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Effects of unilateral and bilateral vertebroplasty on coronal balance

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ABSTRACT

Objectives: Percutaneous vertebroplasty is frequently used to treat osteoporotic vertebral compression fractures (OVCFs) due to its low surgical risks. In this study, we tried to determine the early and late effects of single-pedicle and double-pedicle PVPs on the coronal balance of the vertebrae.

Methods: This study evaluated 95 OVCF patients treated with PVP between 2008 and 2023. Of these patients, 36 were treated with bilateral and 59 with unilateral vertebroplasty. The Coronal Cobb angle, coronal segmental Cobb angle, and coronal balance of the vertebrae were measured in preoperative, early postoperative, and 6-month postoperative radiographs. The results were compared between the two groups and the effects of single or double pedicle procedure on these values were analyzed.

Results: Two study groups were formed, consisting of a total of 95 patients. The mean age was 69.1 years. Fourty-nine patients were female and 46 were male. No significant difference was detected between the groups regarding gender and age. When the data obtained in the preoperative and early postoperative period in patients who underwent single and double pedicle vertebroplasty were evaluated, no statistically significant difference was obtained in coronal balance, Cobb angle, and segmentary Cobb angle measurements.

Conclusions: From the radiographic point of view in the long-term follow-up, we think that bilateral PVP provides an advantage over the unilateral approach in maintaining the coronal balance and stabilization of the coronal Cobb angle in patients with OVCF.

Keywords: Coronal balance at vertebra, percutaneous vertebroplasty, Cobb angle, coronal balance

Osteoporotic vertebral compression fractures (OVCF) are caused by high or low-energy trauma [1]. Pain in these patients is usually caused by instability. It is a pain that increases with movement and decreases with rest. The collapse of the OVCF may lead to spinal instability, scoliosis, and kyphotic deformity. Increasing the load-bearing capacity of the corpus, mobility, and restoration of sagittal and coronal balance are important [2, 3]. Minimally invasive surgical interventions have been used to treat these patients by avoiding radical surgical procedures with high mortality. Percutaneous vertebroplasty (PVP) and percutaneous kyphoplasty (PKP) have been increasingly used in recent decades. The risk of complications of this method is less compared to open surgical procedures [2]. There are numerous advantages including restoration of height, stabilization of the vertebral body, significant reduction of pain, early mobi-

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lization, and significant reduction of mortality [4, 5]. It is a great advantage to use in elderly patients with a high general anesthesia risk.

PVP was initially performed through bilateral pedicles. Some authors recommend performing the procedure through a single pedicle to shorten the duration of the long surgical procedure and reduce the radiation dose. This also reduces the cost of the operation and significantly decreases the complications of placing a second cannula, in short, the complications of vertebroplasty [6, 7].

It is observed that some OVCFs continue to align in the normal coronal and sagittal plane after PVP or PVK, while others cause distortions in the coronal and sagittal planes.

Although publications indicate that both PVPs significantly improve the clinical outcomes of patients, there are no clear studies on their effects on the stability of the vertebra [7]. Some studies show that both techniques of PVPs with single pedicle access or double pedicle access do not impair or even correct sagittal balance and do not cause a significant loss of lordosis [7, 8]. However, there are few studies on the effects of PVPs on the coronal balance of the vertebrae. In this study, we tried to determine the early and late effects of PVPs with single-pedicle and double-pedicle access on the coronal balance of the vertebrae.

METHODS

This study evaluated OVCF patients treated with PVP between 2008 and 2023. Patients with neurological deficits, bone compression of the canal, obesity, severe cardiovascular diseases, cancer, regional infection, radiotherapy, and patients with insufficient documentation were excluded. Perop specimens for pathology were obtained from all patients. A total of 95 OVCF patients who met these criteria were included in the study. Of these patients, 36 were treated bilaterally and 59 with unilateral vertebroplasty. Coronal Cobb angle, coronal segmental Cobb angle, and coronal balance of the vertebra were measured in the radiographs taken before surgery, in the early postoperative period, and in the 6th month after surgery. We compared the results between both groups and tried to reveal the effects of single or double pedicle procedure on these values. This study was approved by the Erciyes University institutional ethics committee (2023-788).

