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Surgery for Spinal Deformities in Patients with Osteoporosis — A Secondary Publication

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Abstract: *Objective:* This review aims to present relevant considerations for the surgical treatment of spinal deformities accompanied by osteoporosis, how surgeons are trying to overcome the challenges posed by osteoporosis in patients with spinal deformities, and directions for further development. *Summary of literature review:* Various trials have been carried out to overcome the short- and long-term complications associated with osteoporosis in order to achieve successful clinical results in the surgical treatment of spinal deformities. *Methods:* A comprehensive review of relevant articles was conducted. *Results:* The surgical goal of treating spinal deformities is to reverse neurological compromise and restore balanced spine alignment. To achieve these goals, several surgical considerations should be kept in mind. Osteoporosis is an important issue related to early and long-term complications following surgery. Methods of overcoming the challenges posed by osteoporosis such as rigid fixation techniques, proper selection of the fusion levels, perioperative medical treatment, and effective bone grafting materials are described herein; however, further development in these areas is also necessary. *Conclusions:* Osteoporosis may be a major obstacle in spinal deformity surgery. Although several effective attempts have been made to overcome these limitations, further research and trials are necessary to obtain better results.

Keywords: Spine; Deformity; Osteoporosis; Kyphosis; Scoliosis

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1. Introduction

In the treatment of spinal disorders that have all three components of musculoskeletal symptoms including pain, paralysis, and deformity, the goal of surgical treatment is to treat neuropathy caused by nerve compression and, if necessary, decompress the nerves through fusion. The goal is to achieve a balanced spinal alignment through the correction of deformities. As life expectancy increases due to advances in medicine, the number of people suffering from musculoskeletal disorders is gradually increasing and the demand for active treatment is rising. In the case of spinal deformity, surgical treatment requires fusion of the long segments to achieve correction of the deformity. Osteoporosis, which is particularly associated with short-term and long-term prognosis of surgical treatment, is a common limitation for clinicians, and many attempts have been made to overcome this. This review article aims to address the issue of osteoporosis in the surgical treatment of spinal deformity by summarizing the existing studies on this topic.

2. Spinal deformities

Among spinal deformities, adult spinal deformities are congenital and developmental spinal deformities that occur in the adult forms of spinal deformity, secondary degenerative spine diseases that develop later in life, deformities associated with infection, trauma, or surgery, and systemic conditions such as ankylosing spondylitis. It occurs for various reasons, such as deformation of the spine that occurs in connection with the disease (**Table 1**). Surgical treatment consists of treatment for neuropathy and correction of the deformity in conjunction with the purpose of restoring a balanced alignment of the spine in the sagittal and coronal planes. The definition and classification of these adult spinal deformities was first proposed by Aebi in 2005, focusing on coronal plane deformities [1], followed by Glassman [2] in 2007, who recognized that sagittal plane imbalances were more clinically significant than coronal plane imbalances. Since its publication, studies have reported on the importance of restoring and maintaining pelvic spinal alignment and alignment of the entire spine along with sagittal balance, and classifications of adult spinal deformity based on sagittal balance have been proposed [3]. Since this article is limited in scope to provide a comprehensive classification of these adult spinal deformities and their treatment, we would like to present points to consider when planning surgical treatment for spinal deformities accompanied by osteoporosis.

Table 1. Classification of adult spinal deformities according to causes

Type	Examples
Type I: Adult form of developmental deformity	Adult form of AIS Adult form of congenital abnormality Adult form of Scheurmann's disease
Type II: De novo spinal deformity	Degenerative kyphosis/ Scoliosis Senile kyphosis Hip/knee spine syndrome
Type III: Secondary deformity	Post-traumatic Post-infection Post-surgery
Type IV: Systemic condition related	Ankylosing spondylitis Parkinsonism Connective tissue disorders

