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Clinical Article

Bone Cement Augmentation of Short Segment Fixation for Unstable Burst Fracture in Severe Osteoporosis

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Objective : The purpose of this study was to determine the efficacy of short segment fixation following postural reduction for the re-expansion and stabilization of unstable burst fractures in patients with osteoporosis.
Methods : Twenty patients underwent short segment fixation following postural reduction using a soft roll at the involved vertebra in cases of severely collapsed vertebrae of more than half their original height. All patients had unstable burst fracture with canal compromise, but their motor power was intact. The surgical procedure included postural reduction for 2 days and bone cement-augmented pedicle screw fixations at one level above, one level below and the fractured level itself. Imaging and clinical findings, including the level of the vertebra involved, vertebral height restoration, injected cement volume, local kyphosis, clinical outcome and complications were analyzed.
Results : The mean follow-up period was 15 months. The mean pain score (visual analogue scale) prior to surgery was 8.1, which decreased to 2.8 at 7 days after surgery. The kyphotic angle improved significantly from 21.6±5.8° before surgery to 5.2±3.7° after surgery. The fraction of the height of the vertebra increased from 35% and 40% to 70% in the anterior and middle portion. There were no signs of hardware pull-out, cement leakage into the spinal canal or aggravation of kyphotic deformities.
Conclusion : In the management of unstable burst fracture in patients with severe osteoporosis, short segment pedicle screw fixation with bone cement augmentation following postural reduction can be used to reduce the total levels of pedicle screw fixation and to correct kyphotic deformities.

KEY WORDS : Unstable burst fracture · Osteoporosis · Short segment fixation.

INTRODUCTION

The goals of surgical treatment of unstable thoracolumbar burst fractures are to restore stability to the vertebral column and to decompress the spinal canal, leading to the early mobilization of the patient. Unstable thoracolumbar burst fractures may be treated with anterior, posterior, or circumferential fusion. Regardless of the approach used, one surgical goal of internal fixation is to minimize the number of levels fused by using short-segment fixation[1,5]. Traditional short-segment fixation involves pedicle screw placement only at the levels immediately adjacent to the fractured vertebral body. While this procedure is popular, several groups have reported unacceptably high failure rates with this technique[6,13]. Potential causes of fusion failure include poor fixation due to severe osteoporosis, insufficient points of fixation and failure to correct kyphotic deformities[19,21]. The traditional procedures for the treatment of unstable burst fractures in osteoporosis entail spinal decompression and fusion with supplemental instrumentation. But these surgeries are fraught with complications due to the debilitated state of elderly patients. The current retrospective study describes the results of our investigations into bone cement augmented short segment fixation of osteoporotic unstable burst fracture.

MATERIALS AND METHODS

This study included 20 patients (19 : female, 1 : male) with unstable thoracolumbar burst fractures accompanying severe osteoporosis (bone mineral densitometry : T-score <-3.0). Study inclusion was limited to 1) neurologically intact patients, despite severe canal encroachment in the thoracolumbar burst fracture, and 2) the loss of anterior

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body height exceeding 50% and with more than 20° of sagittal angulation. The mean age of the participants at the time of injury was 60.5 years (range 42-67 years). The mean follow-up period was 15 months and ranged from 12 to 25 months. As mentioned above, all patients with T-scores lower than -3.0 by BMD were considered to have severe osteoporosis, and the mean T-score of the patients included in this study was -3.62. The vertebral height (H) of the fractured vertebra was defined as the distance between identical points on the superior and inferior endplates at the posterior (Hpf, line ab), middle (Hmf, line cd), or anterior (Haf, line ef) location. The relative posterior (Hp=Hpf/Hpn), middle (Hm=Hmf/Hmn), and anterior (Ha=Haf/Han) heights were then calculated. Vertebral heights are reported as fractions of the referenced height. The kyphotic angle was the angle in degrees defined by the intersection of the superior and inferior endplates of the fractured body (lines ae and bf) (Fig. 1).

Lateral radiographs were taken and analyzed at four different times.

1) Preoperative lateral.
2) After postural reduction for 2 days using a soft roll under the collapsed vertebra in the supine position (hyperextension position).
3) Postoperative lateral (correction of kyphotic deformity by longitudinal distraction during operation).
4) At final follow-up.

