Prophylactic adjacent-segment vertebroplasty following kyphoplasty for a single osteoporotic vertebral fracture and the risk of adjacent fractures: a retrospective study and clinical experience

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OBJECTIVE This study investigated the benefit of prophylactic vertebroplasty of the adjacent vertebrae in single-segment osteoporotic vertebral body fractures treated with kyphoplasty.

METHODS All patients treated with kyphoplasty for osteoporotic single-segment fractures between January 2007 and August 2012 were included in this retrospective study. The patients received either kyphoplasty alone (kyphoplasty group) or kyphoplasty with additional vertebroplasty of the adjacent segment (vertebroplasty group). The segmental kyphosis with the rate of adjacent-segment fractures (ASFs) and remote fractures were studied on plain lateral radiographs preoperatively, postoperatively, at 3 months, and at final follow-up.

RESULTS Thirty-seven (82%) of a possible 45 patients were included for the analysis, with a mean follow-up of 16 months (range 3–54 months). The study population included 31 women, and the mean age of the total patient population was 72 years old (range 53–86 years). In 21 patients (57%), the fracture was in the thoracolumbar junction. Eighteen patients were treated with additional vertebroplasty and 19 with kyphoplasty only. The segmental kyphosis increased in both groups at final follow-up. A fracture through the primary treated vertebra (kyphoplasty) was found in 4 (22%) of the vertebroplasty group and in 3 (16%) of the kyphoplasty group ($p = 0.6$). An ASF was found in 50% ($n = 9$) of the vertebroplasty group and in 16% ($n = 3$) of the kyphoplasty group ($p = 0.03$). Remote fractures occurred in 1 patient in each group ($p = 1.0$).

CONCLUSIONS Prophylactic vertebroplasty of the adjacent vertebra in patients with single-segment osteoporotic fractures as performed in this study did not decrease the rate of adjacent fractures. Based on these retrospective data, the possible benefits of prophylactic vertebroplasty do not compensate for the possible risks of an additional cement augmentation.

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KEY WORDS kyphoplasty; prophylactic; vertebroplasty; adjacent-segment fracture; osteoporotic; thoracic; lumbar

EVERY year approximately 1.4 million patients suffer from osteoporotic vertebral compression fractures worldwide.¹⁴ Due to demographic shifts this could become a major health care problem of increasing impact.⁵ The estimated lifetime risk of developing an osteoporotic vertebral fracture in white women is about 15%, and increases up to 27% in patients over 65 years

of age.^{8,22} If treated conservatively, the rate of recurrent fractures ranges from 12% to 20%.¹⁰ The risk of further vertebral fractures depends on several factors, including the number of affected vertebrae and the shape of the prevailing deformities. The risk of further vertebral fractures is 3-fold higher after the first fracture has occurred and increases up to 23 times after the third fracture.²⁰

ABBREVIATIONS ASF = adjacent-segment fracture.

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Kyphoplasty is an option to treat painful osteoporotic compression fractures that do not respond to conservative treatment.³¹ The most frequently observed complication is adjacent-segment fractures (ASFs), with a risk between 2% and 23% in kyphoplasty³ and up to 52% in vertebroplasty.¹³ Other complications such as cement leakage (which is mostly asymptomatic), spinal compression with radiculopathy, cement embolism, and infections are rarely observed.¹⁷ The majority of ASF occurs within 2 months postoperatively.¹⁰ High preoperative segmental kyphosis, as well as comorbidities such as rheumatoid arthritis, have been found to be risk factors for ASF after kyphoplasty.²⁷ Further possible reasons for this increased rate of ASF include the following: amount of cement injected, increased stiffness, load transmission to the adjacent vertebra, and progressing osteoporosis.

The use of prophylactic cement augmentation appears to be a viable option to prevent ASF after kyphoplasty, and biomechanical studies supporting this thesis have been published.⁷ Due to the endplate deflection fracture mechanism⁹ and the load transmission with lower failure strength in the adjacent vertebrae,⁴ these studies suggest building a gradient in mechanical properties through application of the cement near to the neighboring endplate. However, the lack of clinical evidence raises questions about the benefit of a prophylactic vertebroplasty or kyphoplasty.^{3,19,25} To the best of our knowledge, there is no clinical data concerning the rate of ASF after prophylactic vertebroplasty following kyphoplasty. The purpose of the study was to investigate the benefit of prophylactic vertebroplasty in preventing ASF in cases of single-segment osteoporotic vertebral fractures treated with kyphoplasty.

