Four year experience with the AO Anterior Thoracolumbar Locking Plate

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For decades spinal surgeons have attempted to design simple, single stage anterior internal fixation systems for the thoracic and lumbar spine. Early devices presented both biomechanical and technical problems. The AO Anterior Thoracolumbar Locking Plate (ATLP) was designed to solve some of the problems encountered with early anterior instrumentation. The ATLP system is constructed in Commercially Pure titanium. It is a low profile device indicated for use for unstable burst fractures in the anterior column; metastatic tumor management; and degenerative diseases of the thoracolumbar spine between levels T10 and L5. Implantation of the device involves direct anterior decompression with sagittal reduction and corpectomy. This is followed by grafting reconstruction, and plate fixation. This device has been implanted in 25 patients with an average follow-up of 38 months. There were five (5) broken screws in three (3) patients, and no broken plates. Implant related postoperative complications included two misplaced screws. Preliminary results indicate that the ATLP system seems to be a safe, low profile, MRI/CT compatible device that provides definitive single stage fixation of the anterior spinal column.

Keywords: internal fixation; thoracolumbar spine; AO Anterior Thoracolumbar Locking Plate; anterior column

Introduction

Anterior instability of the thoracic and lumbar spine, with and without neurological deficit has been a controversial area of management for spinal surgeons for decades. Reliable techniques were developed utilizing posterior instrumentation for unstable fractures in the 1960s with Harrington rods. Harrington instrumentation was biomechanically flawed^{1–4} and had serious rotational instability drawbacks. Subsequent posterior devices were developed including the AO Internal Skeletal Fixator;^{1,2,6–8} and the Cotrel-Dubosset,^{9–11} and the Isola types of rod/screw constructs. These devices provided stability for immediate mobilization and powerful reduction and fixation capabilities. Even with these improved devices, posterior instrumentation alone for an anterior column injury was a controversial approach. The inadequacy of posterior instrumentation to solve all spinal instability problems necessitated the development of anterior fixation systems.

Several authors^{8,12–17} have demonstrated the advantages of direct anterior decompression for anterior neural compression in burst fractures as was first popularized by Bohlman in the 1970s.^{1,18,19}

Initially, the corpectomy defect was stabilized with a tricorticate iliac crest graft or fibular strut allograft. Posterior instrumentation or external immobilization was still necessary to provide reliable stability. This caused prior investigators to develop anterior fixation devices to allow definitive single stage decompression and anterior stabilization.^{7,8,12–15,20,21} The early devices such as the AO DCP plate¹⁶ and the Contoured Anterior Spinal Plate system²⁰ lacked reduction capabilities and did not have rigid plate-screw interfaces to stop adjacent segments from falling into kyphus. Other systems developed include the Kostuik device,²¹ and the first generation AO plate developed by Yuan.⁸ These devices also lacked a rigid fixed plate-screw interface which could lead to kyphus and screw migration from the plate.

Anterior fixation systems that were more rigid in design were developed by Dunn,²² and Kaneda¹⁵ simultaneously. The Dunn device provided immediate rigid stability of the fracture. However, it was a high profile device that led to reported cases of death caused by aortic erosion.²³ The Kaneda system also provided rigid stability of the fracture but was too technically demanding.

Another drawback shared by all of these prior devices was that each was manufactured in stainless steel which seriously interferes with postoperative MRI

and CT images. Also, many patients are allergic to the high content of nickel found in stainless steel. The recently developed Z-plate by Zdeblick,²⁴ is a fairly rigid device which is manufactured in titanium. However, the Z-plate is a relatively high profile device and lacks a locking screw/plate interface.

AO stands for Arbeitsgemeinschaft fuer Osteosynthesefragen, or in English, Association for the Study of Internal Fixation. The AO is a non-profit foundation whose primary philosophy is: 'anatomic reduction, stable fixation, atraumatic surgical technique, and early mobilization foregoing external fixation'. The Anterior Thoracolumbar Locking Plate (ATLP, Synthes USA, Paoli, PA) was developed by the AO with this philosophy in mind. The system provides compression and rigid fixation across a bone graft in the anterior thoracolumbar spine and allows for rapid mobilization of the patient in lieu of external fixation. The ATLP is approved by the United States Food and Drug Administration for use between levels T10 and L5. It is inherently low profile, with a smooth, rounded contour (Figure 1). This device can be turned either so that the curve is in lordosis or in kyphosis, depending on which is needed. This implant was designed to be placed anterolaterally. The ATLP system is a rigid fixed angle system which allows a stable sagittal plane reconstruction. The plate design allows for two screw fixation points per anchoring vertebral body. The posterior screw orientation is perpendicular to the plate, thus avoiding spinal canal penetration. The anterior screw orientation is posteriorly directed to give a triangulation effect in the vertebral body which prevents screw 'back-out' (Figure 2). The ATLP system includes a titanium plate in various sizes depending upon anatomical differences, and titanium screws. Four screws are permanently seated in the chosen vertebral bodies at the conclusion of implantation. Two temporary screws are used to hold the plate in place for drilling and seating of the permanent screws; to provide direct compression across the graft; and secure the plate to the spine. A specific set of instruments (AO/ASIF Spinal Instruments for Anterior Surgery) are used to facilitate implantation of this system.

