



RESEARCH

EFFECT OF BALLOON KYPHOPLASTY TREATMENT FOR OSTEOPOROTIC VERTEBRAL FRACTURE ON SPINAL BALANCE

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ABSTRACT

Introduction: Osteoporotic vertebral fractures and spinal degeneration are common consequences of aging, and co-occurrence of these two pathologies can impair spinal balance leading to development of further deformities. The most common treatment measure for osteoporotic vertebral fractures is percutaneous balloon kyphoplasty which can potentially improve spinal balance along the sagittal and coronal planes. However, there is limited evidence in support of this issue to date.

Materials and Methods: This study included 49 patients (27 males, 22 females) who were diagnosed with osteoporotic vertebral fracture. The patients were evaluated preoperatively and one year postoperatively using three-dimensional thoracolumbar computed tomography scans. The lumbar lordosis and sacral slope angle were used to assess the sagittal plane, while coronal plane assessment was carried out using Cobb's angle. The angle values before and after treatment were compared statistically.

Results: The mean age of the study participants was 72.16 years (range: 61–94 years), and 28.6% and 71.4% of the patients exhibited thoracic and lumbar vertebral fractures, respectively. Moreover, 19 patients exhibited spontaneous or minor traumatic vertebral fractures, and 16 patients diagnosed with degenerative scoliosis exhibited a significant improvement in Cobb's angle after treatment. The comparison of pre-and postoperative mean sacral slope and lumbar lordosis angles showed an increase in both values and these differences, although not statistically significant, in agreement with previous literature.

Conclusion: Percutaneous balloon kyphoplasty has become an increasingly popular treatment measure for osteoporotic vertebral fracture due to its ability to effectively correct spinal imbalance in patients.

Keywords: Kyphoplasty; Osteoporosis; Spinal Fractures; Postural Balance.



INTRODUCTION

Spinal degeneration, an inevitable consequence of aging, typically affects the intervertebral discs, facets, vertebral endplates, and ligaments and can eventually lead to spinal deformity (1). Severe vertebral degeneration is often associated with impaired spinal balance, resulting in deformities such as degenerative scoliosis, spondylolisthesis, and/or kyphosis. Previous studies have shown that spinal degeneration and its accompanying deformities are relatively common in elderly individuals, affecting their quality of life considerably (2).

Osteoporosis, another inevitable consequence of aging, is also relatively common and can be attributed to chronic vitamin D deficiency, hormonal withdrawal syndromes, malnutrition, immobility, and steroid use, particularly in socio-culturally underdeveloped societies. It is characterized by decreases in the anatomical strength of the bone structure and bone matrix density, leaving the lower thoracic and lumbar vertebrae particularly susceptible, as they bear the majority of the body weight. An initial microtrauma to the bones can, over time, lead to vertebral deformities and severe collapse fractures that affect the patient's spinal balance, resulting in symptoms of varying severity (3).

Minimally invasive methods have become increasingly popular in spinal surgery, such as percutaneous balloon kyphoplasty (PBK), used for the treatment of pathologies affecting multiple vertebrae (e.g., osteoporosis), has been shown to be associated with significantly lower morbidity and mortality rates than other treatment methods (4). PBK typically involves percutaneous insertion of a Jamshidi biopsy needle into the collapsed vertebral corpus, followed by inflation of a balloon that facilitates reshaping of the deformed vertebrae. The balloon is then removed and materials such as poly methyl acrylate (PMMA) that harden in the corpus and restore the strength of the vertebrae are placed in the cavity created to allow three-

dimensional remodeling (5). Previous studies have shown that elderly patients with severe preexisting spinal degeneration exhibit a marked improvement following PBK treatment for osteoporotic vertebral fractures (OPVFs), and it has been suggested that this can likely be attributed to partial recovery of spinal balance. A limited number of studies to date have evaluated improvements in spinal balance along the coronal and sagittal planes following PBK treatment for OPVF (6). A limited number of studies to date have evaluated improvements in spinal balance along the coronal and sagittal planes following PBK treatment of OPVF, potentially due to the rarity of co-occurrence of deformities along both of these planes (7,8). Therefore, the current study aimed to evaluate the effects of PBK treatment for OPVF on coronal and sagittal balance in elderly patients.

