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Transdiscal screw fixation in L5-S1 spondylolysis: A biomechanical study

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Abstract
Aim: This study aimed to investigate whether the L5-S1 transdiscal screw fixation is biomechanically sufficient against axial loads and the resulting shear forces.
Material and Methods: Eighteen fresh calf spines under 1 year of age were used in this study. Two randomly selected spines were used as test materials. The inferior facet and ligamentum flavum were removed in 7 randomly selected spines. In these spines (transdiscal screw group), two transdiscal screws were placed bilaterally between L5 and S1. Tests were performed on the remaining 9 spines, while the spines were initially intact (intact group) and after creating a listhesis model (injury group). The extent of displacement occurring as a result of axial loading was noted in all groups in order to calculate the load-displacement curves.
Results: The mean displacement as a result of successive axial loadings of 5000 N was as follows: 3 mm (range: 2.4 - 4 mm) in the intact group, 3.5 mm (range: 3 - 4.5 mm) in the transdiscal screw group and 4.5 mm (range: 3.9 - 5 mm) in the group with injury. The difference was statistically significant ($p<0.05$). None of the samples exhibited broken screws, screw deformation or dislocation, even in failure tests, in the transdiscal screw group.
Discussion: These findings have shown that transdiscal screw fixation can be biomechanically sufficient against the shear forces occurring as a result of axial loading. We believe that this technique can be a good alternative as a fixation method for the L5-S1 spondylolisthesis.

Keywords
Biomechanics; Spondylolisthesis; Transdiscal Screw

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Introduction

The surgical fixation technique to be employed in spondylolisthesis remains controversial due to the challenges in achieving reliable fixation. Spinal fusion has long been used for the stabilization of vertebral segments with abnormal mobility [1]. The posterolateral fusion technique employed without instrumentation is known to be associated with high rates of pseudoarthrosis in the surgical treatment of spondylolisthesis, particularly at the L5-S1 level. As the severity of listhesis increases, it becomes more difficult to achieve fusion, which leads to higher rates of failure and pseudoarthrosis [2,3]. Significantly increased fusion rates were observed with segment instrumentation that prevents movement [1,4].

The pursuit in this field is still ongoing, although pedicle screws constitute an important step considering the history of segment fixation techniques. The transpedicular screw fixation technique was first described by Harrington and Tullos in 1969 [5]. This technique is still considered the gold standard by some authors, due to its biomechanical advantages and high fusion rates. Abdu et al. described the transdiscal screw fixation technique in 1994 and used transdiscal screws in combination with pedicle screws [6]. The biomechanical and clinical advantages of this combined technique were later demonstrated by numerous authors [3,7,8]. Grob et al. published a case series of 16 patients in which they used transdiscal screws alone in 1996. In the mentioned study, fusion was achieved in all patients according to the radiologic assessment, and it was stated that the transdiscal screw fixation technique alone was both simple and minimally traumatic with highly successful clinical outcomes [9].

A fixation method should be able to provide resistance against the strong mechanical forces that will be endured until the achievement of fusion in order to be suitable or ideal for the surgical treatment of spondylolisthesis. Therefore, biomechanical testing of the said method is of utmost importance for determining the suitability of a fixation technique.

This study aimed to investigate whether the L5-S1 transdiscal screws are biomechanically sufficient against axial loading and the resulting shear forces.

Material and Methods

Eighteen fresh calf spines under 1 year of age were used in this study. The spines were kept at -20° until testing. Biomechanical tests were conducted on the sacrum and on the vertebra that is adjacent and superior to the sacrum. Two randomly selected models were used as test materials. These two spines were observed in terms of deformation under various loads. As a result of these tests, the upper limit of loading and test speed were determined to be 5000 N and 5 mm/min, respectively.