3. Preoperative evaluation and preparation

When it comes to the assessment of osteoporosis, bone mineral densitometry (BMD) has been the most utilized test, and it is used as the standard for treatment of osteoporosis based on the T-score. However, due to insurance coverage of the test in limited cases and factors that affect the measurement of degenerative changes in the spine and aortic calcification, questions about clinical reliability and meaning, as well as problems with discrepancies in hip joint and spine have been raised. However, as there is currently no indicator that can be used as an alternative, it has been used as a standard for preoperative evaluation [4]. In addition to the preoperative evaluation of osteoporosis, it is also important to evaluate for factors associated with previous osteoporosis, such as vertebral compression fractures. Many of these adult spinal deformities with osteoporosis are accompanied by degenerative sagittal imbalance, and one of the pathological mechanisms is suggested to be a decrease in the central trunk muscles, including the erector spinae, so it is also necessary to evaluate sarcopenia through analysis of muscle mass, strength, and walking ability [5,6]. The diagnostic criteria of sarcopenia are based on imaging studies such as MRI/Dual-energy x-ray absorptiometry (DEXA), measurement of muscle mass, gait speed, and assessment of muscle strength using instruments such as dynamometers [5]. However, considering that in many cases of patients with degenerative sagittal imbalance in clinical practice, grip strength, which is used as a measure of muscle contractility, does not decrease, and the contractility of the central muscles of the trunk is significantly reduced, it is believed that more research is needed on this. In addition, there is some controversy regarding the treatment of osteoporosis before surgery. There are reports that the use of osteogenesis stimulants is more beneficial than bone resorption inhibitors in the initial treatment of osteoporotic vertebral body fractures, and that it promotes union when used after fusion surgery [7,8]. Although more research needs to be done on its use before and after surgery, given the fragmentary but consistent results reported in these studies, the preoperative use of osteogenesis stimulants is recommended. However, there is insufficient evidence to support the use of bone resorption inhibitors and their replacement, so it is difficult to draw conclusions about the choice of osteoporosis medication in relation to surgery.

4. Intraoperative considerations

During surgical treatment of spinal deformity accompanied by osteoporosis, the expected complications related to osteoporosis are the problems of loosening of the internal fixation within the first 3 months, leading to loss of reduction of the deformity, causing recurrence of neurological symptoms or nonunion. Long-term problems can be caused by failure of fusion, which manifests itself in the form of damage to the internal fixation and is often accompanied by worsening clinical symptoms. Additionally, increased dynamic stress on adjacent segments due to osteoporosis or fusion may lead to fractures of adjacent segments. In an effort to reduce the morbidity of early internal fixation, the most commonly used methods are UIV (upper instrumented vertebra) and LIV (lower instrumented vertebra) with osteosynthesis of either polymethyl methacrylate (PMMA) or calcium-based bone cement. Biomechanical studies have shown that in the case of vertebrae without osteoporosis, this method of reinforcement makes a difference in the resistance to traction force of the internal fixator. However, in the case of vertebral bodies with osteoporosis, it is reported that the addition of reinforcement procedures increases the resistance to traction force by about 1.5 to 2 times [9]. Some studies report similar results in studies of the toggling load applied to internal fixation due to the effects of repetitive axial compression. In a study on the amount of bone cement inserted in such reinforcement surgery, the amount of 2–3 cc of bone cement was sufficient for the fixation within each corner [10], and in case of a larger volume, the risk of complications such as leakage of bone cement following insertion is increased, but the mechanistic benefit is not high. The timing of the insertion of the internal fixture after the injection of the bone cement is important. In many cases, the internal fixture is inserted after the injection of cement and before the hardening of the bone cement (soft cement technique), but in some cases, the internal fixture is inserted after the cement has solidified (hard cement technique). In studies comparing the two techniques, the mechanics are similar, but the risk of fixation failure due to crossing the stress point is higher in the soft cement technique. In the case of fixation failure with soft cement, the failure may be due to dissociation between the osteoid and trabecular bone. The number of internal fixture inserted using the soft cement technique is lower. It is believed that the soft cement technique has the advantage of reducing the number of internal fixture insertions and obtaining initial fixation between bone cement and internal fixture [11,12]. In a study on the use of fenestrated pedicle screws and regular screws, fenestrated internal fixators have the advantage of reducing the insertion time. In addition, the method of inserting an internal fixation after cement injection may require a long insertion time and has disadvantages in terms of leakage of bone cement, but the results of research so far show that the difference in mechanics is not significant [13,14]. In the case of bone cement used, when comparing PMMA and calcium-based cements such as calcium sulfate and calcium phosphate, PMMA has higher initial strength, but it has the disadvantage of a higher risk of leakage. In addition, calcium-based cements have the advantage of osteogenic ability, but the hardening process of inserted calcium-based cement requires time. It is disadvantageous in terms of stability of the initial internal fixation because it requires time to harden and set. The design of the internal fixation may also have an impact, and there are design changes that seek to increase the initial fixation force by making a difference in the screw lines of the vertebral body and pedicle positions through changes in the design of the pedicle screw line, and other changes in the internal fixation. Studies are being conducted to overcome this problem by changing the internal fixation. In addition, proximal fixation with hooks other than pedicle screws, such as ultrahigh molecular weight polyethylene (UHMWPE) and UIV +1 vertebroplasty have been attempted, but reports on long-term outcomes are required [15-17].

