Vertebral body height changes in acute symptomatic osteoporotic vertebral compression fractures treated with vertebral cement augmentation. Which factors affect vertebral body height?

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Abstract

Changes in vertebral body height depend on various factors which were analyzed in isolation and not as a whole. The aim of this study is to analyze what factors might influence restoration of vertebral body height after vertebral augmentation. We analyzed 48 patients (108 vertebrae) with osteoporotic vertebral fractures underwent vertebral augmentation when conservative treatment proved unsatisfactory. Analyses were carried out at the time of the fracture, during surgery (pre-cementation and post-cementation), at first medical check-up (6 weeks post-surgery) and at last medical check-up. Average vertebral height was measured and differences from preoperative values calculated at each timepoint. Pearson correlation coefficient and linear multivariable regression were carried out at the different timepoints. The time since vertebral fracture was 60.4 ± 41.7 days. Patients' average age was 70.9 ± 9.3-years. The total follow-up was 1.43 ± 1-year. After vertebral cementation there was an increase in vertebral body height of + 0.3cm (13.6%). During post-operative follow-up, there was a progressive collapse of the vertebral body and pre-surgical height was reached. The factors that most influenced vertebral height restoration were: grade III collapse, intervertebral-vacuum-cleft (IVVC), and use of a flexible trocar before cement augmentation. The factor that negatively influenced vertebral body height restoration was location in the thoracolumbar spine.

Introduction

Different meta-analyzes compared percutaneous vertebroplasty (PVP) with conservative treatment for osteoporotic vertebral compression fractures (OVCFs), reaching the conclusion that PVP achieves greater pain relief, greater functional recovery and better quality of life during the first post-operative year[1–3].

Although vertebral height restoration is not an objective of PVP, numerous studies showed that there is an increase in vertebral body height after PVP of 1.2-2.3mm[4–9]. However, increase in vertebral body height is frequently calculated comparing pre and postsurgical measurements, which means that changes because of the patient's position (standing to prone position) are not taken into account, and could bias the vertebral augmentation effect[4,7,9–11].

Increase in vertebral body height depends on different factors. Dynamic mobility, conditioned by the patient's position, is the change in the vertebral body height when the patient goes from standing to supine or prone position, and constitutes one of the most important factors[8,12–16]. The type of vertebral fracture (wedge, biconcave or burst) determines which area of the vertebral body (anterior, middle, or posterior) experiences greater mobility[7,9,15]. Vertebral fractures of the thoracolumbar region have greater mobility than those in the thoracic region or lumbar region[14,15]. Percutaneous kyphoplasty (PKP) achieves greater restoration of vertebral height than PVP[5,6]. The presence of intervertebral vacuum cleft (IVVC) is another important factor[8,9], and these clefts are usually located in the thoracolumbar region. All these factors are generally analyzed in isolation and not as a whole, so the surgeon does not really know when these factors may exert an influence during patient follow-up. The aim of this study is to specify the factors influencing restoration of vertebral body height after PVP, from the vertebral body fracture until the patient is definitively discharged.

Materials And Methods

Approval for this prospective study was given by the Regional Ethical Review Board at our institution (University of Navarra, reference code, 2018.044). Before participating, all patients gave written consent to participate in this study after having received oral and written information. In addition, the study was conducted in accordance with the 1975 Helsinky Declaration, revised in 2013.

