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Minimally Invasive Augmented Fixation for Anatomical Reduction of Grade 2 and Grade 3 Listhesis in Patients with Osteoporosis

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Study Design: A retrospective study.
Purpose: To study the efficacy of augmented fixation for anatomical reduction of grade 2 and grade 3 listhesis in patients with osteoporosis.
Overview of Literature: Spondylolisthesis in osteoporotic patients requiring spinal fixation are associated with complications such as loss of surgical construct stability, screw pulling out, and screw loosening. Augmented fixation is a novel strategy to achieve necessary construct integrity.
Methods: Thirteen consecutive patients with grade 2 or grade 3 listhesis, with proven osteoporosis on dual energy X-ray absorptiometry (DEXA) scan, and who underwent augmented fixation for reduction of listhesis were retrospectively analyzed. In all patients, surgical access was achieved with a fixed 22 mm tubular retractor. A modified technique of bilateral, sequential, transforaminal decompression and discectomy, followed by reduction of listhesis using unilaterally placed augmented screws was employed in all the cases. Patients were followed up with plain X-rays at regular intervals to assess for implant stability and fusion status. All patients were started on medical treatment for osteoporosis.
Results: The mean age of the patients was 52.46 years, with 12 females and one male. The median T-score on DEXA scan was –3.0. Of the 13 patients, listhesis was at L4–L5 in five and at L5–S1 in eight. Nine patients had grade 2 listhesis, while four patients had grade 3 listhesis. Complete reduction was achieved in 10 patients. The median duration of follow-up was 18 months. Postoperative outcomes were satisfactory in all cases.
Conclusions: Augmented fixation is a useful technique for achieving anatomical reduction of listhesis in patients with osteoporosis.

Keywords: Spondylolisthesis; Bone cement; Osteoporosis; Spinal fusion; Minimally invasive surgeries

Introduction

Osteoporosis is a silent disease, reflected in low bone density. In India, estimates put the number of patients with osteoporosis at 25–36 million [1]. Due to higher life expectancy, the numbers of patients presenting with spinal conditions featuring osteoporotic bone are increasing. Spondylolisthesis is an important disorder of the aging

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spine and has a significant effect on health-related quality of life in symptomatic adults. Surgical interventions and routine bone screw fixations are perilous to this group of patients because of complications such as loss of surgical construct stability, screw loosening, pull out, and implant failure. A strong transpedicular screw construct is essential for achieving and maintaining anatomical reduction in patients with osteoporosis and listhesis. Augmented fixation is a novel strategy for enhancing bone for screw purchase to achieve necessary construct integrity [2]. Use of cannulated fenestrated screws that deliver the cement concentration at the distal tip of the screw within the vertebral body addresses this concern in these patients. The present case series elaborates outcomes after using minimally invasive augmented fixation with cement injected through fenestrated screws for achieving reduction of listhesis in patients with osteoporosis.

Materials and Methods

Thirteen consecutive patients with grade 2 or grade 3 listhesis and proven osteoporosis (T-score <−2.5) on dual energy X-ray absorptiometry (DEXA) scan were retrospectively analyzed for demographic, clinical, and radiological (dynamic plain radiographs and magnetic resonance imaging of lumbosacral spine) data. Visual Analog Scale scores were individually assessed for axial and radicular symptoms during the preoperative period, on the first postoperative day, and at 3-month follow-up. Japanese Orthopedic Association (JOA) scores were assessed preoperatively and at 3 months postoperatively. JOA recovery rate was calculated by Hirabayashi formula and was used to assess clinical improvement. Plain standing radiographs were performed on the second postoperative day and at 3 months. Fusion status was assessed using a dynamic radiograph at the time of the latest follow-up for each patient.