In adult spinal deformities, restoring coronal and sagittal plane balance is an important factor in the maintenance of initial fixation and the success rate of fusion. The selection of an appropriate range of fusion is critical, and there is much more to this topic than can be covered here. However, in general, current research suggests that restoration of the sagittal plane is more important. A method has been proposed to predict and restore appropriate lumbar lordosis and thoracic lordosis by taking into account the spine-pelvis relationship completed during the individual's growth. In many cases of degenerative kyphosis, the posterior dislocation of the pelvis is the main change, so it is necessary to correct it to restore the normal sagittal plane. For this purpose, correction between the spine and pelvis is often required, and it is necessary to select the extent of distal fusion using iliac screws, etc. (**Figure 1**) [18,19].

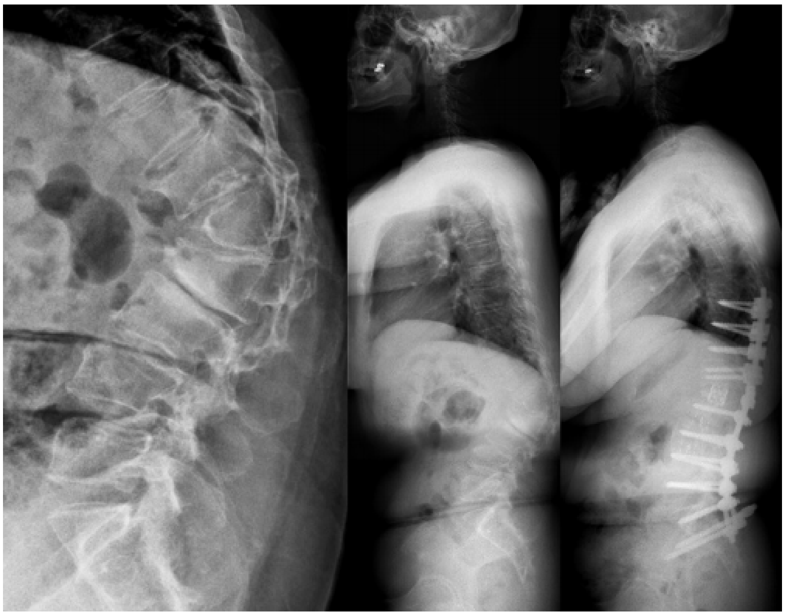

Figure 1. A 65-year-old woman underwent anterior-posterior reconstructive surgery for secondary kyphosis related to congenital anomaly. To prevent pseudoarthrosis at the osteotomy site, anterior fusion was also performed.

The selection of the proximal fusion site beyond the thoracolumbar transition area is the most common method to date. However, there are relatively many proximal transitional kyphotic deformities and the problems resulting from them. Recently, there have been claims that it is necessary to select the upper thoracic spine as the proximal fusion range due to the occurrence of such cases. In adolescent spinal deformity or neuropathic spinal deformity, for which surgical treatment is performed at a relatively young age, the frequency of nonunion is 1.4 to 2.0%. However, in adult spinal deformities, many of which are accompanied by degenerative changes, osteoporosis, and sarcopenia, a higher rate of nonunion (6.3%) has been reported [20]. Therefore, in the surgical treatment of adult spinal deformities, analysis of the cause and extent of the deformity and the selection of an appropriate fusion range are also important to achieve good clinical outcomes.