Surgical methods

The lesion was reached using the posterior midline approach with the patient under general anesthesia and in the prone position. The lesion was sufficiently exposed, and bone cement-augmented transpedicular screwing was performed one level above and below the fracture site and at the fractured level itself with *in situ* posterolateral bone graft. Tapping was performed using small-sized pedicle screws under the C-arm guide, taking the location in which the bone cement would be injected into consideration. A bone biopsy needle was inserted into the tapping site, located in the 1/2-1/3 anterior area of the vertebral body. Bone cement with a viscosity slightly thinner than that of toothpaste was prepared. Bone cement was injected under the C-arm guide, through a bone biopsy needle, and it was allowed to be maximally localized in the vertebral body area. The bone biopsy needle contained approximately 2.5 cc of bone cement, and therefore about 5 cc per vertebra was injected. Transpedicular screws were inserted as soon as possible after the injection of bone cement under the C-arm guide (Fig. 2). Bone cement augmented transpedicular screwing was performed in adjacent vertebra using the exact same method. It took anywhere from a few minutes to 10 minutes for the bone cement to become completely hardened, and therefore the rod was connected after at least 10 minutes. Postural and instrument reduction was performed to achieve satisfactory reduction and was

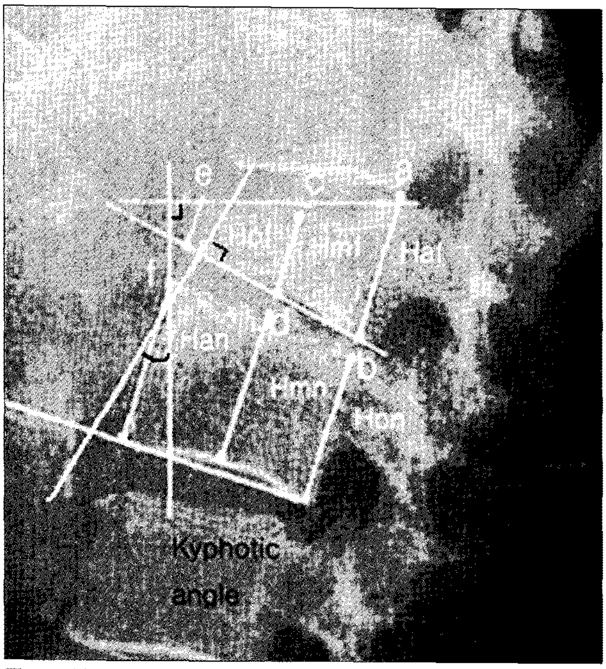

Fig. 1. Measurement of kyphotic angle, normal posterior (Hpn), normal middle (Hmn), normal anterior (Han) vertebral height and fracture posterior (Hpf), fracture middle (Hmf), and fracture anterior (Haf) vertebral height.

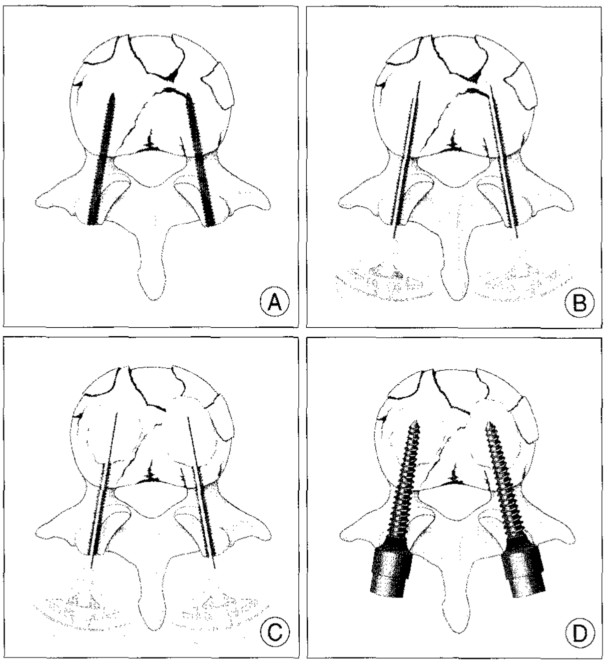

Fig. 2. A : Insertion & removal of small-sized screws. B : Insertion of bone biopsy needle. C : Insertion of bone cement. D : Insertion of transpedicular acrews.

checked by an intraoperative image intensifier. No laminectomy for decompression of the dural sac by retropulsed bony fragments was performed in any patient. The autogenous bone chips mixed with sufficient allograft bone chips were put on to the decorticated laminae which were harvested from the laminae and spinous processes of the fixed segments while doing decortication.