Patient selection

Our cohort consisted of patients who had been treated for acute painful OVCFs and who met the inclusion criteria over the period February 2015 to February 2020. Recruitment criteria were: acute painful OVCFs, failure of conservative treatment (non-steroidal anti-inflammatory drugs, soft orthosis and lumbar exercises), progressive collapse of the vertebral body, reproducible pain at the level of the fractured vertebra, with either current MRI showing bone edema on the STIR sequence or cement augmentation without instrumentation. The patients were excluded if they did not meet inclusion criteria, if they had a vertebral fracture secondary to oncological disease, or if cement augmentation was associated with instrumentation. Of 50 patients (117 vertebrae) treated with cement augmentation, 2 (9 vertebrae) were excluded because they were lost to follow-up. Finally, 48 patients (108 vertebrae) were included. Eighty-eight vertebrae were treated with percutaneous vertebroplasty (DePuy Synthes, Oberdorf, Switzerland) and twenty vertebrae were treated with a flexible trocar StabiliT® MX System (DFine, San José, USA). All patients underwent conventional AP/Lateral X-Rays as well as MRI pre-surgery. The location of the treated vertebrae was as follows: T5 (n = 2), T6 (n = 9), T7 (n = 9), T8 (n = 10), T9 (n = 6), T10 (n = 6), T11 (n = 5), T12 (n = 10), L1 (n = 10), L2 (n = 12), L3 (n = 10), L4 (n = 10) and L5 (n = 9). The demographic parameters of our cohort are shown in Table 1.

Table 1
Demographic characteristics.

Gender	
Male	14 (29.2%)
Female	34 (70.8%)
Age, SD	70.9 ± 9.3
BMI (kg/m^2), SD	26.5 ± 4
T-Score, SD	-1.9 ± 1.1
Vertebral fracture age	
< 6 weeks	49 (45.5%)
> 6 weeks	59 (54.6%)
Vertebral segment treated	
Thoracic (T1 - T10)	42 (38.9%)
Thoracolumbar (T11 – L2)	37 (34.3%)
Lumbar (L3 – L5)	29 (26.8%)
Type of fracture*	
Wedge	33 (30,6%)
Biconcave	75 (69.4%)
Severity of fracture*	
Grade I	39 (36.1%)
Grade II	29 (26.9%)
Grade III	40 (37%)
IVVC	
No	85 (78.7%)
Yes	23 (21.3%)
Volume of cement injected	3.5 ± 1.18

Gender
BMI: Body Mass Index
SD: Standard Deviation
IVVC: Intervertebral vacuum cleft
*According Genant classification[17]

Description of the surgical technique

Surgical treatment was performed under general anesthesia in prone position. We did not perform any maneuver to restore vertebral height before or during the procedure. Two imaging systems (SIEMENS Arcadis Orbic and SIEMENS Arcadis Varic) perpendicular to each other and centered on each vertebra were used. All vertebroplasties were performed through a bilateral transpedicular approach. Under fluoroscopic guidance, cement was injected. The cement injection continued until the vertebral body was filled toward the posterior 25% of the vertebral body or until leakage occurred. After cement injection, the patient remained prone on the table for approximately 20 minutes.

The differences between using the StabiliT® MX System and PVP are: before injecting cement, a path is created with a flexible trocar, administration of cement is carried out with a remote control and cement viscosity is controlled by radiofrequency. The main benefit of this system is to try to reduce the volume of injected cement.

Collected data

All patients were studied pre-surgery, pre-cementation, post-cementation, at first medical check-up (6 weeks post-surgery) and at last medical check-up (minimum 6 months). Lateral X-ray was used to take the measurements. All images were taken at a distance of one meter from the patients ensuring that the upper and lower plate were properly aligned. In each vertebral body, anterior, middle (most collapsed zone and least collapsed zone) and posterior edge heights were measured (Fig. 1). Average vertebral height was measured and the difference calculated, in each period, from preoperative values. The posterior edge of one adjacent nonfractured vertebral body was also measured in each study period to validate the measurements. The first author made the measurements using a digital PACS caliper and he was blinded to clinical context in each case.

Other assessed parameters were demographic data (age, gender, body mass index – BMI-, T-Score), vertebral fracture evolution time (less or more than 6 weeks), the type and severity of vertebral fracture according to the Genant classification[17], IVVC presence, vertebral augmentation technique and volume of cement injected. The vertebral fracture location was classified as follows: thoracic (T1-T10), thoracolumbar (T11-L2) or lumbar (L3-L5).