Radiological Evaluation

90×35 cassettes called scoliosis cassettes and radiographs taken with the same device (Multifunctional Radiograph Unit Siemens-GERMANY) were used as standard. For coronal plan imaging, radiographs taken from 1.8 meters in the posterior-anterior direction with the patient's arms on both sides and standing were obtained. Cobb and coronal balance measurements were performed using the software in Picture Archiving and Communication Systems (PACS). The same neurosurgeon made all the measurements. Cobb angle measurements are used for coronal segmental Cobb angle and coronal Cobb angle, and the distance between the central mid-sacral line and the C7 plumb line is evaluated for coronal balance examination [9, 10] (Fig. 1).

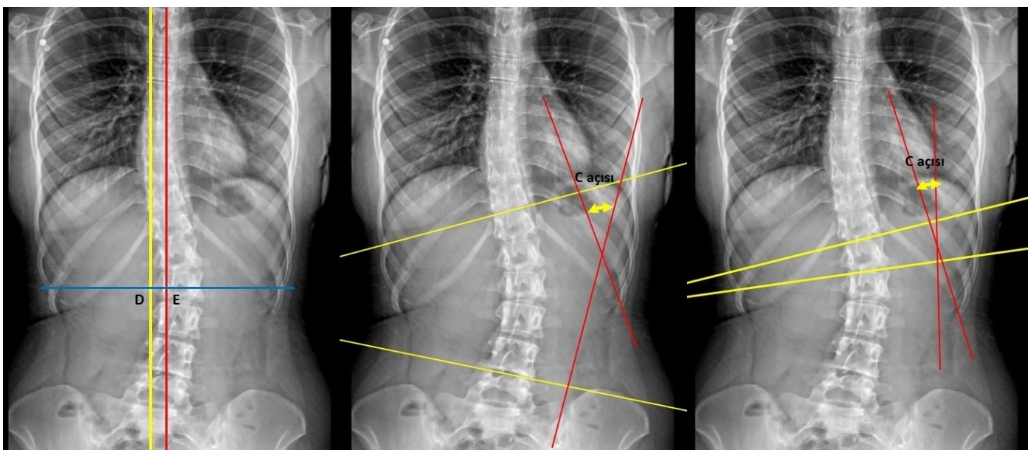

Fig. 1. (A) Coronal balance, (B) Cobb angle, and (C) Segmentary Cobb angle.

Surgical Methods

All interventions for PVP were performed in the operating rooms. Patients were placed in the prone position. Silicone pillows were placed under the chest and hips to correct the kyphosis. Vertebroplasty was performed percutaneously under C-arm control. All patients received prophylactic first-generation cephalosporin (Cefazolin) preoperatively. Local anesthesia and sedation were preferred for the procedure. Local anesthesia was performed with 1% lidocaine. General anesthesia was used in 7 cases where sedation failed and the patient did not communicate well. In patients undergoing unilateral VP procedure, the procedure was performed by entering 5 mm more laterally to deliver the bone cement to the centralized region. Polymethylmethacrylate (PMMA) bone cement (Berlin Germany) was used in all cases. Average 2-3.5 cc methylmethacrylate was used in bilateral VP, and 3.5-4 cc methylmethacrylate was used in unilateral VP. Patients were followed up during the operation. Possible complications were observed. Patients were mobilized with a corset 3 hours after the operation. The patients were discharged the same day after a control X-ray and, if necessary, a control computed tomography scan (according to the X-ray image). General anesthesia patients were discharged the next day under the same conditions [11].

Statistical Analysis

The data were analyzed using SPSS 22 software. Frequency, percentage, mean value, standard deviation, median value, and highest and lowest (min-max) values were used for descriptive statistics. Pearson Chi-square test was applied for statistical analysis of categorical data. Shapiro Wilk test was used to check the suitability of the data for normal distribution. Since the independent groups of quantitative data did not conform to normal distribution, the Mann-Whitney U test was used in paired groups. The Wilcoxon test was used to determine whether there was a change in the quantitative values measured in the first and 6th month after surgery. The Pearson correlation coefficient was used to show the relationship between the variables. The statistical significance of the difference was accepted as $P<0.05$.

RESULTS

Of the 95 patients enrolled in the study, 49 (51.6%) were female and 46 (48.4%) were male. The mean age of the patients was 69.1±11.5 (range: 45-89) years. When the patients were categorized into two groups under 65 years and 65 years and over, 37 (38.9%) patients were under 65 years and 58 (61.1%) patients were 65 years and over. 59 patients (62.1%) were operated on unilaterally and 36 patients (37.9%) were operated on bilaterally. There was no significant correlation between the surgical operation group and the gender and age groups of the patients ($P>0.05$) (Table 1).