Safety and Outcome Evaluation

The patients were evaluated according to a modified version of MacNab's criteria for characterizing the clinical outcome after spinal surgery at final follow-up (Table 1). When appropriate, radiographs were used to evaluate the angulation and instrumentation integrity at the level of operative segments, respectively.

Statistics

Statistical analysis, including mean values (MV) and standard deviations (SD), was performed using SAS 6.12 (SAS Institute, Inc., Cary, NC). Comparisons between different time points were done using paired Student's test. Differences were considered statistically significant at $p<0.05$.

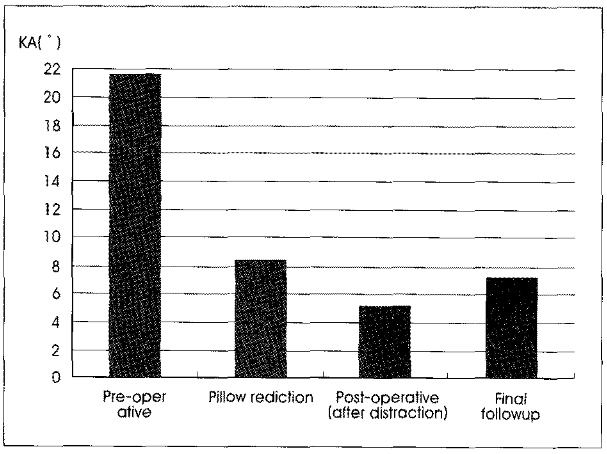

Fig. 3. Changes in the kyphotic angle (KA). Values are given as the mean±SD; comparisons by means of paired t test. *p<0.01 for pillow reduction versus preoperative, **p<0.01 for postoperative versus pillow reduction, ***p<0.01 for final follow up versus preoperative.

Table 1. Modified MacNab's criteria for characterizing the outcome after spinal surgery

Outcome	Description of Criteria
Excellent	No pain; no restriction of mobility; return to normal work & level of activity
Good	Occasional nonradicular pain; relief of presenting symptoms; return to modified work
Fair	Some improved functional capacity still handicapped and unemployed
Poor	Continued objective symptoms of root involvement; additional operative intervention needed at the index level regardless of the length of postoperative follow-up

RESULTS

Overall reduction of kyphotic deformity

The most commonly involved level was L1 (n=8), followed by T12 (n=6), T11 (n=3), and L2 (n=3). Separate kyphotic angles were measured for each treated level. Every patient achieved at least 10° reduction. The kyphotic angle improved significantly from 21.6±5.8° (range, 20-26°) before surgery to 8.4±4.7° (range, 0-16°) after postural reduction. Intraoperative correction of kyphotic deformities by longitudinal distraction was possible (postoperative kyphotic angle 5.2±3.7°). The improved alignment was maintained on a true lateral radiograph. At the final follow-up, the average amount of correction loss of the kyphotic deformities was 2.0 degrees, representing a 14.4-degree change in angulation from the original ($p<0.05$) (Fig. 3). The fraction of involved vertebral height increased significantly from 0.35±0.12 to 0.70±0.16, and from 0.40±0.16 to 0.70±0.15 at the Ha, and Hm level, respectively ($p<0.05$).

Clinical outcome

Firm bone union was achieved in all patients. The criteria for successful bone fusion included the evidence without a radiolucent halo and below 5° on lateral flexion and extension radiographs. No patient experienced neurological deterioration as a result of the surgery. The mean pain score (VAS) prior to surgery was 8.1 and decreased to 2.8 at 7 days after the operation. All patients subjectively reported relief of their typical fracture pain, and none of the patients complained of severe worsening of pain during the follow-up. Nineteen of the 20 patients were graded as having an excellent or good result according to the modified MacNab's criteria (Excellent : 15 patients, Good : 4 patients, Fair : 1 patient). There were no major complications, such as deep wound infection, bone cement leakage, or screw pull-out. One patient had a T9 compression fracture due to an accident in which the patient slipped and fell down after the 6-month follow-up. Two weeks after the injury, the patient underwent balloon kyphoplasty, and complete pain relief was achieved. In another case of seroma, a debridement with secondary suture was necessary (Fig. 4-6).