1. Surgical technique

All patients were operated under general anesthesia in the prone position, on bolsters, and with abdomen free on a spinal surgery table. A 2.5-cm vertical incision was made on the more symptomatic side just lateral to the lateral pedicular line (under anteroposterior fluoroscopic guidance), and coaxial to the desired disk space (under lateral fluoroscopic guidance). With serial dilatation, a fixed 22-mm tubular retractor (MetRx system; Medtronic Sofamor Danek, Memphis, TN, USA) was docked on to the desired facet joint complex. Under an operating microscope, a facetectomy of the ipsilateral side was performed with a high-speed drill. The ligamentum flavum was excised, and the desired disk space and exiting and traversing nerve roots were identified. Discectomy was completed, and the endplates were meticulously prepared for subsequent interbody fusion. The tubular retractor was removed and, under fluoroscopic guidance, fenestrated screws (CD Ho-

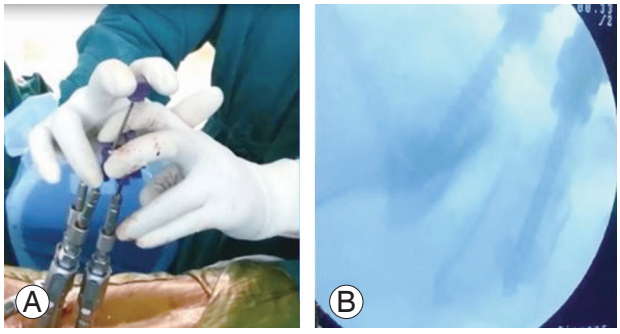

Fig. 1. (A, B) Bone cement injected into cannulated pedicle screws under fluoroscopic guidance.

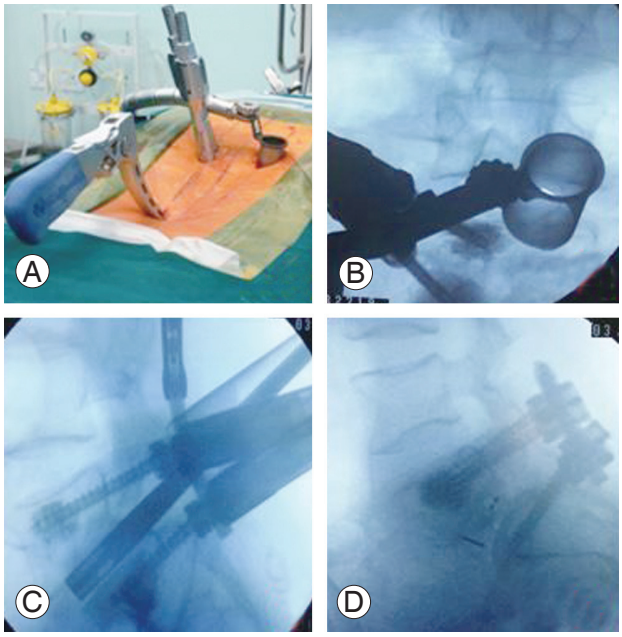

Fig. 2. (A) Placement of contralateral tubular dilators after the insertion of augmented pedicle screws and rod on the ipsilateral side. **(B)** Tubular dilator over the contralateral facet complex to perform facetectomy and discectomy. **(C)** With the extended sleeve device reduction of listhesis was achieved. **(D)** Placement of the interbody polyetheretherketone cage on the contralateral side, and similarly augmented pedicle screws, were placed and stabilized over the rod.

rizon Legacy FNS, Medtronic Sofamor Danek) coupled to reduction screw extenders (CD Horizon Longitude, Medtronic Sofamor Danek) were percutaneously placed into each pedicle on the ipsilateral side and attached to an adaptor sleeve to facilitate cement injection.

Bone cement (Osteopal V; Heraeus Medical GmbH, Wehrheim, Germany) was prepared by standard mixing techniques and loaded into the bone filler device. Once the desired consistency of the cement was achieved, approximately 1–1.5 mL of cement was injected into the cannulated screws under fluoroscopic guidance, thereby making it safe and controlled, and the injection could be stopped immediately in the event of any extravasation (Fig. 1). Once the cement was set, the adaptor sleeves were removed and an appropriately sized rod was placed. No reduction was attempted at this point.