Methods

Study Population

We performed a retrospective analysis of medical records and radiographs of all patients who underwent single-segment kyphoplasty at our department from January 2007 to August 2012; the mean follow-up duration of these patients was 16 months. Information about sex, age, hospital stay, fracture level, and complications was collected from medical records and operative protocols.

All patients were admitted to the hospital for a painful single-segment osteoporotic fragility fracture, defined as a fracture after a fall from a standing height or lower that would normally not cause a fracture. Additionally, these

patients must have undergone unsuccessful conservative treatment, been symptomatic for less than 6 weeks, and/or had MRI with edema demonstrated in the fractured vertebra. Exclusion criteria included pathological fractures (caused by tumors), incomplete radiographic follow-up (at least 3 months), patients presenting with multiple osteoporotic fractures, patients with a history of prior spinal surgery, and multilevel osteoporotic vertebral body fractures.

All patients were treated with kyphoplasty alone or with additional prophylactic vertebroplasty of the adjacent segment, depending on the surgeon's decision and experience. Kyphoplasty was performed according to the methodology described in the literature.¹² To prevent higher failure load from too much cement, while still applying enough volume to reinforce the intact vertebral body, the surgeons filled approximately 20% of its volume with approximately 5 ml of cement using vertebroplasty.²⁸ Accordingly, all included patients were allocated to either the kyphoplasty group or the vertebroplasty group. The fractures were classified according to the AOSpine classification system.²¹ In the vertebroplasty group, the segment to be treated prophylactically was chosen depending on the type of fracture. Fractures that were classified as type A1.2.1 were augmented cranially, and as type A1.2.3 were augmented caudally, whereas fracture types with involvement of both endplates (collapse and complete burst fractures [A1.3, A3.3] as well as pincer fractures [A2.3]) were augmented on both sides (Table 1).

Data Collection

Patients routinely underwent postoperative follow-up evaluations at 6 weeks and 3 months. The radiographic assessment consisted of standing plain lateral radiographs preoperatively, postoperatively, at 3 months, and at the final follow-up. The local and segmental kyphotic angles were digitally measured according to the method described by Cobb, which has previously been validated to show excellent intrarater and interrater reliability^{6,34} (Figs. 1 and 2). The local kyphosis was defined as the angle between the upper and lower endplates of the fractured vertebra, whereas the segmental kyphosis was defined as the angle between the upper and lower endplates of the intact adjacent vertebral bodies. The occurrence of new vertebral fractures was assessed for all patients. All measurements were performed by the first 3 authors and verified by repeated measurement conducted by the first and last author. If discordant values were observed, a consensus

TABLE 1. AO classification of thoracolumbar fractures*

Type A. Vertebral body compression								
A1 Impaction fractures			A2 Split fractures			A3 Burst fractures		
A1.1. Endplate	A1.2. Wedge	A1.3. Vertebral body collapse	A2.1. Sagittal	A2.2. Coronal	A2.3. Pincer	A3.1. Incomplete	A3.2. Burst-split	A3.3. Complete
	A1.2.1 Superior					A3.1.1 Superior	A3.2.1 Superior	A3.3.1 Pincer
	A1.2.2 Lateral					A3.1.2 Lateral	A3.2.2 Lateral	A3.3.2 Complete flexion
	A1.2.3 Inferior					A3.1.3 Inferior	A3.2.3 Inferior	A3.3.3 Complete axial

* The AO classification also includes: Type B, anterior and posterior element injury with distraction; and Type C, anterior and posterior element injury with rotation.

FIG. 1. Standing lateral radiographs obtained immediately postoperatively (**left**) and at the last follow-up (**right**) showing an ASF in the prophylactically augmented vertebral body. Measurement of the local (α) and segmental (β) kyphosis using the Cobb method is also shown. Figure is available in color online only.

was obtained by measuring the endplates together to determine the correct angle.

