BIOMECHANICAL ANALYSIS OF SPINAL INSTRUMENTATION FOR LUMBAR BURST FRACTURES

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The goal of this study was to assess of axial stiffness of several Alıcı Instrumentation procedures. Compressive axial stiffness were measured in eight calf lumbar spines at the Middle East Technical University. A corpectomy was performed to simulate a burst injury. One calf spine was tested intact. The tested construct pattern were: corpectomy model without instrumentation (ICM); upper and lower hook pattern (HPI); upper claw and lower hook pattern (CPI); upper claw with lower pedicle screws (CTPI); short segment pedicle instrumentation (SPI). In addition to tests performed for CTPI and anterior instrumentation with anterior strut grafts (CTPIG, AIG) were employed. These analysis showed that the stiffest construct was the posterior instrumentation with anterior strut (CTPIG). In addition to these findings claw pattern and pedicle screws were found to be the best bone-metal connections.

***Key Words:** Biomechanics, Burst Fractures, Posterior Instrumentation.*

INTRODUCTION

A number of spinal implants are available for the treatment of vertebral burst fractures. Implant configurations include rods with sublaminar wires, hooks, transpediculer screws and plates etc.

Previous investigators have studied the biomechanics of spinal instrumentation systems by employing different methods of stimulating decompression and instability, different types of materials to simulate a bone graft, and different species for testing (3, 4, 5, 6).

Abumi and Panjabi (1) compared seven fixation devices. Transpedicular external fixator with interbody bone graft provided good resistance and stability in all load modes.

Gurr (5) studied a calf corpectomy model with different types of anterior and posterior instrumentation that the least rigid construct were iliac grafting alone, Harrington-rod instrumentation and Luque rectangular instrumentation. The most rigid constructs were the anterior Kaneda device, transpedicular Cotrel-Dubousset instrumentation and Steffee screws and plates.

Gurwitz (6) compared VSP plates and Kaneda systems on swine spines. He suggested that anterior-posterior approach restores axial stiffness to that of the intact spine with the anterior-posterior approach restores axial stiffness to that of the intact spine with the anterior approach being significantly more stiff and providing better biomechanical characteristics overall and posterior approach alone.

In our study we compared different types of Alıcı posterior and anterior instrumentations with or without anterior strut grafts.

MATERIAL AND METHOD

Seven of the eight fresh calf lumbar spines were stripped of soft tissue, leaving the discs ligaments, joint capsules, superior and inferior end plates intact. L3 bodies and posterior longitudinal ligaments of species were removed to simulate burst fracture injuries.

Our models were: intact spine; corpectomy model without instrumentation (ICM); upper and lower hook pattern (HPI); upper claw and lower hook pattern (CPI); upper claw hook with lower pedicle screws (CTPI); short segment pedicle instrumentation (SPI); CTPI with anterior strut graft (CTPIG); anterior instrumentation with anterior strut graft (AIG).

All biomechanical tests were carried out on Mohr & Federhaff Universal Testing Machine at Middle East Technical University. The tests were run under the costant loading speed of 5 mm/min.

RESULTS

The compression tests results of eight calf lumbar spines containing different Alıcı configurations were as follows.

1. Ultimate compressive load for intact spine was 17000 N.
2. Posterior column of ICM was fractured under axial compressive loading of 2350 N