When the data obtained in the preoperative and early postoperative period in patients who underwent single and double pedicle vertebroplasty were evaluated, no statistically significant difference was obtained in coronal balance, Cobb angle, and segmentary Cobb angle measurements, although there were partial changes in the measurement values in both groups ($P<0.05$) (Table 2).

Table 1. Age and gender relationship with the surgical groups of the patients

Variables		All Patients		Patient Surgical Groups				P value
				Single Pedicle		Bilateral Pedicles		
		n	%	n	%*	n	%*	
Gender	Female	49	51.6	31	63.3	18	36.7	0.810
	Male	46	48.4	28	60.9	18	39.1	
Age Groups	65 years ↑	37	38.9	21	56.8	16	43.2	0.391
	65 years ↓	58	61.1	38	65.5	20	34.5	
All Patients		95	100.0	59	100.0	36	100.0	

*Percentage of rows was used. Pearson chi-square test was used.

Table 2. The preop, early postoperative, and 6th-month measurements of unilaterally/ bilaterally operated patients

Measurements	Single Pedicle	P value	Bilateral Pedicles	P value
Coronal Balance preop (mm)	2.5±1.9	**<0.05**	4.5±3.7	**<0.05**
Coronal Balance (early) mm	2.5±1.9		4.5±3.8	**0.035**
Coronal Balance (6. month) mm	4.0±3.0	**<0.001**	4.8±3.8	
Cobb Angle preop(°)	3.9±3.0	**<0.05**	5.9±4.9	**<0.05**
Cobb Angle (early) (°)	4.0±3.0		5.9±5.0	0.782
Cobb Angle (6. month) (°)	6.5±4.3	**<0.001**	6.0±5.1	
Segmentary Cobb Angle (preop) (°)	3.9±2.9	**<0.05**	6.0±5.1	**<0.05**
Segmentary Cobb Angle (early) (°)	4.0±3.0		6.0±5.2	0.796
Segmentary Cobb Angle (6. month) (°)	6.7±4.2	**<0.001**	6.0±5.1	

Data are shown as mean±standard deviation. Wilcoxon Signed Ranks Test was used.

When the data obtained in the early and late (mean 6 months) postoperative period in patients who underwent vertebroplasty from a single pedicle were evaluated. Coronal balance was measured as 2.5±1.9 in the early postoperative period and 4.0±3.0 in the 6th month and this change was statistically significant (P<0.001). Cobb angle was 4.0±3.0 in the early postoperative period and 6.5±4.3 at the 6th month and this change was statistically significant (P<0.001). Segmentary Cobb angle was 4.0±3.0 in the early postoperative period and 6.7±4.2 in the 6th month and the change was statistically significant (P<0.001) (Table 2).

When the data obtained in the early and late (mean 6 months) postoperative period in patients who underwent double pedicle vertebroplasty were evaluated. Coronal balance was 4.5±3.8 in the early postoperative period and 4.8±3.8 in the 6th month and this change was statistically significant (P=0.035). Cobb angle was measured as 5.9±5.0 in the early postoperative period and 6.0±5.1 in the 6th month and the change was not statistically significant (P=0.782). Patients who underwent bilateral operations. Segmentary Cobb angle was 6.0±5.1 in the early postoperative period and 6.0±5.1 in the 6th month and the change was not statistically significant (P=0.796) (Table 2) (Figs. 2, 3 and 4).

When all patient groups (single and double pedicle interventions) were evaluated according to gender, preoperative, early postoperative, and 6th-month coro-

Fig. 2. CT view of cleft at osteoporotic vertebral compression fracture (OVCF).