DISCUSSION

According to the Denis three-column concept, a burst fracture is a 2-or-3-column injury that may lead to an unstable spinal column when presenting with greater than 50% loss of anterior vertebral height, angular deformity greater than 20°, multiple contiguous fractures, any neurologic injury, or in patients with extensive associated injuries[4]. Symptomatic unstable burst fractures typically require operative reduction and stabilization. However, the treatment of unstable burst fractures without neurologic deficits of the thoracolumbar spine remains controversial. Nonoperative treatment for burst fractures

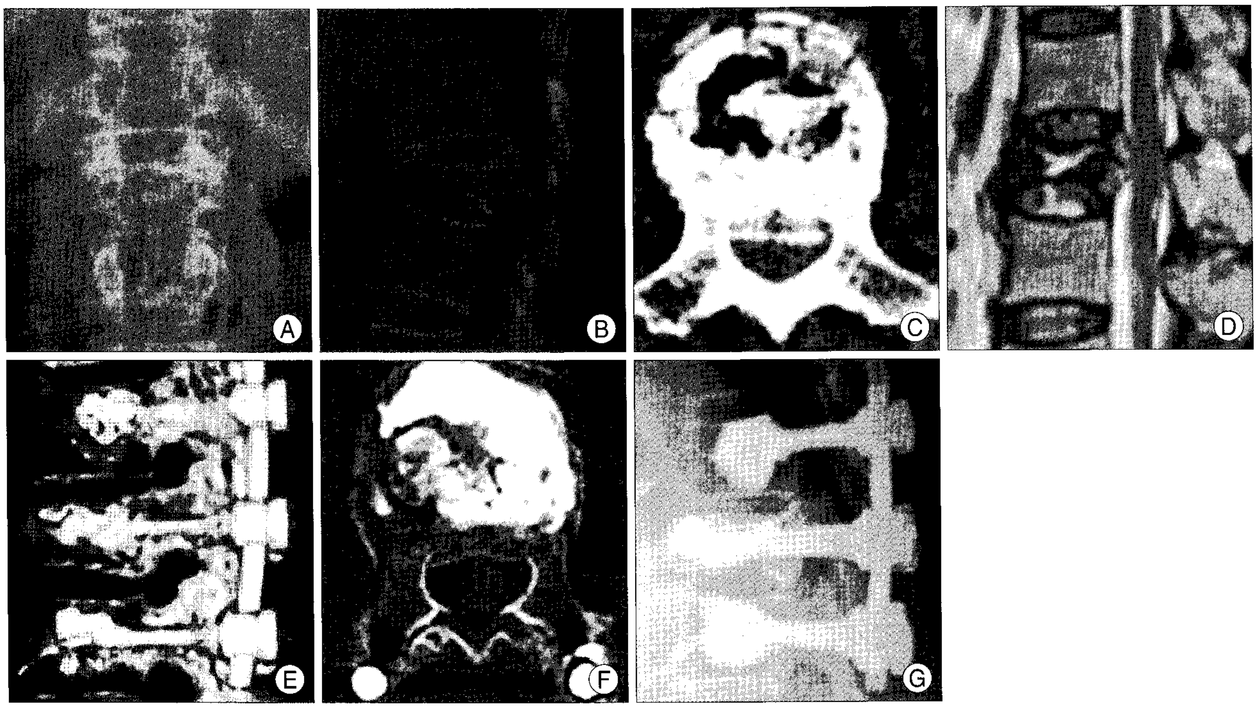

Fig. 4. A 62-year-old woman fell down and sustained an unstable L1 bursting fracture. A, B, C : Preoperative simple radiographs, computed tomography scan demonstrate about 50% canal compromise, 20° of kyphotic deformity and 80% loss of anterior vertebral height. D : The collapsed vertebra was somewhat re-expanded with postural reduction using a soft roll. E, F, G : Postoperative simple radiograph and 3-dimensional computed tomography scans show improved kyphosis correction and restoration of the anterior vertebral body height to 70%.