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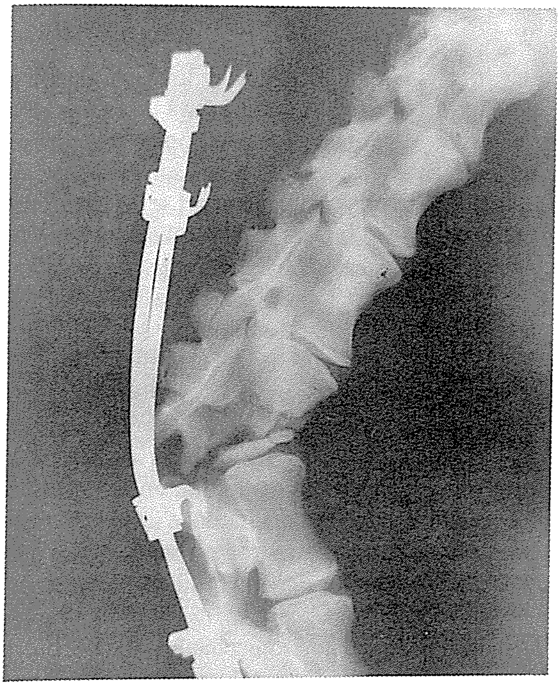

Fig. 1. Lateral radiograph of failure upper hooks of the HPI model

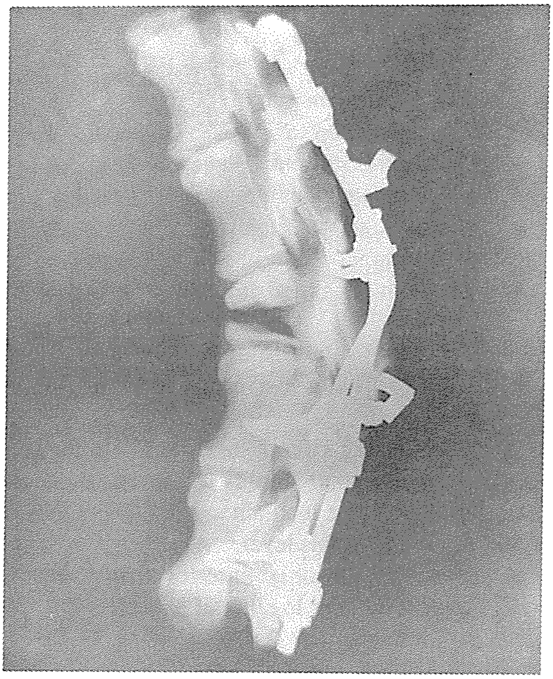

Fig. 2. Lateral radiograph of CTPI model. Although bending of upper hooks, no separation was seen.

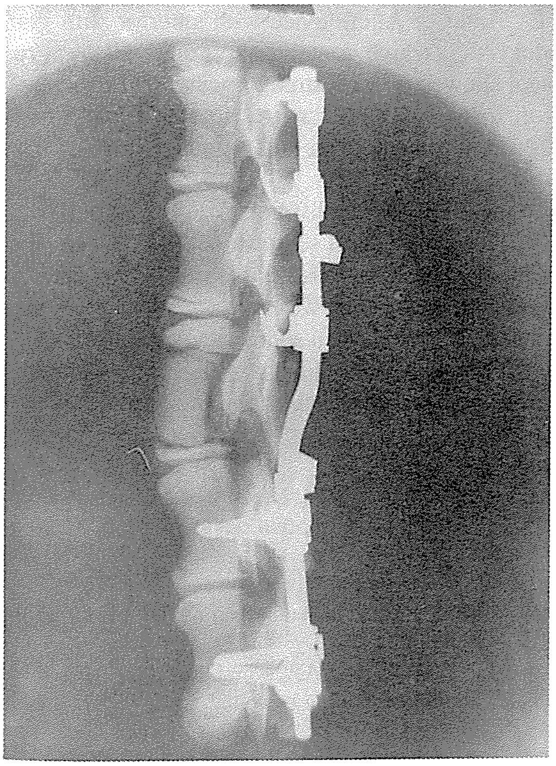

Fig. 3. Our stiffest model was CTPIG.