MATERIALS AND METHODS

Patient population

This retrospective study examined 112 patients who underwent PBK treatment between 2016 and 2022 at a neurosurgery clinic of a university hospital. Of these, 49 patients (27 males, 22 females) who were over 60 years of age, diagnosed with OPVF, and had completed the first year of postoperative follow-up were included in the final study sample. Local ethics committee approval was obtained (13-06, 30/11/2022). Patients with a previous history of spinal surgery, spinal tumors, congenital malformations, or exposure to major trauma were not included. The study was carried out in accordance with the Declaration of Helsinki, and data on the patient's age, gender, fracture level, presence of trauma, and quantity of PMMA injected during treatment were recorded. The Cobb's angle, sacral slope (SS) angle, and lumbar lordosis (LL) angles were measured pre- and postoperatively, and the changes in these measures after treatment and the amount of PMMA used were also assessed.

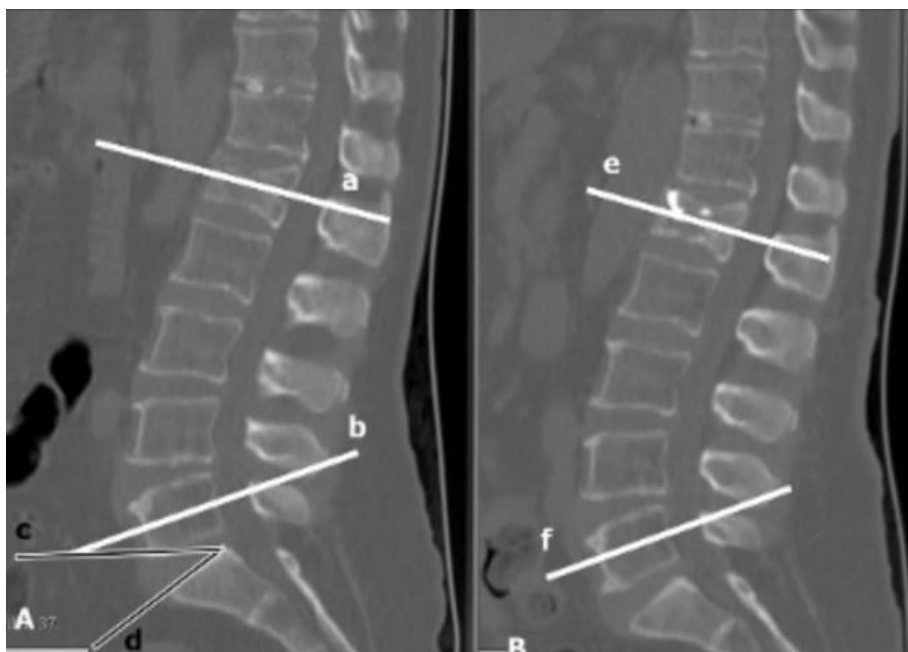


Figure 1. LL angle (between lines a and b) on a sagittal CT image. (A) Preoperative SS angle (between lines c and d), and (B) no significant change in LL angle (between lines e and f) seen postoperatively.

Radiological analyses

The patients included in the study sample were placed in a neutral supine position and thoracolumbar computed tomography (CT) scanning was carried out using the Aquilion Lightning™ system, a 16-row 32-section helical CT manufactured by Canon Medical. The resultant images were transferred to a computer using the DICOM PACS program, and the LL, SS, and Cobb's angles were measured using the Clear Canvas program. During thoracolumbar CT scanning, CT was checked that it was obtained from the T1 vertebral upper-end plate to the femoral head of pelvis. The SS angle was defined as the angle formed by a line parallel to the S1 endplate and a reference horizontal line, while the LL angle was defined as the angle between the horizontal midpoints of L1 and L5 (Figure 1). In 16 patients with lumbar degenerative scoliosis, the Cobb's angle was defined as the angle between two

planes drawn along the upper and lower ends of the affected region (Figure 2).

