away from painful side
  - Hand contact on the upside
  - Thrust delivered with thumb over the articular pillar

Figure 1. *The biplane imaging system configured to collect dynamic biplane radiographs during HVLA manipulation. The X-ray sources are to the right, and image intensifiers and high-speed cameras to the left, providing sagittal-oblique views of the spine without occlusion from the clinician.*

Data Collection

- Synchronized, 2.0 ms duration pulsed biplane radiographs (70 kV, 320 mA).
- 160 images per second for 0.8 seconds during manipulation.
- CT scans of C1-C7 were collected from each participant (0.29 x 0.29 x 1.25) mm.

Data Processing

- A validated volumetric model-based tracking process was used to track bone motion during manipulation with sub-millimeter accuracy[3] (Figure 2).
- Bone kinematics were filtered using a 4th-order Butterworth filter with filter frequency (10 Hz) determined by residual analysis[4].
- Facet joint gapping was calculated as the average distance between adjacent articular facet surfaces.

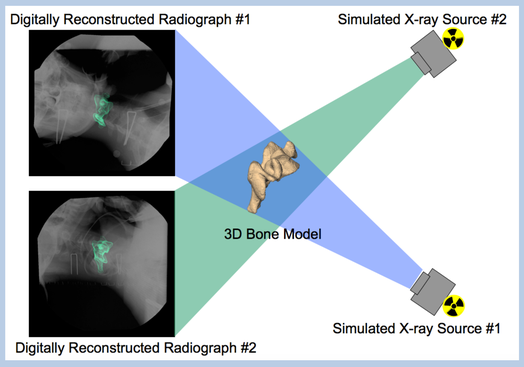

Figure 2. *The volumetric model-based tracking process. Subject-specific bone models were placed into a simulated biplane imaging system that was geometrically identical to the lab-based system. Simulated x-rays were directed through the bone model to create digitally reconstructed radiographs (DRRs) (green). An automated optimization process matched the DRRs to the original biplane radiographs.*

Outcome Parameters

- Change in facet joint gap during manipulation (pre-manipulation to peak gap).
- The rate of facet gapping.
- The time to peak facet gap (Figure 3).

Results

- For 3 participants, the upper cervical spine was occluded, either by the chiropractor's hands or the patient's mandible.
- For one participant, there was no audible cavitation.
- For one participant, the timing between the manipulation and radiographic imaging was not synchronized.
- The final analysis included data from 5 participants (2 M, 3 F; average age 38±15 years).
- Motion of 3 to 5 vertebrae from C2 to C6 was tracked during each manipulation.

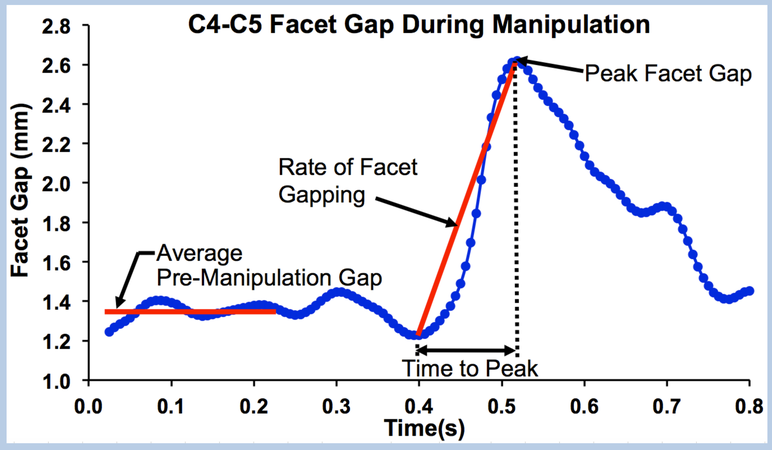

Figure 3. *Facet gapping during manipulation and measured outcome parameters for one representative subject. Each blue data point represents one frame of tracked motion during the manipulation.*

- The maximum increase in facet gap from pre-manipulation to peak facet gap averaged 0.98±0.30 mm.
- The average increase in facet gap over all tracked motion segments was 0.87±0.32 mm.
- The average time to peak facet gap was 129±55 ms.
- The average rate of facet gapping over all motion segments was 7.4±2.9 mm/s.
- A strong relationship was observed between the rate of facet gapping and the increase in facet gap during manipulation (R^2 = 0.57).
- Facet joint gapping consistently occurred across all tracked vertebrae (Figure 4).

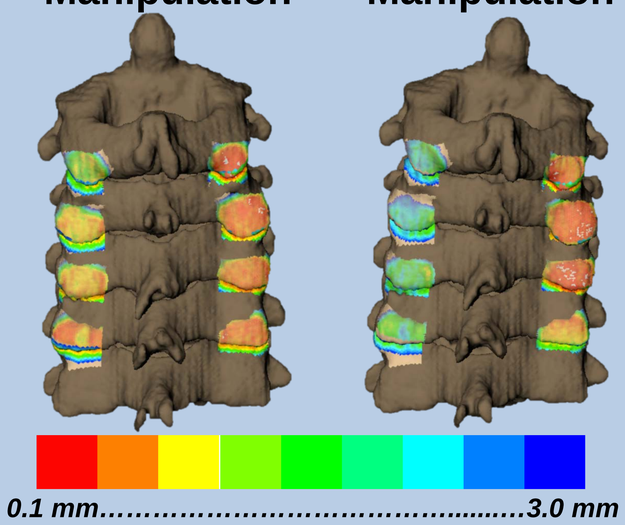

Figure 4. *A posterior view of the cervical spine pre-manipulation (left) and during manipulation (right). Gapping of the left facet joints is demonstrated by the color-coded facet joint surfaces.*

Scan for video

Discussion

- This study demonstrates our ability to characterize facet gapping, believed to be one of the key mechanical events of spinal manipulation.
- Cervical manipulation induces supraphysiologic facet joint gapping, evidenced by a peak facet gap during manipulation that is more than double the peak facet gap during full range of motion flexion/extension[5].
- Future work will investigate the relationship between mechanical events, such as facet gapping and applied forces, and the mechanical and/or neurologic responses that lead to positive clinical outcome.

References and Acknowledgement

1.Hogg-Johnson, S., et al. *Spine.* 33(4 Suppl), S39-51, 2008. 2. Cramer, G.D., et al. *J Manipulative Physiol Ther.* 36(4) 203-17, 2013. 3. Anderst, W., et al. *Spine*. 36(6), E393-400, 2011. 4. Winter, D., *Biomechanics and Motor Control of Human Movement (4th Edition)*. 2009, Hoboken, NJ: Wiley. 5. Anderst, W., et al. *Spine*. 39(8), E514-20, 2014.

Funding for this project was provided by a grant from the NCMIC Foundation.