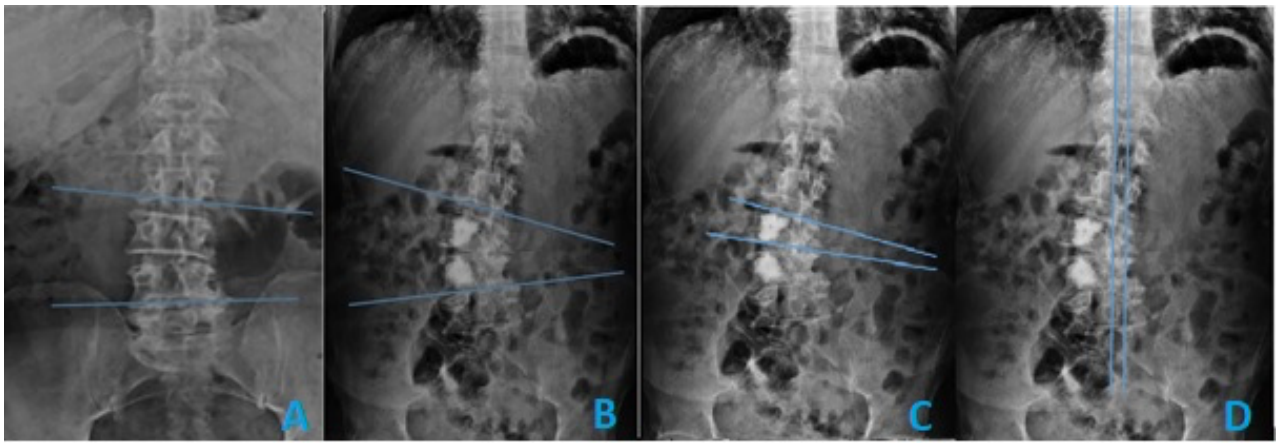

Fig. 3. **(A) Preoperative Cobb, (B) Postoperative Cobb, (C) Postoperative segmentary Cobb, and (D) Postoperative coronal balance.**

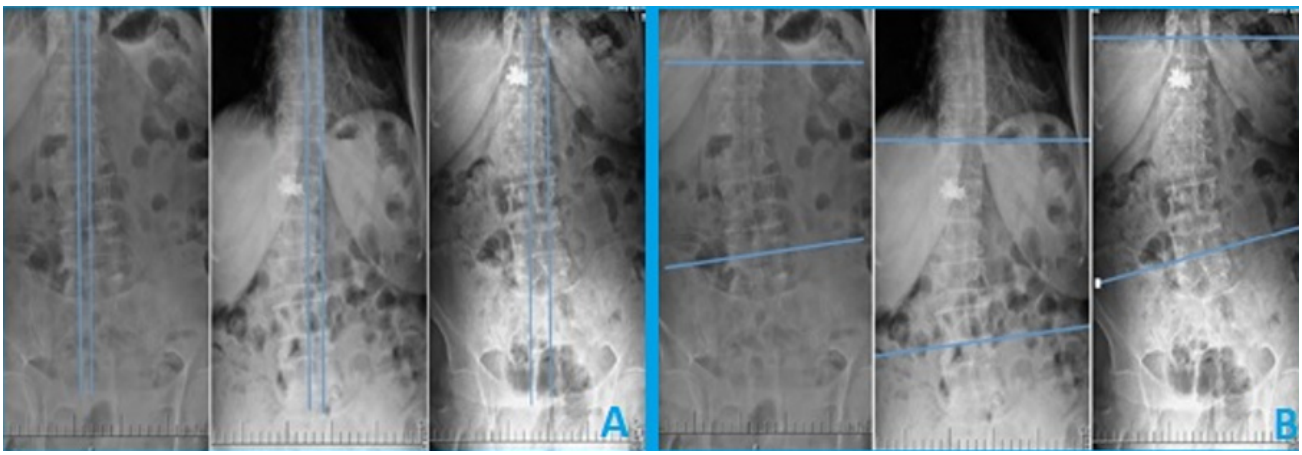

Fig. 4. **(A) Preoperative/postoperative early/postop 6. month coronal balance and (B) Preoperative/postoperative early ve 6. month Cobb angle.**

Table 3. **Preoperative/postoperative measurements according to age groups**

Measurements	Age groups		
	65 years ↓	65 years ↑	P value
Coronal balance preop (mm)	1.8±2.2	4.0±2.2	**<0.001**
Coronal balance (early) mm	1.9±2.6	4.1±2.8	**<0.001**
Coronal balance (6. month)	2.5±3.1	5.5±3.0	**<0.001**
Cobb angle preop(°)	2.6±3.1	5.8±3.1	**<0.001**
Cobb angle (early) (°)	2.8±3.6	5.9±3.7	**<0.001**
Cobb angle (6. month) (°)	4.1±3.7	7.8±4.6	**<0.001**
Segmentary Cobb angle (preop) (°)	2.7±3.2	5.6±2.9	**<0.001**
Segmentary Cobb angle (early) (°)	2.8±3.7	5.9±3.8	**<0.001**
Segmentary Cobb angle (6. month) (°)	4.2±3.8	7.8±4.5	**<0.001**