Statistical analysis

All statistical analyses were performed using SPSS, version 23.0. Descriptive analyses included calculation of the mean, standard deviation, and minimum and maximum values for numerical variables and frequencies and percentages for categorical variables. Following confirmation of a normal distribution, an independent t test was used to examine the association between the pre- and postoperative (after one year of follow-up) Cobb's, SS, and LL angles. The Mann-Whitney U test was used to examine the association between the amount of PMMA used and postoperative changes in the Cobb's angle as the data were not normally distributed. The level of statistical significance was set at p-value of <0.05.

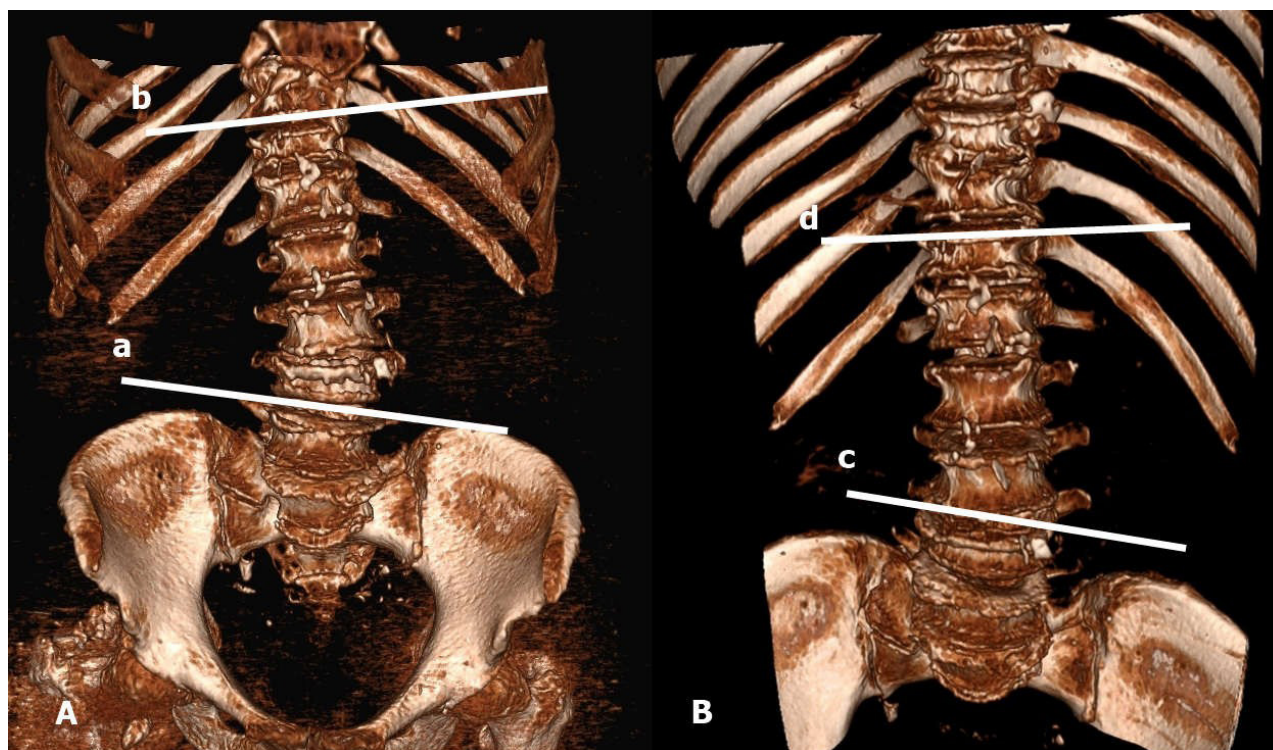


Figure 2. Three-dimensional reformat CT image showing collapse of the L3 vertebral corpus. (A) Preoperative Cobb angle (between lines a and b) of 18°, and (B) postoperative Cobb angle (between lines c and d) of 14°.