Next, the tubular retractor was placed on the contralateral side and similar steps of facetectomy, discectomy, and interbody preparation were performed. At this point, when bilateral decompression was achieved, reduction was attempted using the screws on the first side, at the same time maintaining interbody disc space distraction from the other side. Once maximum possible reduction was achieved, an interbody cage and graft were placed (Fig. 2). Placement of fenestrated screws followed by cement injection and rod stabilization were subsequently performed on the other side to complete the procedure, after which the incisions were closed.

Results

The demographic and clinical results are summarized in Table 1. All 13 patients had moderate–severe osteoporosis on DEXA bone mineral density (BMD) examination. Listhesis was at the L4–L5 level in five patients and at the L5–S1 level in seven patients. One patient had a two-level L4–L5, L5–S1 level listhesis. Nine patients had grade-2 listhesis and four patients had grade-3 listhesis (Table 2).

Of 13 patients, complete reduction of listhesis was achieved in 10 and grade 2 and grade 3 listhesis were reduced to grade 1 listhesis in two. In one patient with a dysplastic pedicle and grade 3 listhesis, reduction to grade 2 listhesis was achieved (Fig. 3).

Mean JOA scores were 6.3 (preoperatively), 12.92 (3 months postoperatively), and 13.38 (6 months postoperatively), against a JOA scale of 15. The JOA recovery rate in the patients, calculated by Hirabayashi formula at the end of 6 months, was 81.37%.

Table 1. Demographic and clinical profile postoperative outcome

Characteristic	Value
Mean age (yr)	52.46
Sex	
No. of female patients	12
No. of male patients	1
Dual energy X-ray absorptiometry scores	
Mean T-score	-3
Mean Z-score	-1.7
Listhesis	
Grade 2	9
Grade 3	4
Surgical level	
L4–5	5
L5–S1	7
L4–5, L5–S1	1
Visual Analog Scale back and radicular pain	
Preoperative	8.46
1st postoperative day	3.38
6 Weeks postoperative	1.15
6 Months postoperative	0.76
Japanese Orthopedic Association	
Preoperative	6.3
3 Months postoperative	12.92
6 Months postoperative	13.38
Reduction of listhesis	
Complete	10
Grade 2 to grade 1	1
Grade 3 to grade 1	1
Grade 3 to grade 2	1

No patient had any intraoperative complications, such as extravasation of cement into the spinal canal or cement embolism. Patients were referred to an endocrinologist for the management of osteoporosis. All patients were treated with bisphosphonate therapy (zolendronic acid, 5 mg, intravenous, once a year) for osteoporosis. All patients were perioperatively treated with calcium supplements and of vitamin D_3 (60,000 IU, once a week for 8 weeks, followed by once a month).

The median duration of follow-up was 18 months (range, 6–32 months). All except one patient had a minimum follow-up period of 6 months. Standing dynamic

Table 2. Diagnosis and T-scores of patients

Serial no. of patient	Age (yr)	Sex	Diagnosis	T-score
1	75	Female	L5–S1 grade 2 listhesis	-4.1
2	52	Female	L4–5 listhesis, L1 osteoporotic #	-4.1
3	45	Female	L5–S1 grade 2 listhesis	-3.2
4	55	Female	L5–S1 grade 3 listhesis with dysplastic L5 pedicle	-4.6
5	57	Female	L4–5 grade 2 listhesis	-3
6	32	Female	L5–S1 grade 3 listhesis	-2.7
7	52	Female	L4–5 grade 1 listhesis	-4.0
8	70	Female	L4–5 grade 2 listhesis, L3–4 lumbar canal stenosis	-2.7
9	54	Female	L4–5, L5–S1 degenerative listhesis	-2.6
10	58	Male	L5–S1 grade 2 listhesis	-2.7
11	36	Female	L5–S1 grade 2 listhesis	-2.7
12	45	Female	L5–S1 grade 2 listhesis	-3.6
13	51	Female	L5–S1 grade 2 listhesis	-3.2