Statistical Analysis

A t-test for comparisons of continuous variables between the 2 groups and a chi-square or Fisher's exact test were used for categorical variables. The level of significance was set to $\alpha = 0.05$ throughout the study. The present study was approved by our institutional review board (Kantonale Ethikkommission St. Gallen).

Results

A total of 45 patients met the inclusion criteria. Of these

45 patients, 2 died prior to achieving complete follow-up, 2 patients were lost to follow-up, and 4 patients had incomplete radiographic follow-up because only a preoperative MR image was obtained without a lateral radiograph. Finally, 37 patients (84%; 31 women and 5 men) with a mean follow-up duration of 16 months were eligible to be included in the study. The general patient characteristics of the 2 groups are listed in Table 2.

The descriptive and radiographic data are outlined in Tables 2 and 3. In the vertebroplasty group, 6 prophylactic vertebroplasties were performed above the fractured vertebra and 12 on both of the adjacent levels above and below. In the vertebroplasty group there was a nonsignificant tendency toward older age ($p = 0.06$) and significantly

FIG. 2. Standing lateral radiographs obtained immediately postoperatively (**left**) and at the last follow-up (**right**) showing an ASF in a nonprophylactically augmented vertebral body. Measurement of the local (α) and segmental (β) kyphosis using the Cobb method is also shown. Figure is available in color online only.

TABLE 2. Descriptive data

Variable	Total	Vertebroplasty Group	Kyphoplasty Group	p Value
No. of patients	37	18	19	—
Females (%)	31 (84)	18	13	0.01*
Mean age in yrs (range)	72 (53–86)	75 (62–86)	69 (53–86)	0.06
Mean hospital stay in days (range)	7.5 (2–49)	9 (2–49)	6 (3–13)	0.3
Mean follow-up in mos (range)	16 (3–53)	15 (3–48)	17 (3–53)	0.8
Fracture level (%)				
T10–L2	21 (57)	11 (61)	10 (53)	0.3
T6–8	5 (13)	3 (17)	2 (10)	0.7
L3–5	11 (30)	4 (22)	7 (37)	0.5
AO classification				
A1.2.1	14	6	8	—
A1.2.3	1	0	1	—
A1.3	15	9	6	—
A3.1	4	2	2	—
A3.2	1	0	1	—
A3.3	2	1	1	—

— = not applicable.

* Statistically significant.

more women. There were no significant differences concerning hospital stay, follow-up duration, and fracture location between the 2 groups (Table 2).

The initial local kyphosis was significantly higher in the vertebroplasty group compared with the kyphoplasty group (Table 3). We could observe a corresponding but nonsignificant tendency for segmental kyphosis. When

compared to preoperative values, a slight correction of the local and segmental kyphosis could be revealed in both groups directly postoperatively. However, the segmental kyphosis at the final follow-up exceeded the initial and postoperative values in both groups.

Concerning radiographic complications (Table 3), a significantly higher rate of ASF (50%) was found in the vertebroplasty group, with 9 fractures observed in the prophylactically cemented vertebral bodies (6 above and 3 below the level of kyphoplasty; Fig. 1). In the kyphoplasty group, 3 ASFs (16%) were found in the adjacent vertebrae (2 above and 1 below the level of kyphoplasty; Fig. 2). The number of discal cement extrusions was marginally, although not significantly, higher in the vertebroplasty group. Both groups were comparable regarding the number of cement fractures through the primary treated vertebra (kyphoplasty), remote fractures, and cement extrusion into the spinal canal. None of the patients had any neurological symptoms before or after the treatment.