RESULTS

The mean age of the study participants was 72.16 years (range: 61–94 years), and 28.6% and 71.4% of the patients were diagnosed with thoracic and lumbar vertebral fractures, respectively. Additionally, 19 patients exhibited spontaneous or minor traumatic vertebral fractures. Table 1 includes a heatmap showing the correlation between the pre- and postoperative SS, LL, and Cobb’s angles.

The mean postoperative Cobb angle was significantly lower than the mean preoperative Cobb angle in 16 patients diagnosed with degenerative scoliosis ($p = 0.050$, Graph 1). Moreover, comparison of pre-and postoperative mean SS and LL angles showed an increase in both values and these differences, although not

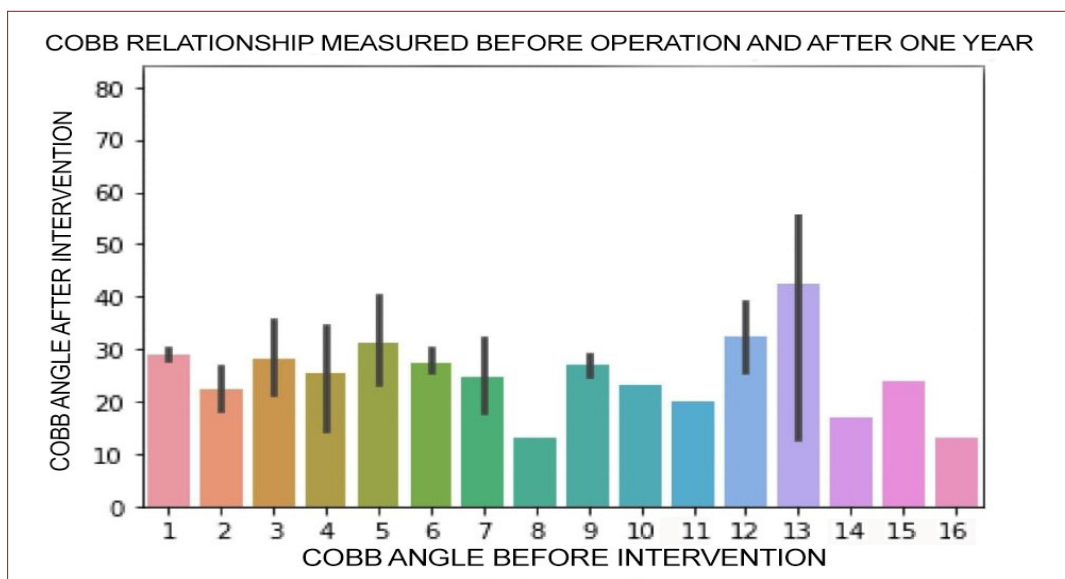
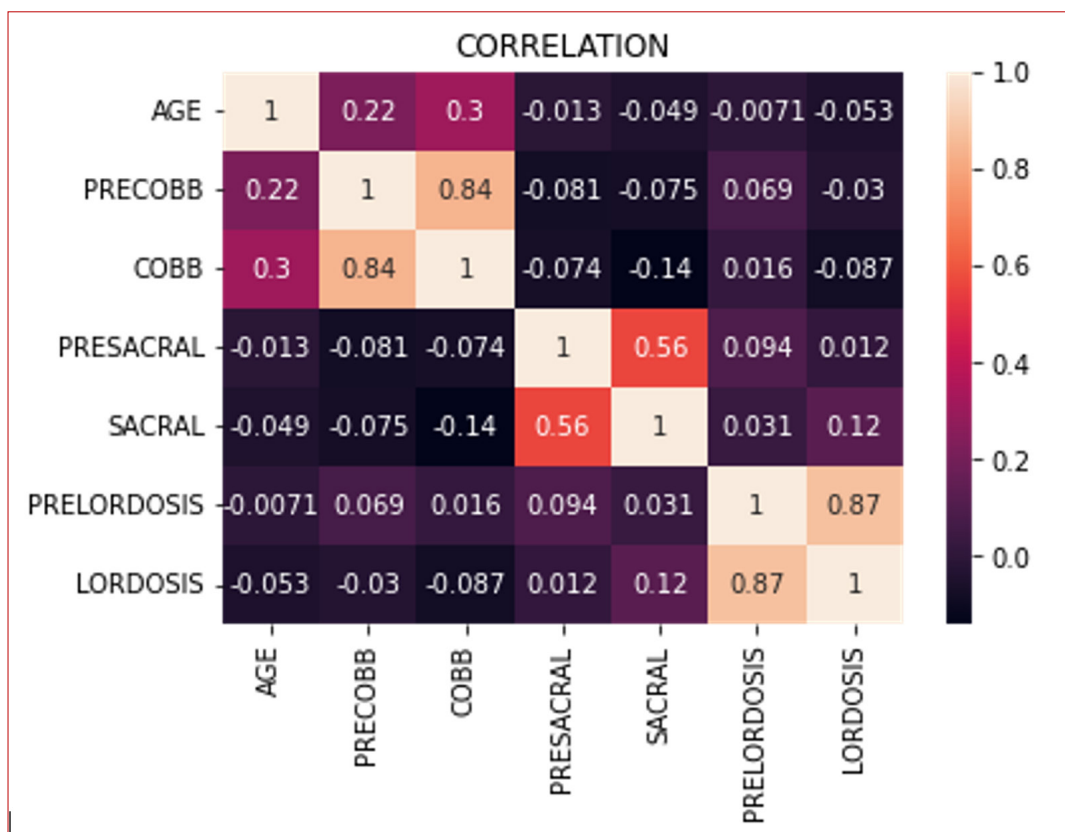
statistically significant, were in agreement with previous literature (Graph 2).