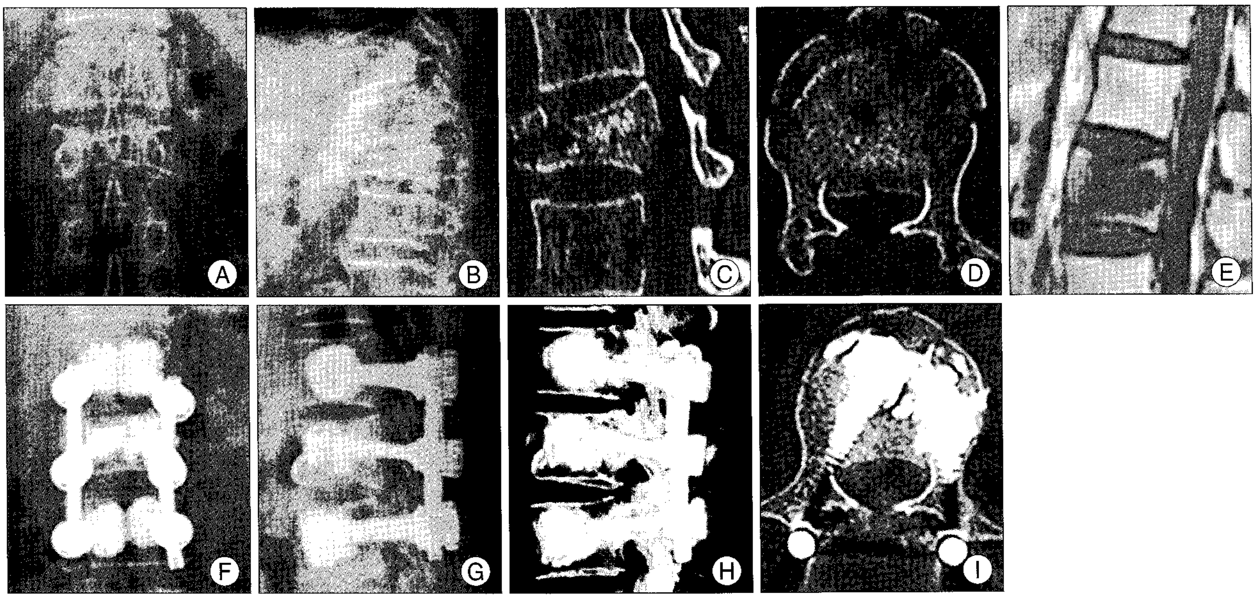

Fig. 5. A 59-year-old female patient fell down and sustained an unstable L1 bursting fracture. A, B, C, D : Preoperative simple radiographs, computed tomography scans demon-strate about 50% canal encroachment, 26° of kyphotic deformity and 60% loss of anterior vertebral height. E : The collapsed vertebra was re-expanded dramatically with postural reduction using a soft roll. F, G, H, I : Postoperative simple radiographs and 3-dimensional computed tomography scans show improved the canal encroachment and anterior vertebral body height to nearly normal status.