Statistical analysis of data

Sample size was determined by two means, taking into account the data published in the article by Röllinghoff et al.[18] This study was chosen because the methodology was similar to our study. The mean and standard deviation of pre-surgical and post-surgical vertebral body height were chosen for vertebroplasty and StabiliT® system (vertebroplasty, 14.1 ± 5.1mm and 17.9 ± 4.2mm; StabiliT® system, 14.7 ± 5.6mm and 19.5 ± 4.5mm). Beta was 0.2 (80% power) and alpha (two-tailed) 0.05. We determined that a minimum of 24 vertebrae was needed if we took into account the results of PVP, or 18 vertebrae if we took into account the results of StabiliT® system.

Descriptive statistics about the sample were obtained. The Shapiro-Wilk test confirmed normal distribution of the variables. Initially, a Pearson correlation coefficient was carried out between the demographic quantitative variables (age, BMI, T-Score) and the difference in overall height of the vertebral body at the different study timepoints regarding pre-surgical status. The gender variable was analyzed using Student's T test at the different timepoints.

Subsequently, we performed multiple linear regression to determine if vertebral fracture time, vertebral segment treated, type of fracture treated, severity of the fracture, IVVC presence or vertebral augmentation technique performed could influence the restoration or loss of vertebral height at each timepoint. Finally, to verify the validity of our model, we checked that the residuals followed a normal distribution.

A 0.05 level of probability was accepted as criterion for statistical significance for all statistical tests. All statistical tests were carried out using Stata software 12.0 version for Macintosh (Data Analysis and Statistical Software, Texas, USA).

Results

Patients

Average time from diagnosis to surgery was 60.4 ± 41.7 days. Specifically, 49 vertebrae (45.4%) were treated before the sixth week and 59 vertebrae (54.6%) were treated after the sixth week. Average age of patients was 70.9 ± 9.3-years. BMI was 26.5 ± 4kg/m^2, and mean T-score was − 1.9 ± 1.1 (Table 1). Thoracic injury predominated, being found in 42 vertebrae (38.9%). According to the Genant classification[17], 75 vertebral injuries were biconcave type (69.4%) and 33 vertebral injuries were wedge type (30.6%). A grade III collapse was the most frequent (Table 1). Average volume of injected cement was 3.5 ± 1.18ml.

Radiological measurement.

Pre-surgical radiography was performed 5.8 ± 3.6 days before the procedure. After surgery X-rays were performed at 46.5 ± 18.1 days (first medical check-up) and 17.1 ± 12 months post-surgery (last medical check-up).

There were no differences, at each timepoint in the height of the posterior edge of one adjacent nonfractured vertebral body compared to the pre-surgical moment. (pre-surgery: 3.12 ± 0.04cm; pre-cementation: 3.11 ± 0.04cm, difference − 0.013 cm, P = 0.277; post-cementation: 3.1 ± 0.04cm, difference − 0.019cm, P = 0.264; first medical check-up: 3.1 ± 0.04cm, difference − 0.023, P = 0.079; last medical check-up: 3.12 ± 0.04cm, difference − 0.001cm, P = 0.911).

Average pre-surgical vertebral body height was 2.2 ± 0.6 and increased to 2.3 ± 0.5 (difference with pre-surgical status of + 0.1 cm, + 4.5%, P = < 0.001) with the patient's position change on the surgical table (from standing to prone position). Post-cementation, vertebral body height increased to 2.5 ± 0.5 (difference with pre-surgical status of + 0.3 cm, + 13.6%, P = < 0.001). At the first medical check-up, vertebral body height increased to 2.3 ± 0.5 (difference with pre-surgical status of + 0.1 cm, + 4.5%, P = < 0.001). Finally, at the last medical check-up, vertebral body height had decreased to pre-surgical levels (2.2 ± 0,5 versus 2.2 ± 0,6, difference of + 0.009cm, + 0%, P = 0.7233) (Fig. 2).