Of the remaining 16 fresh frozen calf spines, 9 randomly selected spines were initially tested while they were intact. The test results of this group were documented as results of the intact group. This was followed by creating a defect at the lamina and isthmus by removing the inferior facet and ligamentum flavum in these 9 spines. This group was subjected to testing once more, after creating an L5-S1 lysis model. The test results of this group were documented as results of the group with injury. A lysis model was initially created in the third group, i.e. the remaining 7 spines. Titanium screws with a diameter of 7 mm were bilaterally inserted from the lateral aspect of the first sacral foramina posteriorly, in the caudal to cranial and lateral to medial direction in a manner to pass through 3 cortical surfaces, i.e. the posterior wall of the sacrum, sacral endplate and L5 endplate, respectively. This group, in which two transdiscal screws were placed bilaterally between L5 and S1, was subjected to testing as the transdiscal screw group. This group was tested once more by removing the upper loading limit of 5000 N. The test was continued until the samples exhibited failure. All tests were performed with a Schimadzu compression testing machine.

The extent of displacement resulting from axial loading was noted in all groups (the group with injury, intact group and the transdiscal screw group) in order to calculate the load-displacement curves. The non-parametric Wilcoxon Test was used to compare the extent of displacement between the groups. $P<0.05$ was considered statistically significant.

Results

The mean displacement resulting from successive axial loadings of 5000 N were as follows: 3.07 ± 0.53 mm (range: 2.4 - 4 mm) in the intact group, 3.5 ± 0.52 mm (range: 3 - 4.5 mm) in the transdiscal screw group and 4.5 ± 0.34 mm (range: 3.9 - 5 mm) in the group with injury. The difference was statistically significant ($p = 0.007, 0.018, 0.034$) ($p<0.05$). None of the samples exhibited broken screws, screw deformation or dislocation, even in the failure tests performed by removing the upper loading limit of 5000 N, in the transdiscal screw group. In this group, all failures were observed at the L5 level.

Discussion

Spondylolisthesis is a dynamic condition that leads to symptoms such as neurogenic claudication, lower back and leg pain, which have been studied by spinal surgeons for a long time. Patients with severe listhesis who do not benefit from nonsurgical treatment are candidates for surgical treatment. The main goal of surgical treatment is to obtain rigid fusion. Pseudoarthrosis rates up to 40% have been reported in fusion procedures performed without internal fixation [2,3]. On the other hand, internal fixation has led to a significant increase in fusion rates [1,4]. Although the relevant scientific evidence is scarce, decompression, instrumentation and posterolateral fusion are considered the gold standards, particularly in the treatment of isthmic spondylolisthesis [10]. However, posterior fusion fails to suffice with increased degree of slippage, thereby leading to higher rates of pseudoarthrosis, especially in high-grade spondylolisthesis [2,3,8,11]. This causes overloading of the instruments, which, in turn, leads to instrument failure [11]. Therefore, spinal surgeons began seeking ways of achieving more rigid fixation.

Lehman et al. demonstrated that tricortical screw fixation provided higher biomechanical strength compared to bicortical screw fixation [12]. In this study, the transdiscal screws were placed in a manner to grip three cortices consisting of the posterior wall of the sacrum, S1 endplate and L5 endplate. Therefore, we believe that these screws are highly resistant to detachment forces.

Solid fusion is essential to obtain good outcomes in surgeries for spondylolisthesis [13]. Moreover, a good fusion requires rigid internal fixation until fusion is achieved. In traditional pedicle screw, fixation performed in high-grade L5-S1 spondylolisthesis, shear forces occurring as a result of axial loads on the anterior column lead to failure, thereby causing slip progression (increase in the extent of slippage). This brings up the necessity of additional anterior support. Beringer et al. reported that the use of a transvertebral interbody cage provided sufficient anterior support against the shear forces in high-grade spondylolisthesis [7].

Highly satisfactory clinical outcomes have been reported in studies employing a combination of pedicle and transdiscal screws [6,11]. Minamide et al. performed biomechanical tests on transdiscal screws used in combination with pedicle screws, and reported that transdiscal screws led to 1.8-fold increase in system strength [3].