Examination of the relationship between the amount of PMMA used and the change in Cobb’s angle after treatment showed that patients who exhibited no change and those who exhibited a decrease one year postoperatively received 3.37 cc and 3.57 cc of PMMA, respectively. A larger mean amount of PMMA was used in patients exhibiting decreases in their Cobb’s angles one year postoperatively, although this difference was not statistically significant.

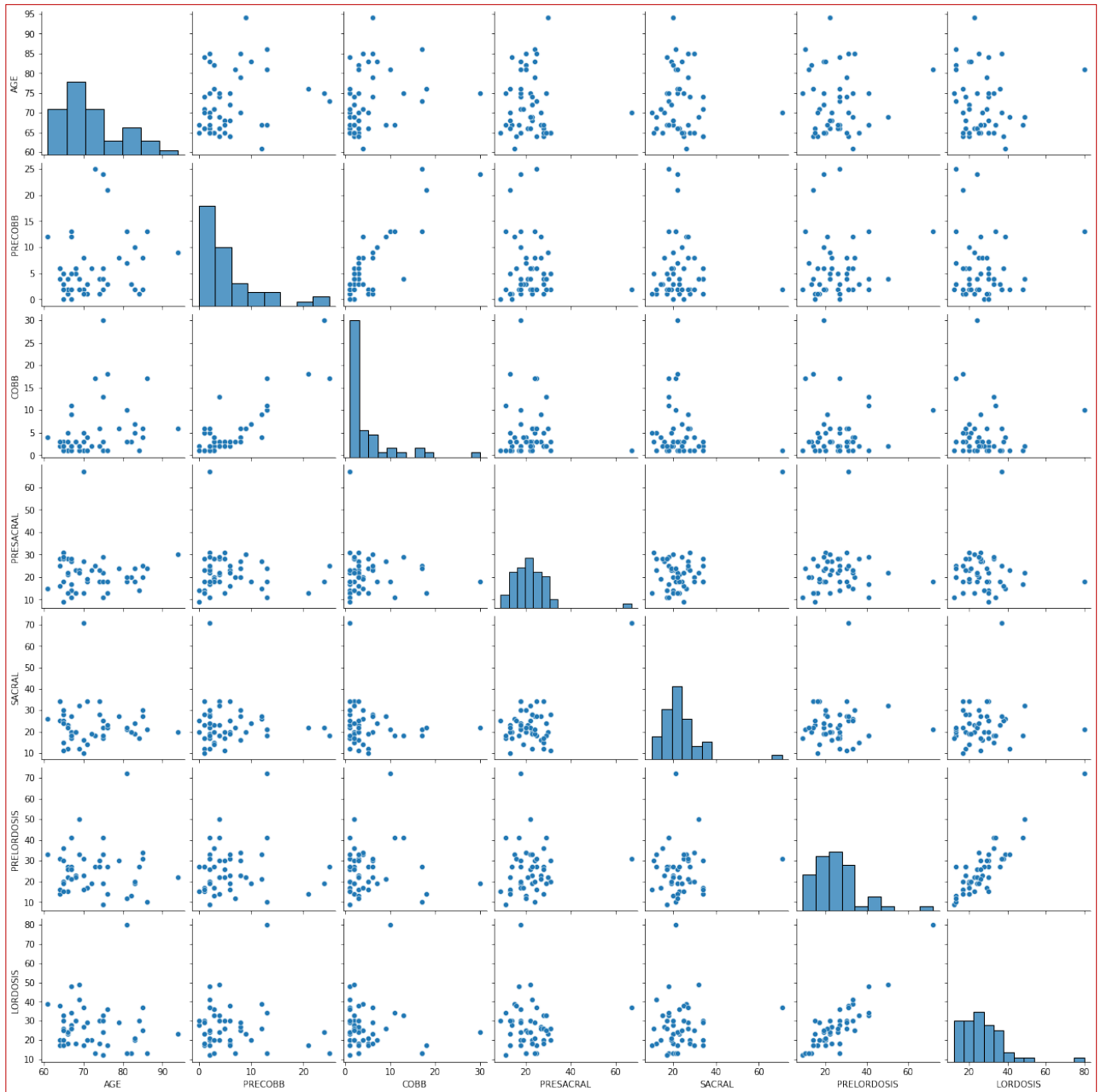
DISCUSSION

Impaired spinal balance, commonly caused by spinal degeneration and OPVF, has a relatively

Table 1. Heatmap showing correlation between pre- and postoperative SS, LL, and Cobb's angles.



Graph 1. Bar-plot showing pre- and postoperative Cobb's angle values.



Graph 2. Pair-plot graph showing association between variables.

high incidence rate among elderly individuals and this can be attributed to spinal aging caused by a combination of various environmental and genetic factors (9,10). The quality of life of patients

diagnosed with OPVF and prominent three-dimensional irregular vertebral collapses may be affected considerably by the fracture itself as well as the development of postural dysfunction secondary

to spinal imbalance (5,9). Previous studies have concluded that partial restoration of spinal balance through PBK treatment of OPVF in elderly patients can improve their quality of life considerably (7,8,11).

Fechtenbaum et al., observed poorer sagittal balance in elderly patients diagnosed with OPVF than in age-matched healthy controls with no spinal complaints (12), while Ishikawa et al., reported that patients with OPVF exhibited higher rates of spinal curvature and compromised postural balance (13). The majority of evidence on improvements in spinal balance in the sagittal and coronal planes following PBK treatment for OPVF has been obtained from reviews of the current literature, with very few clinical studies examining this due to the rarity of both deformities occurring simultaneously (8,14,15). Cao et al. suggested that patients with OPVFs affecting the thoracolumbar junction were more susceptible to spinal imbalances, and PBK treatment resulted in significant improvements in spino-pelvic alignment and overall sagittal balance (7). In the current study, Cobb's angle was used to measure changes in coronal balance, and comparison of the pre- and postoperative values showed a statistically significant improvement after treatment.