5. Efforts to prevent misalignment

As described above, surgical treatment for spinal deformities arising from a variety of causes takes into account a number of factors such as osteoporosis, degenerative changes in the spine, and sarcopenia, and more efforts are made to achieve correction and fusion of the deformity. Among these, in cases of union that are related to long-term prognosis, the presence of osteoporosis is associated with an increase in nonunion along with the dissociation of the initial internal fixation [20,21]. In the presence of concurrent osteoporosis, nonunion is more likely to occur in association with decreased osteogenic capacity. In addition, failure of initial internal fixation may also be associated. Anterior intervertebral fusion is used as a method to overcome this problem, and it has been shown to be effective in correcting deformity [19,22] and its active use is needed to achieve a more robust correction and union (**Figure 2**). Posterior correction and posterior or posterolateral fusion, which are commonly performed, are not complete unions, so in the case of long-segment fusions, even if fusion is confirmed radiologically, anterior motion remains, which can lead to nonunion and rupture of the internal fixator. In one study, posterior fusion for adult spinal deformity was associated with radiographic nonunion and internal fixation failure. In one study, posterior fusion for adult spinal deformity was radiologically determined to be fusion, but it was reported that rupture of the internal fixation and nonunion occurred in 9.5% of cases during follow-up [23]. In the surgical treatment of adult spinal deformity, active anterior fusion is necessary in cases where lumbar and sacral fusion is required; where trilaminar osteotomy is required; and where intervertebral disc gap remains at the site of fusion. As alternative method for posterior fixation, fixation using multiple steel rods and different types of rods has been proposed [24]. In addition, considering the material properties of steel wires, more solid fixation and steel wire of various materials are used for stronger fixation and durability. Bone grafting is the most important element of bone fusion, autologous bone grafting is the best method, but in most cases, the use of bone substitutes is often necessary for long segmental fusion, osteoporosis, and lack of sufficient autologous bone. To date, among the commercially available bone substitutes, bone morphogenetic proteins (BMPs) are the most effective [25], but its general use is limited due to several problems. In addition, research and experiments on the development and commercialization of bone graft materials using autologous cells are underway [26], so it is expected that more diverse bone graft materials will be available to choose from in the future. Although much research is still needed on the use of osteoporosis drugs, most clinical studies report that the use of bisphosphonate, the most commonly used osteoporosis medication, has no clinical impact on bone union. However, laboratory studies, including animal studies, have reported negative effects on early bone union, thus further studies are needed to confirm this conclusion [8,27,28]. Among osteoporosis treatments, the use of osteogenic agents can be considered as it has been reported that they can promote bone union and reduce loosening of internal fixation when used in early fusion [7,8,27]. Furthermore, the long-term outcome remains to be studied.

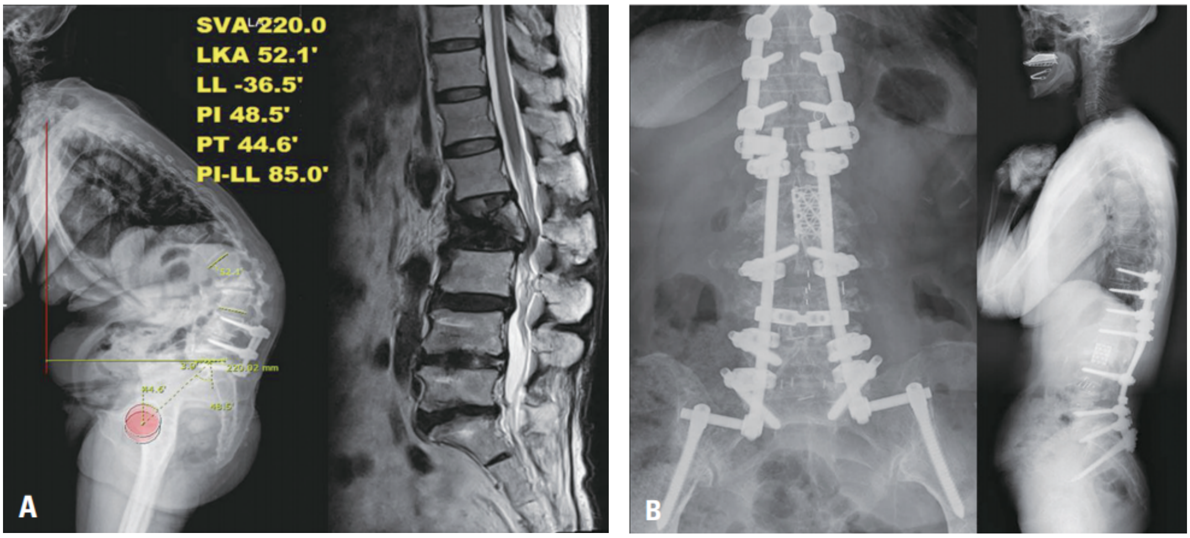

Figure 2. A 76-year-old woman presented with lumbar degenerative kyphosis combined with post-traumatic kyphosis. To restore the sagittal alignment, posterior 3-column osteotomy was done with interbody fusion for the lumbar lesions.

6. Conclusion

Surgical treatment of spinal deformity is aimed at improving neurological symptoms and restoring sagittal and coronal plane balance. Preoperative, postoperative, short- and long-term problems associated with osteoporosis should be recognized and efforts should be made to prevent them. To this end, more research on the scope, method, and selection of appropriate fusion, internal fixation, and bone graft materials is needed.

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Disclosure statement

The authors declare no conflict of interest.

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