We believe that transdiscal screws act like a cage and support the anterior column, which makes them highly sufficient from the biomechanical aspect. This stems from the fact that the location of these screws is very close to the site where interbody cages should be placed. In addition, these screws are placed almost perpendicular to the shear forces resulting from axial loading. This constitutes a biomechanical advantage, which also explains the high resistance to these shear forces.

In conclusion, we are of the opinion that transdiscal screws are biomechanically sufficient against the shear forces resulting from axial loading, and therefore transdiscal screw fixation can be a good alternative as a fixation method for achieving fusion in patients with spondylolisthesis.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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Conflict of interest

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References

1. El Masry MA, McAllen CJ, Weatherley CR. Lumbosacral fusion using the Boucher technique in combination with a posterolateral bone graft. Eur Spine J. 2003;12(4):408-12.

2. Roca J, Ubierna MT, Cáceres E, Iborra M. One-stage decompression and posterolateral and interbody fusion for severe spondylolisthesis. An analysis of 14 patients. Spine (Phila Pa 1976). 1999;24(7):709-14.

3. Minamide A, Akamaru T, Yoon ST, Tamaki T, Rhee JM, Hutton WC. Transdiscal L5-S1 screws for the fixation of isthmic spondylolisthesis: a biomechanical evaluation. J Spinal Disord Tech. 2003;16(2):144-9.

4. Fritzell P, Hägg O, Wessberg P, Nordwall A, Swedish Lumbar Spine Study Group. Chronic low back pain and fusion: a comparison of three surgical techniques: a prospective multicenter randomized study from the Swedish lumbar spine study group. Spine (Phila Pa 1976). 2002;27(11):1131-41.

5. Harrington PR, Tullos HS. Reduction of severe spondylolisthesis in children. South Med J. 1969;62(1):1-7.

6. Abdu WA, Wilber RG, Emery SE. Pedicular transvertebral screw fixation of the lumbosacral spine in spondylolisthesis. A new technique for stabilization. Spine (Phila Pa 1976). 1994;19(6):710-5.

7. Beringer WF, Mobasser JP, Karahalios D, Potts EA. Anterior transvertebral interbody cage with posterior transdiscal pedicle screw instrumentation for high-grade spondylolisthesis. Technical note. Neurosurg Focus. 2006;20(3):E7.

8. Bartolozzi P, Sandri A, Cassini M, Ricci M. One-stage posterior decompression-stabilization and trans-sacral interbody fusion after partial reduction for severe L5-S1 spondylolisthesis. Spine (Phila Pa 1976). 2003;28(11):1135-41.

9. Grob D, Humke T, Dvorak J. Direct pediculo-body fixation in cases of spondylolisthesis with advanced intervertebral disc degeneration. Eur Spine J. 1996;5(4):281-5.

10. Jacobs WC, Vreeling A, De Kleuver M. Fusion for low-grade adult isthmic spondylolisthesis: a systematic review of the literature. Eur Spine J. 2006;15(4):391-402.

11. François J, Lauweryns P, Fabry G. Treatment of high-grade spondylolisthesis by posterior lumbosacral transfixation with transdiscal screws: surgical technique and preliminary results in four cases. Acta Orthop Belg. 2005;71(3):334-41.

12. Lehman RA Jr, Kuklo TR, Belmont PJ Jr, Andersen RC, Polly DW Jr. Advantage of pedicle screw fixation directed into the apex of the sacral promontory over bicortical fixation: a biomechanical analysis. Spine (Phila Pa 1976). 2002;27(8):806-11.

13. Sasso RC, Shively KD, Reilly TM. Transvertebral transsacral strut grafting for high-grade isthmic spondylolisthesis L5-S1 with fibular allograft. J Spinal Disord Tech. 2008;21(5):328-33.

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