Discussion

Bone augmentation with cement is a widely used procedure to relieve pain in osteoporotic compression fractures that does not respond to conservative treatment.^{16,31} Although kyphoplasty and vertebroplasty are considered safe procedures, complications have been reported. One of the most frequent complications is the development of adjacent vertebrae fractures with an incidence of up to 52%.^{1,4,10,13,15,19,20,27} This is the first study to question the benefit of prophylactic vertebroplasty adjacent to kyphoplasty for single-segment osteoporotic vertebral body fractures. Interestingly, instead of observing a lower rate of ASF in the vertebroplasty group, we ascertained a significantly higher rate (50%) than in the kyphoplasty group

TABLE 3. Radiographic data of the 2 groups

Radiographic Variable	Vertebroplasty Group	Kyphoplasty Group	p Value
Mean local preop kyphosis (°)	20	12	0.005*
Mean local postop kyphosis (°)	11	8	0.2
Mean local kyphosis at final follow-up (°)	15	10	0.05*
Mean preop segmental kyphosis (°)	22	14	0.07
Mean postop segmental kyphosis (°)	19	13	0.1
Mean segmental kyphosis at final follow-up (°)	24	23	0.7
No. of re-fractures in the primary cemented vertebral body (%)	4 (22)	3 (16)	0.6
ASF (%)	9 (50)	3 (16)	0.03*
Remote fractures (%)	1 (6)	1 (5)	1.0
Disc cement extrusion (%)	5 (28)	1 (5)	0.06
Spinal cement extrusion (%)	2 (11)	1 (5)	0.5
Neurological complications	0	0	—

* Statistically significant.

without vertebroplasty (16%). However, both groups showed a loss of the slight postoperative correction of local and segmental kyphosis at the final follow-up. Either with or without prophylactic vertebroplasty, a progression of the segmental kyphosis could not have been prevented. The high rate of ASF in the vertebroplasty group raises questions about the benefit of this procedure.

Three main points have been identified that can help explain the trends that were observed in this study. First, a fragility fracture indicates poor bone quality and further fractures may be related to the natural progression of this disease rather than the treatment method. Several studies have shown that after conservatively treated osteoporotic vertebral fractures, further vertebral fractures can be observed at a rate ranging from 12% to 27%.^{13,20,27,29}

Second, from a biomechanical perspective, the increased stiffness due to the cement can alter the biomechanics of load transfer to the adjacent vertebra, therefore causing strain on the neighboring ones. In their biomechanical study, Chun-Kai et al.⁷ suggested that prophylactic cement injection into the adjacent vertebra might reinforce an osteoporotic vertebral body, especially when located at the pivot point of the lordotic level.^{7,11} In their recently published laboratory investigation Nagaraja et al.²⁴ reported that bone cement injected into vertebral bodies alters the local biomechanics, resulting in increased endplate disruption in treated and adjacent vertebrae. More specifically, it increases subsidence in the posterior regions of the treated endplates and the anterior region of the superior caudal endplate. They argue that this may be the initial mechanism leading to subsequent compression fractures after cement augmentation. Cadaveric studies have shown that the bulge of the endplates plays a major role in the mechanics of the intervertebral joint and has a substantial effect on the stiffness of the disc.² With higher loads the annulus fibers stiffen the disc. Without the endplate bulge, the radial bulge of the disc must considerably increase. This may damage the annulus fibers, leading to a decreased buffer action of the cartilaginous component and therefore may increase the risk of new fracture in the adjacent vertebra.

On the other hand, in their finite element analysis, Villarraga et al.³⁰ found only minimal changes in stresses and strains at levels adjacent to a kyphoplasty-treated level. Another important finding was that the stress and strain levels found at the treated levels were within the tolerance limits of cancellous and cortical bone. Molloy and colleagues²³ reported that strength and stiffness were weakly correlated with the percentage fill volume of cement injected. To restore the strength or the stiffness, 16% and 29% of the vertebral body needed to be filled, respectively. Nevertheless, clinically, cement volume is the most important modifiable predictor for pain relief in kyphoplasty, as shown by Roder and colleagues²⁶ from the SWISSspine registry.

Furthermore, the clustering argument shows a higher incident of fractures in the midthoracic (T7–9) and thoracolumbar (T11–L1) regions due to the peculiar forces in this region.³² In particular, the midthoracic region is the location of greatest thoracic kyphosis and the thoracolumbar junction represents the articulation of the rigid thoracic spine and relatively mobile lumbar segments.³³ All

these data support the hypothesis that adjacent vertebral fractures may be related to weakened bone structure (i.e., osteoporosis) rather than the surgical treatment.³⁰

Third, if patients are engaging in more activity postoperatively because of pain relief, this may lead to an increased potential of falling and sustaining additional spinal trauma.