Biomechanically, the system is extremely rigid. This is demonstrated by two common analyses used to test plate rigidity. The system has been tested to dynamic failure at 10,000,000 cycles of a load at approximately 900 newtons. The maximum load before deflection of 15 nm occurs was approximately 1400 newtons. An anterior device must be able to handle the significant compressive forces of the anterior column. These two tests show that the ATLP system can withstand those forces without failure. The screw removal torque is approximately 5.5 nm. This, combined with the advantage of a locking plate/screw interface, ensures the likelihood of screw migration or 'back-out' is reduced significantly compared with previous anterior systems. The mode of failure in an incomplete compressive load cycle is that of plate failure in the

vertebrectomy model. However, if the plate is loaded cyclically, completely in distraction and then completely in compression, the mode of failure is screw breakage.

While the ATLP provides rigid fixation, it does not provide reduction capabilities. Reduction must be attained with supplementary instrumentation and grafting prior to inserting the device. Indications for use of the Anterior Thoracolumbar Locking Plate include burst fractures, metastatic tumors, infections, and degenerative diseases of the thoracolumbar spine

Figure 1 The Anterior Thoracolumbar Locking Plate is curved into lordosis or kyphosis depending on the orientation. It is designed for two screws in each vertebral body and the possibility of intervening segmental fixation. Reprinted from *Manual of Internal Fixation of the Spine*, Thalgott JS, Aebi M (eds) by permission of the publishers Lippincott-Raven

Figure 2 Triangulate-angled screws locked into the plate and shown embedded in the vertebral body

from levels T10 to L5. The system should not be used in patients with poor bone quality; on vertebral bodies too small to hold the construct; or for the management of unreduced fracture dislocations.

Materials and methods

Twenty-five (25) patients, 17 female and eight (8) male, were implanted with the ATLTP. The average age was 43.8 years with a range of 22 to 81 years. Primary diagnoses included 14 fractures at the thoracolumbar junction; three metastatic tumors; one gun shot wound (which we place in the 'traumatic' group), two disc herniations; one failed laminectomy; one post-traumatic kyphosis; one pseudarthrosis; one spondylolisthesis; and one spondylolysis which we place in the 'non-traumatic' group. Twenty-two (22) patients were non-smokers at the time of their surgeries. Twenty-three (23) patients had private insurance and 21 patients had had no prior spine surgeries.

There were no neurological deficits presented in the non-traumatic group. However in the traumatic group, two (2) patients presented with complete paraplegia; one (1) patient presented with spinal canal compromise from a retropulsed fracture fragment and partial paraplegia; one (1) patient presented with spinal canal compromise from a metastatic tumor; and three (3) patients presented with myelopathy. There were four (4) single-level and 20 double-level fusions as well as one (1) triple-level fusion. Alternative approaches to the traumatic group were discussed previously. With respect to the eight (8) patients in the non-traumatic group, each had had conservative treatment for at least 6 months, which had failed, prior to the surgery. Other instrumentation such as transpedicular or translaminar fixation may have been used in conjunction with anterior discectomy and fusion. However, it was decided that single stage anterior fixation was the most beneficial treatment for this set of patients. The greatest deformity or vertebral angulation encountered was in the patient with grade II isthmio-lytic spondylolisthesis. In the judgment of the surgeon, patients with a partial or complete neurological deficit were deemed to be in need of immediate stabilization. The technique used for implantation of the ATLTP was as follows:

Once the decision for anterior decompression and fixation was made, there were several options for approach. These included a thoraco-abdominal; transthoracic; or retroperitoneal approach. It is the authors' personal bias that a right sided approach is best for thoracolumbar fractures or thoracolumbar pathology. The pathological level was identified followed by a standard corpectomy or discectomy with or without neural decompression. Next, an osteotomy was used to square the end plates and make them as parallel as possible. Following this, appropriate sized bone graft or cage was chosen to span the corpectomy site. Choices available to the surgeon included autograft, allograft, or a cage

system. Our current preference is the MOSS titanium cage system packed with coral or autologous bone (Table 1). Once the graft was inserted, the appropriate sized plate was chosen, and was placed anterolaterally on the posterior one-quarter of the vertebral bodies. A lateral radiograph was taken to ensure proper positioning. Temporary fixation was achieved using small fragment titanium screws. Temporary fixation was necessary before seating the permanent screws because the torque required to seat the screws is quite high. Temporary holes were drilled to a depth of 40 mm with a 2.5 mm drill using a DCP drill guide. The temporary small fragment screws were then placed in a 'double DCP' mode. This was done by putting the screws in loosely and tightening each temporary screw against the other providing additional compression across the graft (Figure 3). Once the temporary fixation and resulting compression of the graft were achieved, the posterior holes were drilled. Dedicated drill guides were