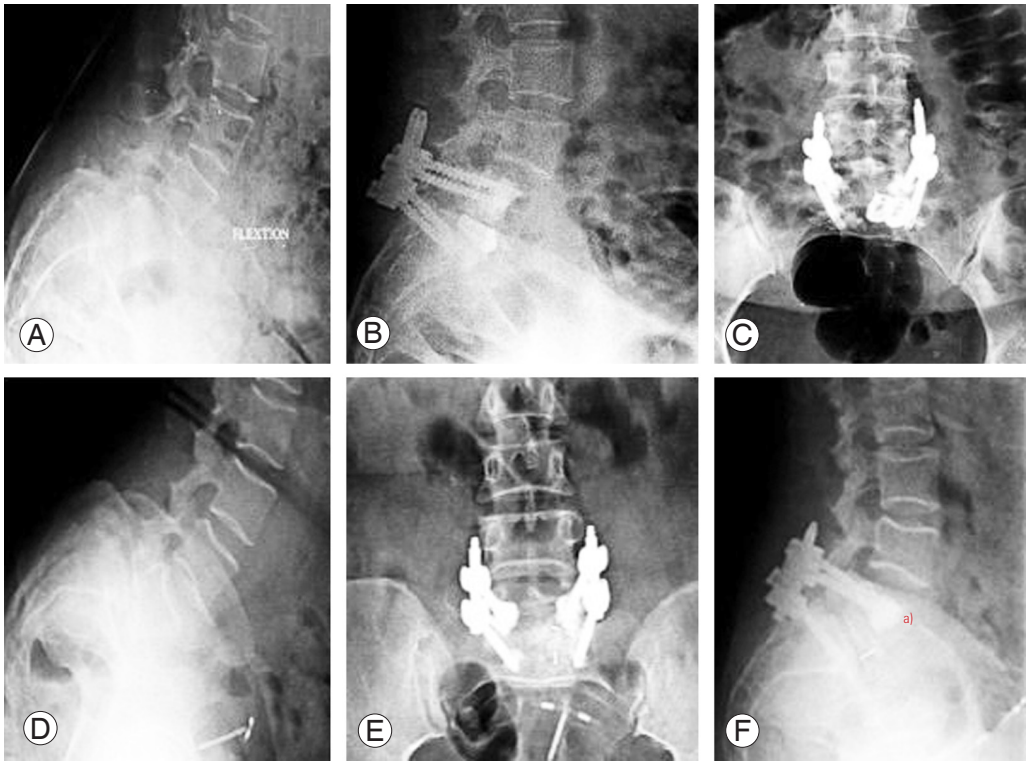

Fig. 3. (A) L5–S1 grade 3 listhesis. **(B, C)** Listhesis reduced to grade 1 with fenestrated screws and augmented construct. **(D)** L5–S1 grade 2 listhesis. **(E, F)** Complete reduction of listhesis with augmented construct. [a]Bone cement within the vertebral body at the distal tip of the fenestrated screw.

radiographs, which was performed in 12 of 13 patients, did not reveal any mobility.

One patient complained of new onset mild numbness and pain in the right lower limb at 6 week follow-up. X-ray examination revealed anterior pullout of the superior screws from the cement mass (Fig. 4). The preoperative T-score of that particular patient was −4.1, and patient was not compliant with osteoporosis treatment. Unfortunately,

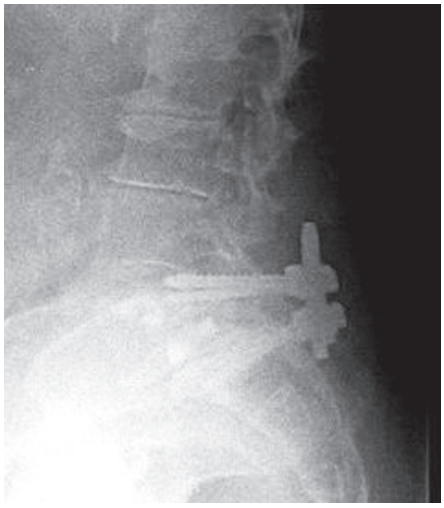

Fig. 4. Displacement of screws.

the patient was not ready for further interventions and was subsequently lost to follow-up.