However, there is only limited information about the clinical benefit of prophylactic vertebral cement augmentation. To the best of our knowledge there is only 1 study, performed by Becker et al.,³ that prospectively compares prophylactic kyphoplasty following kyphoplasty of fractured vertebrae. These authors did not observe a reduced rate of adjacent vertebral fracture and doubted a clinical benefit of prophylactic kyphoplasty. Their results are in accordance with our findings, because we observed a significantly higher rate of ASF in our vertebroplasty group compared with the kyphoplasty group. The fact that the adjacent vertebral body can fracture despite cement augmentation raises questions regarding the clinical benefit of prophylactic vertebroplasty.

Furthermore, an additional prophylactic vertebroplasty of the adjacent segment has no influence on the restoration of the sagittal alignment. Kim et al.¹⁵ demonstrated that the restoration of the vertebral body height is dependent on the fracture but not on the kyphotic angle. There is a lack of information about the restoration of local and segmental kyphosis, especially long-term results. Kim et al. showed no influence, whereas the study by Li et al.¹⁸ demonstrated a significant reduction of the kyphosis comparing kyphoplasty and vertebroplasty.^{15,18} There exists no literature about the influence of augmenting the adjacent vertebra on kyphosis reduction.

Our study has several limitations. The major limitation is its retrospective, nonrandomized design. Because there were not strict guidelines for prophylactic vertebroplasty, this resulted in a tendency to include older patients with more kyphotic fractures in the vertebroplasty group. Nevertheless, Spross et al.²⁷ showed a higher incidence of adjacent vertebral fractures only in patients with increased segmental kyphosis, which did not significantly differ in the two groups. Local kyphosis could not be identified as a risk factor, although the vertebroplasty group had a tendency to have more kyphotic patients, which was not significant. The small changes in preoperative and follow-up measurements may be due to observer-related error; however, we tried to eliminate this error by re-measuring the values by the first and last author and finding a consensus in discordant values. Because MR images were not available in all cases, the degree of disc degeneration could not be addressed. Another weakness is the lack of information about the bone density due to the inability to obtain dual-energy x-ray absorptiometry measurements in the inpatient setting because of guidelines established by our health care system. Another limitation is the relatively small number of patients included due to rigid selection of patients (single-segment fractures, without any prior spinal surgery). Furthermore, because the minimal follow-up in our study was only 3 months but ASFs are known to develop mainly in the first 2 months after percutaneous kyphoplasty,¹⁰ the effective rate of ASF might even be higher

with a longer follow-up duration. Despite these limitations, we believe that the results of this study are clinically relevant as there is very little information about this topic, and we report a significantly higher rate of ASF in the vertebroplasty group than expected.

Conclusions

In our retrospective analysis, prophylactic vertebroplasty of adjacent vertebrae did not lower the risk of ASF in patients with single-segment osteoporotic vertebral fractures treated with kyphoplasty. Therefore, subsequent adjacent fractures are more likely related to underlying osteoporosis rather than to the surgical intervention.

This study raises questions regarding the benefit of prophylactic vertebroplasty, yet definitively demonstrating or excluding a causative relationship is difficult. A larger, homogeneous patient population is needed to consider additional risk factors such as fracture age, number of previous fractures, obtained postoperative correction, localization, antiresorptive therapy, and bone mineral density. Therefore, further randomized control trials investigating the efficacy and usefulness of prophylactic cement augmentation in vertebroplasty or kyphoplasty are necessary.

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Disclosures

The authors report no conflict of interest concerning the materi-

als or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Eichler, Külling. Acquisition of data: Eichler, Spross, Ewers. Analysis and interpretation of data: Eichler, Spross. Drafting the article: Eichler. Critically revising the article: Eichler, Spross, Mayer, Külling. Reviewed submitted version of manuscript: Spross, Külling. Approved the final version of the manuscript on behalf of all authors: Eichler. Statistical analysis: Spross. Study supervision: Külling.

Supplemental Information

Previous Presentations

Portions of this work were presented in a talk at the 73rd Annual Meeting of the Swiss Orthopaedics Association in June 2013 in St. Gallen, Switzerland.

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