Multiple linear regression

A Pearson correlation coefficient was performed between the quantitative demographic variables (age, BMI, T-Score) and the difference in vertebral body height at each timepoint with respect to the pre-surgical moment. No variable was statistically correlated (P = > 0.05) and they presented a weak association, so they were excluded from the multiple linear regression. The gender variable also had no statistical differences when the height difference of the vertebral body was compared at the different timepoints (P = > 0.05), and so this was also excluded from the multivariate analysis.

We performed four multiple linear regression models, one for each timepoint (Table 2). As a dependent variable, the global difference in vertebral body height at the time of study analyzed with respect to the pre-surgical moment was used. The vertebral segment treated, type and severity of vertebral fracture, vertebral fracture time, vertebral augmentation technique and volume of cement injected were used as independent variables.

Table 2
Multiple linear regression for the estimation of the overall vertebral body height at each timepoint with respect to the pre-surgical timepoint.

	Coefficient	SD	t	P value	95% IC
Pre-cementation model					
Vertebral segment treated					
Thoracic (T1-T10)	*Ref.*				
Thoracolumbar (T11-L2)	-0.03	0.05	-0.64	0.524	-0.14 to 0.72
Lumbar (L3-L5)	0.03	0.06	0.48	0.633	-0.08 to 0.14
Type of fracture					
Wedge	*Ref.*				
Biconcave	-0.02	0.051	-0.50	0.617	-0.13 to 0.08
Severity of fracture					
Grade I	*Ref.*				
Grade II	-0.023	0.057	-0.41	0.686	-0.13 to 0.09
Grade III	0.155	0.05	2.83	**0.006**	0.045 to 0.26
IVVC					
No	*Ref.*				
Yes	0.06	0.05	1.16	0.250	-0.05 to 0.18
Vertebral fracture age					
< 6 weeks	*Ref.*				
> 6 weeks	-0.04	0.05	-0.78	0.438	-0.13 to 0.06
Constant	0.05	0.07	0.73	0.465	-0.09 to 0.20
Post-cementation model					
Vertebral segment treated					
Thoracic (T1-T10)	*Ref.*				
Thoracolumbar (T11-L2)	-0.13	0.07	-1.82	0.072	-0.27 to 0.01
Lumbar (L3-L5)	0.006	0.07	0.08	0.939	-0.14 to 0.16
Type of fracture					
Wedge	*Ref.*				

	Coefficient	SD	t	P value	95% IC
Biconcave	-0.03	0.07	-0.47	0.641	-0.17 to 0.11
Severity of fracture					
Grade I	*Ref.*				
Grade II	0.007	0.07	0.1	0.921	-0.14 to 0.16
Grade III	0.18	0.07	2.4	**0.018**	0.03 to 0.32
IVVC					
No	*Ref.*				
Yes	0.19	0.07	2.4	**0.018**	0.03 to 0.34
Vertebral fracture age					
< 6 weeks	*Ref.*				
> 6 weeks	0.03	0.06	0.46	0.647	-0.095 to 0.15
Vertebral augmentation technique					
Vertebroplasty	*Ref.*				
StabiliT system	0.13	0.08	1.66	0.1	-0.02 to 0.29
Cement injected	0.05	0.03	1.69	0.095	-0.01 to 0.1
Constant	-0.03	0.12	-0.22	0.826	-0.26 to 0.21
First medical check-up model					
Vertebral segment treated					
Thoracic (T1-T10)	*Ref.*				
Thoracolumbar (T11-L2)	-0.14	0.06	-2.44	**0.017**	-0.26 to -0.03
Lumbar (L3-L5)	-0.05	0.06	-0.74	0.464	-0.17 to 0.08
Type of fracture					
Wedge	*Ref.*				
Biconcave	-0.05	0.06	-0.93	0.354	-0.16 to 0.06
Severity of fracture					
Grade I	*Ref.*				
Grade II	-0.05	0.06	-0.88	0.379	-0.17 to 0.07
Grade III	0.15	0.06	2.57	**0.012**	0.03 to 0.27

