Biomechanical Analysis of Bilateral Facet Joint Stabilization Using Bioderived Tendon for Posterior Cervical Spine Motion Reservation in Goats

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■ OBJECTIVES: **To investigate the biomechanical properties of a novel stabilization method for posterior cervical motion preservation using bioderived freeze-dried tendon.**

■ METHODS: **Experiments were conducted both in vitro and in vivo. For the in vitro group, 15 fresh-frozen goat spines (C1-C7) were randomly divided into 3 subgroups: intact (INT-vitro, $n = 5$), injury model (IM-vitro, $n = 5$), and bilateral facet joint stabilization (BFJS-vitro, $n = 5$) subgroups. For the in vivo group, 15 adult goats were randomly divided into 3 experimental subgroups: INT-vivo subgroup ($n = 5$), IM-vivo subgroup ($n = 5$), and BFJS-vivo subgroup ($n = 5$). Goats in the in vivo group were euthanized 12 weeks after surgery. Biomechanical tests were performed to evaluate range of motion. Histologic analysis was conducted to evaluate survival and reactions associated with the bioderived tendon.**

■ RESULTS: **Compared with the INT-vitro and INT-vivo subgroups, the flexion of IM-vitro and IM-vivo subgroups increased significantly, respectively ($P < 0.05$). The flexion of the BFJS-vitro and BFJS-vivo subgroups was significantly smaller than in the IM-vitro and IM-vivo subgroups, respectively ($P < 0.05$). Significant differences between the BFJS-vitro and BFJS-vivo subgroups were observed in flexion, lateral bending, and rotation ($P < 0.05$). Histologic evaluation demonstrated that fibers arranged regularly and stained homogeneously. New vessels in growth indicated that the bioderived tendon was survival and processed good regeneration.**

■ CONCLUSIONS: **Bilateral facet joint stabilization can significantly limit excessive flexion motion and maintain adequate stability. Furthermore, the preservation of extension motions without limiting lateral bending and rotation ideally simulates the features of the posterior ligamentous complex. This preserves the dynamic stability of the lower cervical spine.**

INTRODUCTION

The stability and range of motion of the posterior cervical spine is greatly limited when the posterior ligamentous complex is destroyed, even with intact bone structure. Clinical symptoms mainly manifest as instability of the cervical spine and excessive motion, especially in flexion.[1,2] The treatment options for patients with this type of spinal stability loss can be categorized as either conservative or techniques involving fusion. Fusion surgery has been done since the 1910s and is considered to be the gold standard. It is usually performed to restabilize the posterior cervical spine. However, spinal fusion does not make sense for treating patients with this type of connective tissue structural damage, when there is no structural fracture of the bone.[3,4] When cervical stability reconstruction is done, there is a loss of fixed segmental motion, which increases the range of motion in the adjacent segment. Mechanical tests done by Shono et al[5] have shown that spinal fixation changes movement patterns, such as flexion, extension, lateral bending, and rotation, in the adjacent segment. This increases adjacent segment

Key words
- Animal model
- Bilateral facet joint stabilization
- Biomechanical analysis
- Cervical spine
- Motion preservation
- Range of motion

Abbreviations and Acronyms
BFJS: Bilateral facet joint stabilization
IM: Injury model
INT: Intact
ROM: Range of motion

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displacement and increases fixation stiffness and fixes the range of expansion. Long-term studies have shown inevitable degeneration of adjacent segments.[6-9]

Nonfusion techniques are new methods for rebuilding adequate stability and preserving motion. In stability, by appropriately decreasing the stiffness of internal system of the spine, the effect of stress shelter is reduced and the range of motion is appropriately increased. This can improve nutrition metabolization and pressure in the adjacent disk and prevent adjacent segment mobility and increases in joint load, thus reducing the possibility of excessive osteoporosis, bone resorption, facet joint, or intervertebral disk degeneration.[10-13]

Until now, there have been no nonfusion treatments reported for posterior complex ligamentous injuries. However, a method of surgical reconstruction of the knee cruciate ligament, using ligament tendon or artificial materials, has been done for years. Tissue-engineering techniques using bioderived tendon offer potential alternatives for recreating suitable biocompatible fixation materials.[14-17] Therefore it may also be possible to use tendon materials to repair the posterior complex ligamentous by securing with a figure "8" cross-tie in cervical bilateral facet joints for the purpose of cervical dynamic stability reconstruction. This study examines whether this novel posterior cervical reconstruction method has the potential capability of stability reconstruction and motion preservation in the post cervical spine from the point of view of motion evaluation.