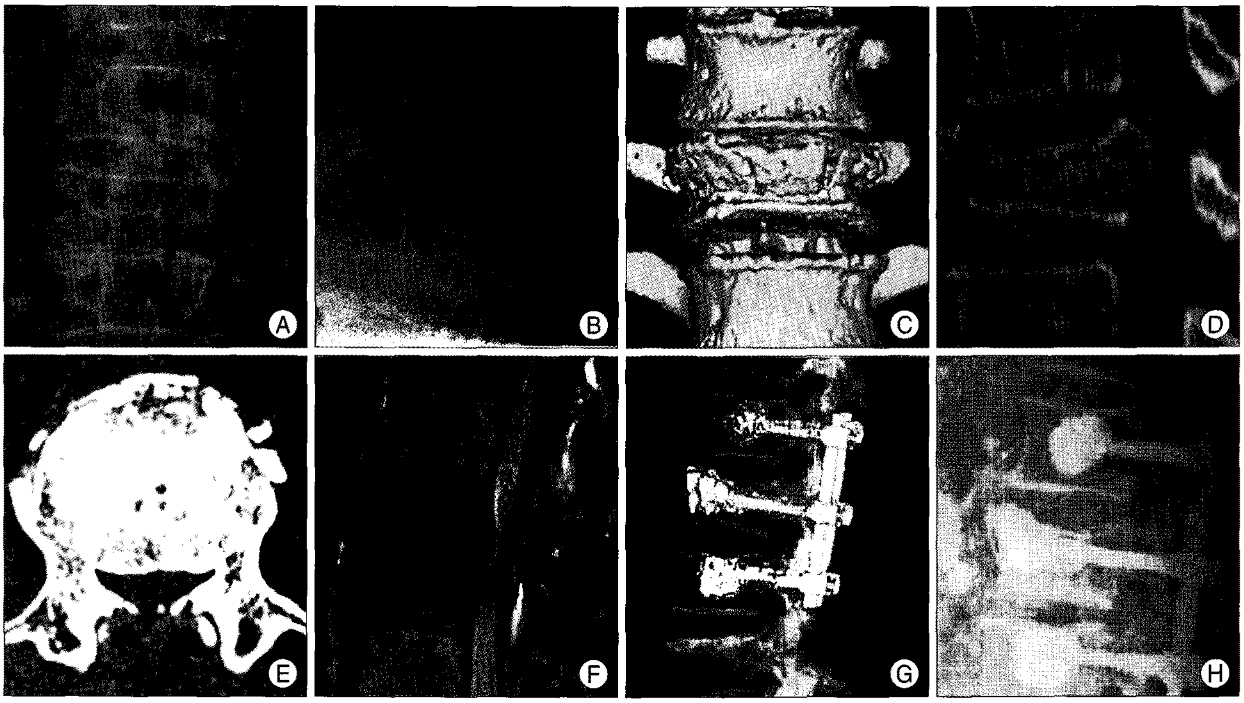

Fig. 6. A 42-year-old female patient fell down and sustained an unstable L2 bursting fracture. A, B, C, D, E : Preoperative simple radiographs, computed tomography scans demonstrate about 55% canal encroachment, 20° of kyphotic deformity and 60% loss of anterior vertebral height. F : The collapsed vertebra was re-expanded dramatically with postural reduction using a soft roll. G, H : Postoperative simple radiograph and 3-dimensional computed tomography scans show improved the canal encroachment and anterior vertebral body height to nearly normal status.