	Coefficient	SD	t	P value	95% IC
IVVC					
No	*Ref.*				
Yes	0.03	0.06	0.53	0.595	-0.09 to 0.16
Vertebral fracture age					
< 6 weeks	*Ref.*				
> 6 weeks	-0.04	0.05	-0.68	0.496	-0.13 to 0.06
Vertebral augmentation technique					
Vertebroplasty	*Ref.*				
StabiliT system	0.22	0.06	3.46	**0.001**	0.09 to 0.35
Cement injected	0.0007	0.02	0.03	0.972	-0.04 to 0.04
Constant	0.12	0.09	1.23	0.221	-0.07 to 0.31
First medical check-up model					
Vertebral segment treated					
Thoracic (T1-T10)	*Ref.*				
Thoracolumbar (T11-L2)	-0.08	0.06	-1.36	0.176	-0.21 to 0.04
Lumbar (L3-L5)	-0.06	0.07	-0.92	0.358	-0.19 to 0.07
Type of fracture					
Wedge	*Ref.*				
Biconcave	-0.06	0.06	-0.97	0.334	-0.18 to 0.07
Severity of fracture					
Grade I	*Ref.*				
Grade II	-0.08	0.07	-1.24	0.219	-0.21 to 0.05
Grade III	0.11	0.06	1.65	0.102	-0.02 to 0.23
IVVC					
No	*Ref.*				
Yes	0.03	0.07	0.42	0.675	-0.11 to 0.16
Vertebral fracture age					
< 6 weeks	*Ref.*				

	Coefficient	SD	t	P value	95% IC
> 6 weeks	0.06	0.05	1.08	0.283	-0.05 to 0.17
Vertebral augmentation technique					
Vertebroplasty	*Ref.*				
StabiliT system	0.21	0.07	3.04	**0.003**	0.07 to 0.36
Cement injected	-0.01	0.02	-0.44	0.66	-0.06 to 0.04
Constant	0.03	0.11	0.35	0.726	-0.17 to 0.24

SD: Standard deviation

IVVC: Intervertebral vacuum cleft

95% IC: 95% confidence interval

Grade I: <25%; **Grade II**: 26–40%. **Grade III**: >41%.

All differences were statistically significant (P = < 0.001). The coefficient of determination squared was 0.1516 at pre-cementation moment, 0.2616 at post-cementation moment, 0.2585 at first medical check-up and 0.2263 at last medical check-up. The different linear regression models performed showed that the main factors influencing vertebral body height restoration were: grade III collapse (at pre-cementation time, post-cementation time and the first post-surgical medical check-up time), IVVC (only at the post-cementation time), and StabiliT® system (at the first and last post-surgical medical check-up). In contrast, a fracture located in the thoracolumbar region negatively influenced vertebral body height (at the first post-surgical medical check-up) (Tables 2 and 3).

Table 3
Factors related to the restoration of the vertebral body height at different timepoints.

	Increase height	Reduce height	Questionable	Not associated
Pre-cementation	Collapse grade III			Demographic factor (age, gender, BMI, T-Score) Vertebral segment treated Type of fracture IVVC Vertebral fracture age
Post-cementation	Collapse grade III IVVC		Thoracolumbar zone Cement injected	Demographic factor (age, gender, BMI, T-Score) Type of fracture IVVC Vertebral fracture age Vertebral augmentation technique
First medical check-up	Collapse grade III StabiliT system	Thoracolumbar zone		Demographic factor (age, gender, BMI, T-Score) Type of fracture IVVC Vertebral fracture age Cement injected
Last medical check-up	StabiliT system			Demographic factor (age, gender, BMI, T-Score) Vertebral segment treated Type of fracture Severity of fracture IVVC Vertebral fracture age Cement injected

Discussion

This prospective study focuses on factors that influence restoration of the vertebral body height during vertebral fracture treatment, quantifying these from diagnosis to discharge. We observed that some factors favor the restoration of the vertebral body height while others affect it negatively. Furthermore, these factors act concretely at different times during patient follow-up.