MATERIALS AND METHODS

Study Design

This study protocol was approved by the Animal Experiment Ethics Committee of West China Hospital, Sichuan University in Chengdu, China. This study's preliminary design comprised 2 parts: in vitro study and in vivo study.

The in vitro group was composed of 15 cervical spines (C1–C7) from 48- to 50-week-old goats, which were randomly divided into 3 subgroups: intact subgroup (INT-vitro) ($n = 5$); injury model subgroup (IM-vitro) ($n = 5$) (**Figure 1**); and the bilateral facet joint stabilization subgroup (BFJS-vitro) ($n = 5$). All spines were harvested, immediately double-wrapped in plastic bags, and stored at −20°C until the day of testing.

The in vivo group was composed of 15 healthy, 48- to 50-week-old goats, which were randomly divided into 3 experimental subgroups, as earlier. In the INT-vivo subgroup ($n = 5$), a sham operation was performed in which the posterior C2-5 laminas and facet joint were exposed and the cervical spine ligamentous complex was kept intact. In the IM-vivo subgroup, the posterior C2-5 laminas and facet joint were exposed and only the cervical spine ligamentous complex

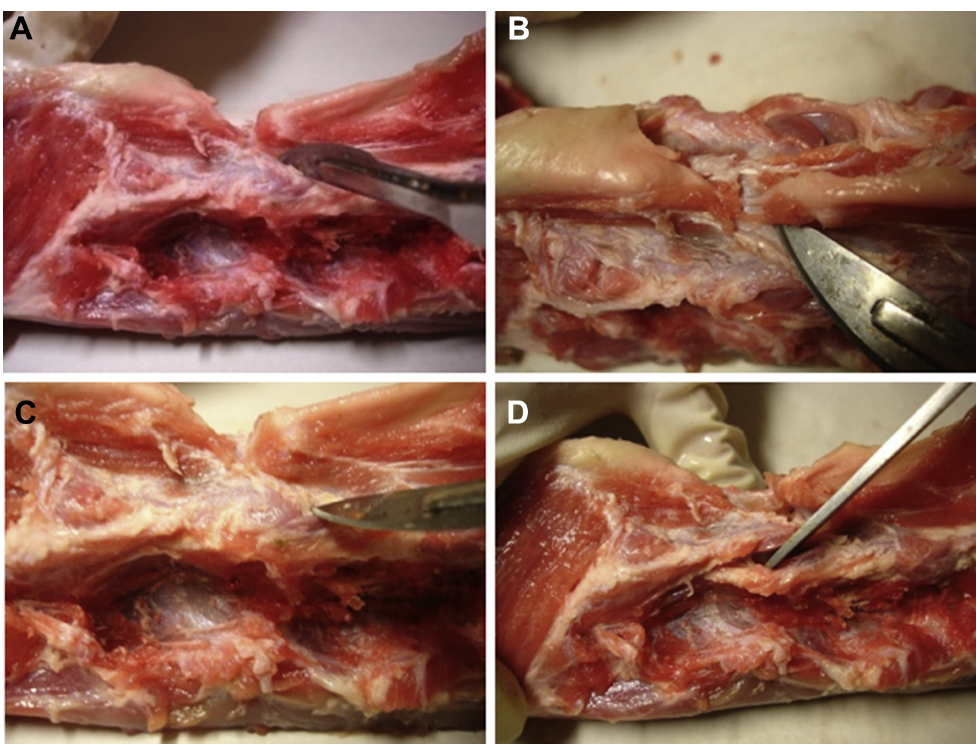

Figure 1. Representative posterior ligamentous complex injury model. (**A**) Resected interspinous and spinous ligaments (lateral view). (**B**) Resected ligament flavum (dorsal view). (**C**) Resected bilateral facet joint capsule (lateral view). (**D**) Lever bilateral facet joint to simulate posterior ligamentous complex injury in acute flexion-distraction cervical spine trauma (lateral view).