Table 1 Fusion materials used with the ATLTP

Graft	No. of patients
Tricorticate autograft/fibular strut allograft	7
Fibular strut allograft	6
MOSS titanium cage/tricorticate autograft	5
Polymethylmethacrylate	2
Fibular strut allograft/GraftOn demineralized bone matrix	1
MOSS titanium cage/polymethylmethacrylate	1
Fibular strut allograft/GraftOn demineralized bone matrix/Pro Osteon 500 coralline hydroxyapatite	1
MOSS titanium cage/tricorticate autograft/GraftOn demineralized bone matrix	1
MOSS titanium cage/tricorticate autograft/GraftOn demineralized bone matrix/Pro Osteon 500 coralline hydroxyapatite	1

Figure 3 The ATLTP after seating the temporary fixation screws on a sawbones model. Reprinted from *Manual of Internal Fixation of the Spine*, Thalgot JS, Aebi M (eds) by permission of the publishers Lippincott-Raven

screwed into the posterior holes of the plate to ensure perpendicular placement of the drill relative to the plate (Figure 4). The holes were drilled to a depth of 30–35 mm. The drill bits used have automatic stops to prevent over-drilling. The correct size screws were selected by measuring the depth of the vertebral body and adding 5 mm for the plate thickness. After drilling the holes, the threaded drill guides were removed and the two 7.5 mm permanent posterior screws were inserted. The temporary screws were then removed. The threaded drill guides were screwed into the anterior holes; the anterior holes were drilled; and the screws were inserted into the vertebral bodies. All four screws must be completely seated into the plate to secure the locking mechanism of the screw (Figure 5). Intraoperative lateral and AP radiographs were taken to ensure proper placement and also to ensure that the screws were entirely contained within the vertebral bodies and did not enter the spinal canal.

Figure 4 The dedicated drill guides are used to ensure angle-perfect placement of the posterior screws

Figure 5 The ATLP with all 4 screws locked into the plate. Reprinted from *Manual of Internal Fixation of the Spine*, Thalgott JS, Aebi M (eds) by permission of the publishers Lippincott-Raven

Results

Of the 25 patients implanted with the ATLP system, the average follow-up time for this group was 38 months with a range of 21 to 52 months. The average blood loss was 800 cc. There were no complications perioperatively. Postoperatively, 19 patients have fully intact instrumentation. Three (3) patients retained a total of five (5) broken screws; and three (3) patients with metastatic disease have died of complications unrelated to their surgery in the perioperative time frame. No patient in the non-traumatic group had any neurological deterioration. In the traumatic group, one female patient developed difficulty with urinary control. No sexual or bowel complications occurred postoperatively. The three (3) patients presenting with myelopathy improved clinically and continue to do so. The patient who had spinal cord compromise from a retropulsed bone fragment now has minimal back pain and no neurological deficit at 24 months. A male patient who presented with complete paraplegia improved considerably and now walks without assistance of any kind at 24 months postoperatively (Figure 6). The other patient who had complete

Figure 6 A lateral radiograph at 8 months postop of a 29 year old male patient presenting with complete paraplegia and anterior burst fracture at L2. The patient now walks without assistance

paraplegia has not improved neurologically, but also has not deteriorated further.

We encountered two postoperative implant complications. In one patient, the plate was too long. Consequently, the screws cut into the endplate and required posterior instrumentation. In another patient, the surgeon became disoriented in the caudal placement of the plate which resulted in violation of the spinal canal by the screw. This was not detected in the intraoperative radiographs but was discovered at follow-up. This did not produce a neurological deficit, but revision with posterior instrumentation was necessary, without sequelae. There was no radiographic evidence of any degree of pseudarthrosis or of resorption of the bone grafts. All of the grafts are either fused or were heavily consolidated, based upon AP and lateral radiographic evaluation.

Discussion and conclusion

Of the patients with broken screws: Two had first generation screws which have subsequently been redesigned. The first generation screw had a very short machine thread which led to a stress riser in the

screw. The machine thread design was lengthened giving a larger cross sectional area at the plate/screw junction. One of these patients lost correction of approximately five degrees but did not require subsequent posterior instrumentation. The third patient, a 65 year old female retained two (2) broken second generation screws. She was severely osteopenic causing the screws to back-out and subsequently fracture at 24 months postoperatively (Figure 7). Her clinical result is good, with no neurological deficit and there appears to be solid fusion. This patient has chosen to refrain from removal of the ATLP.

We feel that after review of the biomechanical studies and our initial clinical experience, this implant proves to be a rather simple, safe device which provides immediate stability after direct anterior spinal decompression for a variety of pathologies. It is also MRI/CT compatible (Figure 8) and allows visualization of the surrounding soft tissues. Anterior fixation technology has evolved over the last two decades with the aim of providing definitive single stage management of anterior pathology. This new implant provides definitive technological advances over conventional anterior systems.

Figure 7 A lateral radiograph at 18 months postop of a 76 year old osteopenic female presenting with pseudarthrosis at T12–L1. Her caudal screws backed out due to her osteopenia and then fractured. Her clinical condition is good with no neurologic deficit and she appears to be solidly fused

Figure 8 A three-dimensional CT scan showing the compatibility of the ATLP with postoperative testing. Reprinted from *Manual of Internal Fixation of the Spine*, Thalgot JS, Aebi M (eds) by permission of the publishers Lippincott-Raven

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