Previously published studies that analyze the change in vertebral body height after vertebral augmentation have various limitations[4,6,7,9,19,20]. Irregularity of the vertebral fracture makes it difficult to select a reference point to carry out the measurements, there is no consensus on how to quantify changes in vertebral body height and studies take into account different factors (dynamic mobility, IVVC, vertebral augmentation technique) that are analyzed in isolation and not as a whole[4,8,9, 12–14,16,19,21]. This means that surgeons do not know at what point in patient follow-up these factors influence vertebral restoration.

Overall changes in vertebral body have previously been studied at two points in time: pre- and post-surgery[4–6, 12,18]. To provide more detailed and accurate information, we analyzed the vertebral body at different timepoints: pre-surgery, intra-operatively (pre-cementation and post-cementation), at first medical check-up (6 weeks) and at last medical check-up (17.1 ± 12 months). To our knowledge our study is the first to analyze changes intraoperatively, establishing the changes due to patient position in order to differentiate the real effect of vertebral augmentation[4,6,7,9–11].

Some authors[12,16] concluded that vertebral height restoration depends more on dynamic mobility than vertebral augmentation. McKiernan et al.[8] observed that approximately 35% of vertebrae were mobile. In our study, we found that after vertebral augmentation there was an increase in vertebral height of + 0.3cm (13.6%). Specifically, the patient's position change (standing to prone position) led to an increase in vertebral height of + 0.1 cm (+ 4.5%) and vertebral cementation caused a further increase in the vertebral body height of + 0.2cm (+ 8.7%). These findings go against the conclusion of Chen et al.[12] and Yokoyama et al.[16], since mobility of the vertebra contributed to a third of the height restoration, and the cementation was the cause of the rest.

If we assess, as a whole, the factors that influence vertebral height restoration, we can see that the factors act at different times. We observed that having a severe collapse (grade III) had the greatest influence when the patient was in the prone position (Tables 2 and 3). This observation differed from the conclusions of McKiernan et al.[8] or Teng et al.[9] who suggested that the change in height was favored by the presence of an IVVC. However, our results show that IVVC had the greatest influence when the vertebral augmentation was performed ($P = 0.018$) and not as a result of the patient's position change ($P = 0.250$). Determining to what extent and when a factor most influences vertebral height restoration is only possible if intraoperative radiographic measurements are performed.

Thoracolumbar zone has greater mobility than thoracic or lumbar fractures[8,14,15]. However, they do not specify whether this factor favors or disfavors vertebral height restoration. Our results show that location in the thoracolumbar area negatively influenced vertebral height restoration (Tables 2 and 3)

Tang et al.[21] and Takahashi et al.[22] suggested that vertebral fracture time evolution influences clinical and radiological results. Vertebral height and vertebral kyphotic angle after kyphoplasty were better in patients treated in the first two months from onset of symptoms. Based on our results, we cannot affirm that the time since vertebral fracture influenced in vertebral body height.

Outcomes in our cohort should be interpreted with some caution due to the potential limitations of the study. We did not compare PVP with PKP. Literature shows that PKP requires more surgical time (which is harmful in elderly patients) and is more expensive, which is why several studies recommend using PVP over PKP[21,23,24]. Measurements were made with radiographs. We used this technique because it is easy to use, it can be performed intra-operatively and it allows us to study the vertebral body in different positions (standing and prone position). The gold-standard technique for making measurements is CT-scan. However, few hospitals can perform intraoperative CT-scan, and, in addition, it would mean exposing the patient to high doses of ionizing radiation. There may be other factors which influence the restoration of vertebral height that we have not collected. To understand factors involved in changes in the vertebral body height better, it would be interesting to make a comparison between a conservatively treated group and a surgical group. However, our present aim was to focus exclusively on vertebrae treated with vertebral augmentation.