without neurologic deficits has been reported to have good results, although a greater residual kyphotic angle was noted[15,17]. However nonoperative treatment may lead to ongoing neurogenic pain, deficits and progressive spinal deformity, especially, the patients with osteoporotic unstable burst fractures. In a multiply injured elderly patients with osteoporosis, prolonged bed rest predisposes to severe and life threatening complications. Surgical treatment more reliably restores sagittal alignment, translational deformities, and canal dimensions than does cast treatment. But, surgical decompression with instrumentation and fusion across the fractured segment is associated with a significant risk of instrumentation failure in osteoporotic bones[3,9,17]. Canal compromise should be assessed in every burst fracture but becomes the primary concern only there is a high degree of compromise. The absolute guidelines for decompression have not been established due to lack of objective evidence. Residual compromise greater than 50% is worrisome at the T12-L1 level where the conus medullaris and cauda equina fill the spinal canal. Small increments of progressive axial or sagittal collapse at this level can compromise the neurologic elements, and anterior decompression and stabilization should be considered for both mechanical and neurologic purposes[4]. Good clinical results have been reported with posterior reduction and short-segment transpedicular screw fixation with posterior fusion and there were also a few reports of good clinical outcomes using short-segment fixation without fusion[16]. Short segment fixation has become a popular treatment option in recent years. However, several studies have reported a high rate of failure with this method. Sasso and Carl found that although the kyphotic deformity was significantly improved initially in thoracolumbar burst fractures treated with short segment posterior pedicle screw instrumentation, kyphosis was aggravated at follow-up with a high percentage of bent or broken screws[3,17]. McLain et al. also reported an extremely high percentage of early failure with short-segment pedicle instrumentation for thoracolumbar fractures[13]. They found vertebral collapse, translation, and hardware failure in the early postoperative period in 10 of 19 patients, and concluded that short segment posterior instrumentation constructs face extensive loads with subsequent hardware failure. Due to the increase in human lifespan and the improvement of the quality of life, the frequency of surgery using transpedicular screwing for burst fracture with poor bone quality is on the rise. However, in severe cases of osteoporosis, the anchoring effect that holds the screw in place is decreased, the probability of screw fixation failure is high, and thus the possibility of nonunion is high. Therefore, apparatus fixation and bone fusion have been contraindications for such patients[19]. To achieve successful transpedicular screwing, the strength of the area of contact between the screws and the vertebra becomes the most important factor. However, firm fixation strength cannot be achieved in osteoporotic patients due to the defective vertebra, and thus additional procedures may be required to improve screw fixation. According to several studies, osteoporosis has been pointed out as a major factor causing poor outcomes in transpedicular screwing for spinal fusion surgery[9]. To solve these problems, the screw relaxation and pull-out, various principles, such as the above and below vertical lengthening of the fixation segment, lessening of the degree of the deformity correction, and avoidance of the internal device fixation surgery in the kyphotic segment, and so on, have been emphasized[7,9]. In addition, methods for improving the fixation by supplementation with hooks or transverse fixators have been suggested as a substitute[8]. Nonetheless, the suggested supplemental measurements necessary for the internal instrumentation for segments to be operated are absent. Zindrick et al. reported that in experimental studies using the lumbar spine in osteoporosis, if the fixation strength was weak during the insertion of a transpedicular screwing, cement reinforcement could be performed in the vicinity of the screws[22]. However, Hu reported that the use of exothermic materials, such as bone cement, in the vicinity of nerve roots was undesirable[9]. Moreover, Soshi et al. reported that the pull-out strength of the spinal pedicular screws could not mediate a positive effect in biomechanical experiments using the vertebra of cadavers in severe cases of osteoporosis, despite the reinforcement of screws with bone cement, and thus effective fixation could not be obtained using screws in any case[19]. Nonetheless, it was the outcome of reinforcement with bone cement at the entrance of pedicle, and thus it was different from the result of our study in which bone cement was injected directly into the cancellous bone in the vicinity of screws, and indeed, we made a bulk of screws with bone cement by injecting bone cement into the cancellous bone, which was thought to prevent the "teeter-totter" motion of screws based on the spinal pedicles until bone fusion[20]. Transpedicular screwing has generally been regarded as difficult to perform in cases of severe collapsed osteoporotic burst fracture due to the kyphotic angle and lack of adequate space in which to insert the pedicular screw. To overcome these issues, postural reduction using a soft roll can be performed for 2 days when there is not enough space for the transpedicular screw. The usefulness of postural reduction in acute thoracolumbar spinal fracture and conservative treatment of compression fracture with postural reduction have been advocated by many authors[2,15]. Bedbrook noted that 90% of the fractures of the thoracic and lumbar spine could be treated using this closed method. The mechanism of injury in osteoporotic compression fractures is usually flexion-compression, in which the anterior and middle columns are compressed with relative sparing of the posterior column. Therefore, postural reduction in the supine hyperextended position may re-expand the compressed anterior and middle column. This can help us to easily perform transpedicular screwing. In contrast to those in the lumbar region, sagittal deformities in the thoracolumbar area are corrected by longitudinal distraction, which may also indirectly reduce some retropulsed vertebral fragments from the spinal canal[13]. In addition, as in our study, an osteoporotic compression fracture may develop in the adjacent level by minor trauma, and thus efforts should be made to treat and prevent osteoporosis through diet or medication, even after surgery.

CONCLUSION

Bone cement augmentation of short segment fixation following the correction of kyphotic deformities and height restoration by postural reduction and intraoperative distraction can be a safe and effective treatment option for patients with unstable burst fracture and severe osteoporosis. It can reduce the total length or levels of pedicle screw fixation without significant postoperative kyphotic deformity and necessity of secondary anterior strut. Kyphosis correction and height restoration were achieved and maintained throughout the follow-up period.

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