Data are shown as mean±standard deviation. Mann Whitney U Test was used.

nal balance, Cobb angle and segmental Cobb angle measurements did not differ significantly in both groups (P>0.05). When both groups were evaluated according to age, preoperative, early postoperative, and 6-month postoperative Cobb angle, segmental Cobb angle, and coronal balance measurements of patients aged 65 years and older were significantly higher (P<0.001). In both intervention groups, there was a positive correlation between age and Cobb angle, segmental Cobb angle, and coronal balance measurements in preoperative, early postoperative, and 6-month measurements (P<0.05) (Table 3) (Figs. 2, 3 and 4).

DISCUSSION

PVP is a much more successful treatment method than conservative treatment methods in treating treatment-resistant pain or acute pain in OVCF patients [11]. Moreover, when applied in multiple vertebral fractures, it has been reported to be effective and has similar results compared to single-level procedures in terms of healing, gaining mobility and pain relief [7, 12, 13]. Tohmen *et al*. [13] reported in their biomechanical tests on cadavers that unilateral or bilateral PKF did not affect the recovery of the vertebral corpus to its preoperative strength or stiffness.

In a study published in 2023, Tan *et al*. [8] showed that unilateral and bilateral PVP gave similar results in reducing pain complaints and maintaining the height of the vertebra, both models had a positive effect on the restoration of lordosis with no significant difference on sagittal balance. However bilateral PVP had advantages over unilateral PVP in stabilizing coronal balance. They reported that the loss of improvement in coronal balance was more pronounced in multilevel vertebroplasty. In this study, they also stated that balance changes are not only caused by the loss of height in the vertebral body but also by the adjacent segment and the intervertebral disc. Secondary scoliosis that may occur after surgery is caused by the effect of these factors.

In our study, there was a statistically significant loss of coronal correction in the measurements of patients who underwent unilateral PVP after 6 months of surgery, whereas no measurements were obtained to show loss of coronal balance in the measurements of patients who underwent bilateral PVP. In addition, it was observed that coronal imbalance of the vertebrae after vertebroplasty was more common in patients over 65 years of age than in patients under 65 years of age. Cement distribution affects biomechanical balance [14]. It is recommended to place the bone cement symmetrically in the corpus during the PVP procedure [12, 15]. If the PVP is done through both pedicles, the stiffness of the spine increases on both sides of the corpus, but if this is done unilaterally and the cement is not evenly distributed and limited to only one side of the corpus, then only the side that is cemented will increase in stiffness and the other side will be weaker. This will create a biomechanical stress imbalance on the adjacent vertebrae. [15, 16]. This may explain the negative effect of unilateral PVP on coronal balance. The increased use of PVP in the treatment of OVCFs has led to more careful observation of the clefts in the vertebrae called clefts in OVCFs. Filling the clefts should be the primary goal in PVP. Patients with incomplete filling of the clefts are thought to achieve a return to preoperative baseline pain and deformity within 6 to 12 months [18]. Recent studies suggest that intervertebral clefts in OVCF affect the effects of PVP on clinical recovery and complications that may occur [18]. Therefore, it is necessary to detect intervertebral clefts during the treatment of patients with OVCF. MRI images are important here. Contrast MRI may show a hypointense area in a homogenous contrasting corpus or a hyperintense area in T1 and T2 sequences [19].

CONCLUSION

Patients with OVCF have significant clinical improvement as a result of PVP made of single or double pedicles. Pain is greatly reduced. Height improves significantly. However, from the radiographic point of view in the long-term follow-up, we think that bilateral PVP provides an advantage over the unilateral approach in maintaining the coronal balance and stabilization of the coronal Cobb angle in patients with OVCF, and that age over 65 years is a negative factor in terms of the coronal balance of the vertebrae after vertebroplasty. We believe that more long-term and numbered studies are also necessary.

Ethical statement

Ethics committee approval (number: 2023-788) was obtained from the from the Clinical Research Ethics Committee of Erciyes University.

Authors' Contribution

Study Conception: MM; Study Design: MM; Supervision: MM; Funding: MM; Materials: MM; Data Collection and/or Processing: MM; Statistical Analysis and/or Data Interpretation: MM; Literature Review: MM; Manuscript Preparation: MM, RKK and Critical Review: MM, RKK.

Conflict of interest

The authors disclosed no conflict of interest during the preparation or publication of this manuscript.

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