Discussion

Attempting anatomical reduction in patients with osteoporosis and spondylolithesis increases the biomechanical demand on the instrumentation, thereby increasing the risk of hardware failure, ranging from 0.6% to 11% [3], due to loosening at the implant–bone interface. Biomechanical studies have demonstrated that screw pull-out strength is directly related to BMD [4-6]. As BMD decreases, the force required for axial pull out of the pedicle screws also reduces, irrespective of the length, diameter, or triangulation of the screws [6-8]. It is observed that pedicle screws failed by stripping the cancellous bone within the pedicle track, consistent with the predominant effect of osteoporosis on cancellous bone.

To overcome this issue, various strategies of spinal fixation in patients with osteoporosis have been described. Appropriate pilot hole preparation by not tapping or under tapping before screw placement [9] and screw augmentation with hooks [10,11], though commonly employed, do not increase the load to failure to the expected values. Use of various absorbable and nonabsorbable bone cements to strengthen pedicle screws is considered an effective method to stabilize and support the osteoporotic spine [12]. Various studies showed that augmented fixation of osteoporotic spines enhanced bone screw purchase from 49% to 162% [3].

Conventionally, augmentation was achieved by inserting a pedicle screw into a screw hole prefilled with PMMA (bone cement). Apart from the concern that injecting cement into the pilot hole is uncontrolled, it also primarily functions as bone void filler and not as a true adhesive [13], as the doughy curing cement simply coats the screw threads, thereby effectively reducing screw purchase. Moreover, the technique has associated complications, such as leakage of bone cement into the spinal canal, neural foramina, and vertebral venous plexus causing damage to the spinal cord, nerve roots, and vital organs. Other rare, but dreaded, complications, such as pulmonary embolisms, paraplegia, and death, are also concerning [14].

To overcome these complications, in 2005, Yazu et al. [14] described a technique that involved injecting cement through cannulated screws with distal fenestrations, thereby delivering cement in a controlled and accurate manner, only at the tip of the screw, and reducing the risk of cement leakage into the spinal canal/foramen.

Injection of cement through cannulated fenestrated screw after insertion of the screw allows the cement to infiltrate the cancellous bone and leads to the formation of a new cement bone complex, producing an anchoring effect to increase screw stability [15]. Amendola et al. [16], in their prospective series of 21 cases operated by conventional open technique, concluded that augmented fixation with FNS screws facilitates effective and long lasting fixation in patients with poor bone quality due to osteoporosis or tumors. Lubansu et al. [2] described their clinical experience of minimally invasive spinal fixation in patients with osteoporosis using cannulated and fenestrated augmented screws for degenerative discopathy of various etiologies, fractures, and canal stenosis. Their series represented cases where in-situ fixation was done and augmented fixation was not used to reduce listhesis or deformity. To the best of our knowledge, ours is the first series to report the usage of augmented fenestrated screws in a minimally invasive procedure for achieving anatomical reduction in patients with osteoporosis and grade 2 or grade 3 listhesis.

Apart from the increased bone screw purchase, other advantages of minimally invasive procedures include the low rate of perioperative blood loss; early ambulation of patients; and reduced postoperative pain, hospital stays, and recovery time.

Postoperative osteoporosis treatment is very essential for favorable fusion outcomes. Osteoporosis therapy failure may result despite using augmented fixation, as was

seen in one of our cases. Another major disadvantage with this technique is the difficulty in revision procedures or screw removal, if the need arises. Because of these reasons, augmented screws are not universally used and the indications for using them during surgery should be carefully weighed against the potential risks.

Conclusions

Minimally Invasive augmented fixation is an effective technique for the anatomical reduction of grade 2 and grade 3 listhesis in patients with osteoporotic spines. However, proper treatment for osteoporosis, preferably with bone forming agents, is essential to prevent complications.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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