Conclusion

Our study found that the patient's position change (from standing to prone position) and vertebral augmentation produced an increase in the vertebral body height. After surgery there is a progressive collapse of the vertebral body that returns to pre-surgical values. The main factors that favor vertebral height restoration are: grade III collapse, IVVC, and vertebral augmentation technique. In contrast, a thoracolumbar location influenced vertebral height restoration negatively.

Declarations

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AUTHOR CONTRIBUTIONS

J.P., M.A designed the study. J.P, R.L and M.A carried out data collection. J.P performed data analysis. All authors wrote the manuscript, critically reviewed and revised the manuscript for content and approved the manuscript for publication.

DECLARATION OF CONFLICTING INTERESTS

The authors declares that there is no conflict of interest.

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Figures

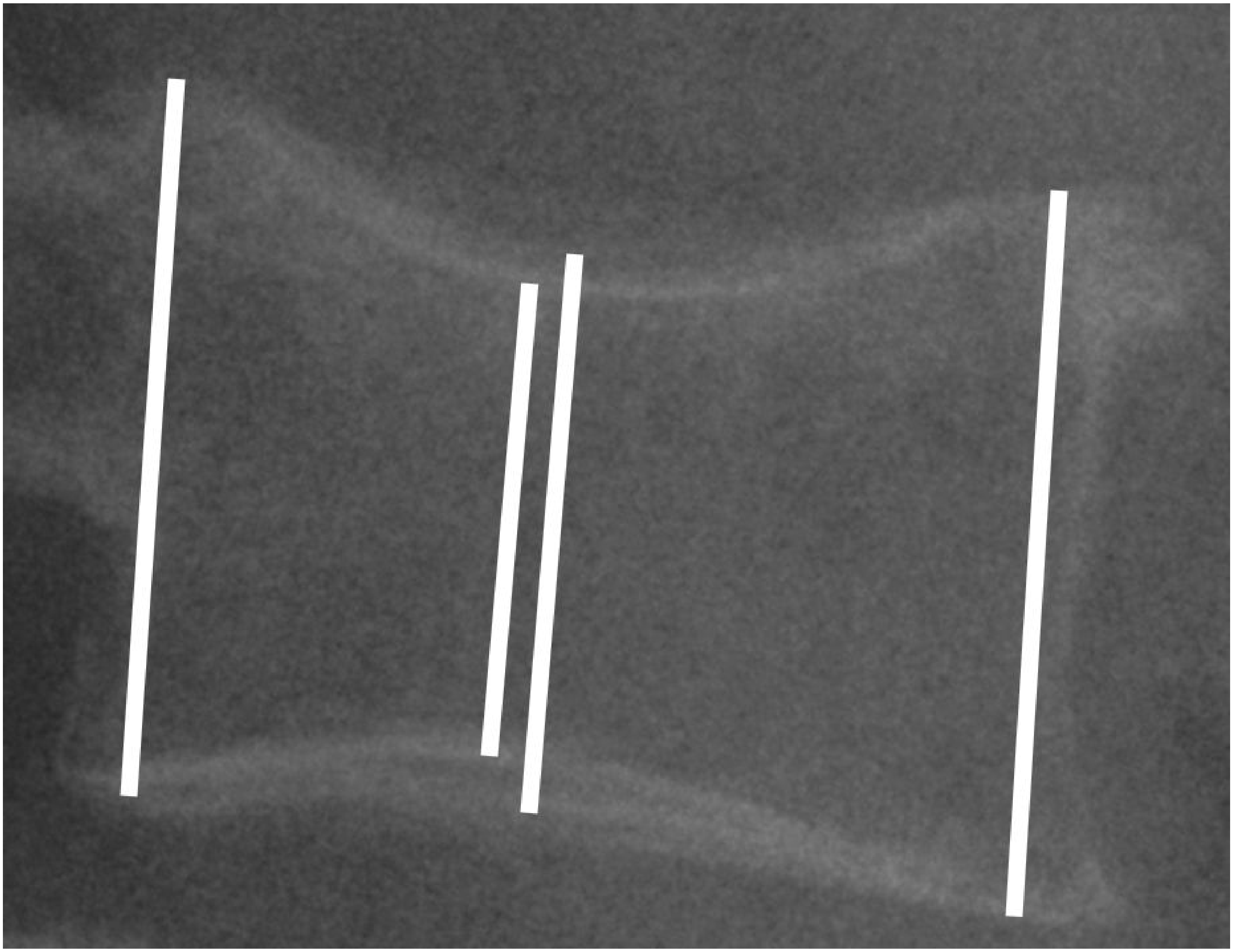

Figure 1

Lateral X-ray showing the measurements performed in the anterior, middle (most collapsed zone and least collapsed zone) and posterior edge.

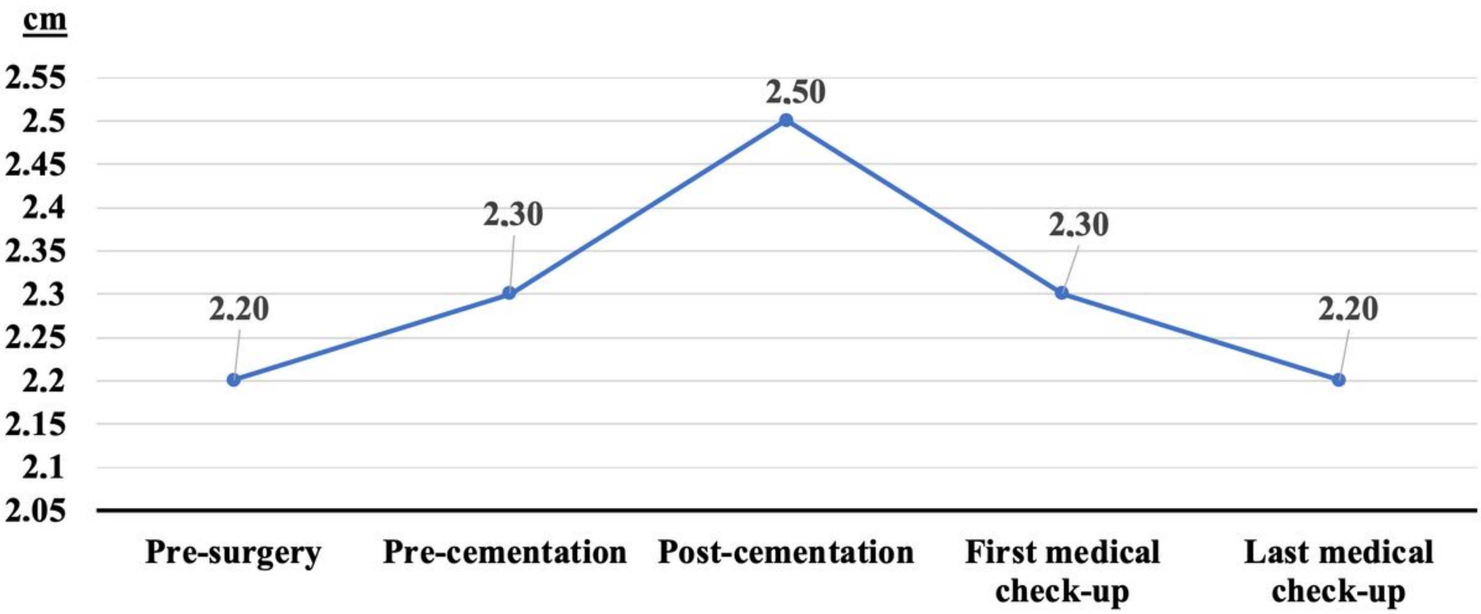

Figure 2

Changes in vertebral body height during follow-up. First medical check-up at 46.5±18.1 days from surgery. Last medical check-up at 17.1±12 months from surgery.

Supplementary Files

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- Table1.docx
- Table3.docx
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