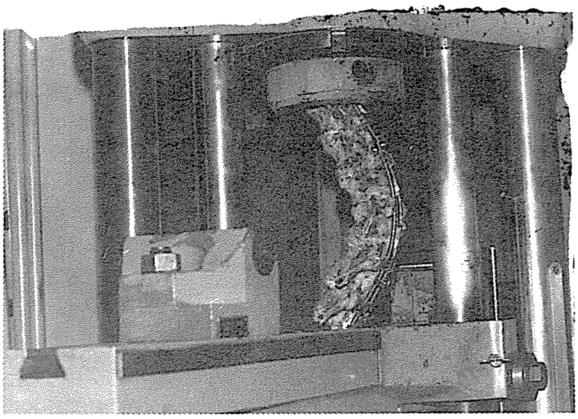

Fig. 4. Calf lumbar spine specimen mounted in the testing machine.

3. HPI was broken under the axial loading of 2450 N. Before the test completed the upper hooks were separated from the spine.

4. CPI resisted up to 3500 N. No separation took place between the spine and upper hooks. But lower hooks were separated from the spine at this level.

5. The ultimate compressive load for CTPI was 3680 N. The upper claw hooks and transpedicular screws were not separated from the spine during the test.

6. SPI model showed no separation between the spine and transpedicular screws under the compressive loading of 3300 N.

7. CTPI model containing anterior strut graft (CTPIG) resisted up to 7000 N which was the highest ultimate compressive load among the others. No separation were seen at this level.

8. AIG was the only anterior instrumentation model that failed under loading of 3800 N.

DISCUSSION

Burst fractures, which disrupt both the anterior and middle columns, have been described as inherently and often require surgical treatment (2). Experimental burst fracture models (4, 7) or corpectomy models were used for biomechanical studies. The corpectomy model presents a worst case model for anterior and middle column injury (6). When comparing the instrumentation, various prototypes of the spine (calf 11, swine 6, cadaver 3, 8) were used without correlating the anatomic and biologic differences among these models.

There are three basic biomechanical tests: strength, fatique and stability (9). In this study, the ultimate compressive strengths of calf lumbar spines containing various types of Alıcı configurations were determined. In the first experiment which has been conducted on ICM model, the fracture took place on posterior column of the spine under the compressive load of 2350 N. HPI model was fractured under the load of 2450. When these two models (ICM and HPI) are compared, it is seen that they have almost an equal strength. The reason for HPI model having a low strength as ICM model was due to the separation of upper hooks from the spine.

When the claw pattern was used instead of caudal upper hooks (CPI) no separation took place at the upper hooks but cephalad lower hooks were separated from the spine during the test. Then lower hooks were replaced by a pair of transpedicular screws (CTPI). In this case, the upper hooks and transpedicular screws kept their original positions during the test. The same results can be obtained by using claws instead screws. These results showed that claw hooks and pedicle screws were rigidly connected to the spines.

In our clinical experience of short segment pedicle instrumentation, we had seen the broken screws. But no broken screws were seen when we tested SPI model. We concluded that fatigue failure might be the main reason for fracturing the screws.

The ultimate compressive loads for HPI, CPI, CTPI and SPI models were 2400, 3500, 3680 and 3300 N, respectively. Differences between these results were not significant. Comparing these results with either 17000 N of intact spine and 7000 N of CTPIG values a significant difference in strength values was seen. These high strength values indicated that increase in rigidity occured with the addition of an anterior strut graft.

Conclusions: 1. The biomechanical study on calf corpectomy models under axial compressive loading showed that Alıcı posterior instrumentation with anterior strut graft having 7000 N strength was found to be the most rigid system.

2. Anterior Alıcı device with anterior strut graft model (AIG) which contains short and unilateral rod system showed a lower strength value than Alıcı posterior instrumentation with anterior strut graft (CTPIG). But it was more stiff than the other posterior models.

3. No significant difference in strength values was seen between short segment pedicle instrumentation model and other posterior models. However, in our clinical experience we have seen that short segment pedicle systems had some disadvantages.

4. Pedicle screws and claw pattern were found to be the best bone-metal connections.

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