While impaired sagittal balance is typically compensated for by the thoracic, lumbar, sacral, and hip joints, compensation of coronal imbalance is more difficult in the elderly population and usually relies on positional stance (16, 17). Therefore, the most common symptom of three-dimensional spinal deformity is impaired coronal balance, and treatment measures tend to result in marked improvements (18). In the current study, OPVF patients with degenerative scoliosis exhibited a significant improvement in the Cobb's angle after PBK treatment and, as this angle is minimally affected by compensatory mechanisms for spinal balance, this change can likely be attributed to the treatment itself. However, further prospective studies using larger sample sizes are necessary to confirm this.

OPVF most commonly affects the lumbar vertebrae as this region bears the main load of the trunk, is frequently traumatized, and is more mobile than the other vertebral levels (4). In the current study, lumbar vertebral fractures were observed in 71% of patients. At the same time, the LL angle was higher than that of thoracic kyphosis in healthy individuals. Pathologies affecting the lumbar vertebrae often lead to severe spinal imbalance along the sagittal plane (19). The current study assessed sagittal balance using the SS and LL angles, and comparison of the pre- and postoperative values showed a larger change in the latter compared to the former, although this difference was not statistically significant (as shown in the heatmap in Figure 1).

OPVF can occur spontaneously or after a minor trauma. In their large cohort study including 4349 patients with osteoporosis, Melton et al. found that the majority of new bone fractures observed in 896 patients during the follow-up period occurred spontaneously or could be attributed to minor trauma. Moreover, vertebral fractures without any clinical symptoms were more common in these patients than in the normal population (20). Similarly, in the current study, 19 patients were diagnosed with OPVFs that developed either spontaneously or after minor trauma.

Important considerations of PBK treatment include differences in outcomes between bilateral/unilateral injections and by the amount of PMMA injected, with previous studies suggesting that injection of PMMA at an optimal angle from the side with an intact pedicle can reduce the risk of complications (21,22). Therefore, unilateral PMMA injections were performed in the current study. With regards to the amount of PMMA required, the general consensus leans toward quantities that can safely fill the cavity (22). The current study observed no association between the amount of PMMA injected and the extent of improvement in coronal balance, as patients exhibiting a significant



improvement in the Cobb's angle have received only a very slight excess of PMMA. In the future, larger studies should aim to examine these outcomes on the vertebral side where coronal balance is deviated.

The advancement of science and informatics have made the severity of disease, treatment outcomes, and risk of complications more predictable. Rath et al., proposed the multiple linear regression model that examined the coexistence of metabolic and infectious diseases taking various demographic and medical parameters into consideration, and suggested that it could be used to predict the patient's clinical progression (23). Similar studies could be used for OPVF treatment, and the rate of deformity improvement after PBK can be predicted at a higher rate.

The current study included patients who underwent a standard PBK surgical procedure under fluoroscopy. PMMA was injected from the most suitable side of the pedicle and to the most reliable localization of the vertebra. Although the extent of correction of the spinal imbalance can potentially be improved through administration of the injection on the side/location with the greatest collapse using advanced technologies such as intraoperative CT and/or robotic surgical equipment, these methods are limited by their ethical considerations (increased X-ray exposure, infection rate, surgery time and anaesthesia medication) and poor cost-effectiveness (24,25).

CONCLUSIONS

Elderly patients diagnosed with OPVFs exhibit a significant improvement in symptoms after PBK treatment, potentially due to its ability to effectively correct sagittal and coronal imbalances.

Conflict of Interest

The authors declare that there is no conflict of interest between them

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