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ORIGINAL RESEARCH

Minimally invasive approach and posterior instrumental arthrodesis in earthquake-related vertebral fractures

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Abstract

Background: On the morning of 06 February 2023, a devastating earthquake of magnitude 7.8 occurred, affecting the south and east of Turkey and the north and west of Syria. High-energy traumas, like earthquakes can cause vertebral burst fractures. In surgical treatment, arthrodesis with pedicle screw-rods or minimally invasive percutaneous systems are often applied depending on the patient's condition. A comparative analysis was conducted to evaluate the efficacy and outcomes of surgical interventions for thoracolumbar vertebra fractures caused by seismic events. The techniques examined included classical pedicle screws and rods, as well as minimally invasive percutaneous cementoplasty. **Methods**: The study included 42 patients who had undergone surgery at the Neurosurgery Clinic of Kayseri City Hospital, Kayseri, Turkey, with a diagnosis of burst fracture subsequent to the earthquake. The surgical approach employed was either classical open surgery with the use of screws and rods or minimally invasive vertebral cementoplasty. **Results**: In this retrospective study, comprising 23 females (54.8%) and 19 males. A minimally invasive procedure was performed in 25 patients (59.5%), an instrumental procedure in 15 patients (35.7%), and a combination of both in 2 patients (4.8%). Patients who underwent instrumental surgery were younger, while patients who underwent minimally invasive surgery were older ($p < 0.05$). **Conclusions**: In vertebral fractures caused by earthquakes, the results obtained with pedicle screwing and minimally invasive methods were consistent with those reported in the literature. Minimally invasive treatment was also frequently preferred and had good results similar to open surgery and faster recovery times.

Keywords

Spinal fractures; Cementoplasty; Minimally invasive surgical procedures; Natural disasters

1. Introduction

The most common subtype of spine injury is a burst fracture, which can occur due to a fall from a height, a motor vehicle accident or a ground-level fall [1, 2]. These injuries are frequently observed in the thoracolumbar region of the vertebral column. High-energy traumas resulting from seismic events can also lead to vertebral burst fractures.

On the morning of 06 February 2023, a magnitude 7.8 earthquake struck, affecting southern and eastern Turkey, as well as northern and western Syria. During catastrophes like the aforementioned, injuries such as vertebral fractures can be attributed to several causes. During an earthquake, individuals sustain injuries while attempting to escape by jumping out of windows, falling from heavy building structures or being struck by overturned household items. It is crucial that individuals retrieved by search and rescue teams and transported to hospitals in the immediate aftermath of a disaster receive prompt diagnosis and treatment in emergency services. These patients should undergo vertebral column imaging, typically with computed tomography, in the emergency department before surgical intervention by neurosurgeons working collaboratively. Furthermore, it is essential to recognise the multidisciplinary nature of the surgical team (neurosurgeons, anaesthesiologists and nurses) who coordinate closely during the operation. In the earthquake cited earlier, the number of victims requiring hospitalisation was exceptionally high in the initial days following the disaster.

Patients presenting with a vertebral burst fracture should be evaluated for neurological deficits and overall medical condition. Factors such as patient age, pre-existing comorbidities and kidney function must also be considered. Surgery should be performed without delay in patients with burst fractures who do not have more serious accompanying injuries. The location and severity of the fracture are crucial in selecting the appropriate treatment method. Spinal mechanical stability depends on the integrity of both bone and soft tissue structures. Determining stability, selecting the appropriate treatment plan,

and predicting the prognosis of vertebral fractures are of utmost importance. Many physicians rely on established criteria to evaluate surgical indications, with mechanical spinal stability being a key consideration.

The thoracolumbar spine, particularly the area between T10 and L2, is the region most frequently affected by traumatic injury [3]. Among vertebral segments, L1 is the most commonly fractured, followed by T12. Several anatomical and biomechanical factors contribute to the increased susceptibility of this region to injury.

In surgical treatment, the objective is to decompress, reduce and stabilise the fracture to maintain spinal stability and alleviate pain. The prompt implementation of surgical interventions can effectively reduce pain, shorten the length of hospitalisation, and facilitate early mobilisation. This approach also decreases the incidence of comorbidities and ensures the efficient progression of patients in healthcare facilities during natural disasters, such as earthquakes. Despite the limited scope of surgical options, techniques such as pedicle screw-rod arthrodesis, minimally invasive percutaneous screw fixation and percutaneous cementoplasty can be employed, depending on the characteristics of the fracture and the patient's condition.

Regarding the optimal treatment of incomplete burst fractures without neurological deficits, there is currently no consensus. Both conservative and surgical approaches can be employed in such cases [4, 5]. In classical open surgical treatment, isolated posterior pedicle screw fixation allows for the anatomical reduction of the spine and correction of kyphotic deformities. However, in some cases, a second surgery and anterior fusion may be necessary, as this method alone may be insufficient to fully correct kyphotic deformity [6]. Fixation with pedicle screws and rods is often used for fusion purposes. If the vertebral body is severely damaged and fragmented, surgical placement of anterior corpectomy materials and fusion systems can restore adequate vertebral height and alignment.

Ulu *et al.* [7] demonstrated significant improvements in postoperative Cobb angles (18.6° to 12.8°) and vertebral height.

Vertebroplasty and balloon kyphoplasty are minimally invasive techniques used to manage vertebral fractures with a collapse of at least 30–40% at the thoracolumbar level. These procedures can restore vertebral height and correct kyphotic deformities [8]. Two methods of application are possible.

The injection of bone cement into the fractured vertebra during balloon kyphoplasty has been shown to reduce pain and correct deformities associated with compression fractures. In balloon kyphoplasty, the burst fractures are filled with cement (poly-methyl-methacrylate) into the intravertebral space, thereby stabilising micro-fractures in the affected area.

A review of the literature revealed a lack of studies on isolated earthquake-related traumatic vertebral fractures and treatment approaches. However, several emergency clinical studies on the 2023 Turkey–Syria earthquake were identified [9, 10]. In the aftermath of this devastating natural disaster, which affected 11 cities in our country, patients were promptly transferred to neighbouring cities for treatment. Patients diagnosed with vertebral fractures after CT (computerized tomography) scans performed in the emergency room were transferred to the ward in consultation with the neurosurgeons [11].

A literature review was conducted to identify articles describing vertebral fractures and minimally invasive approaches over the past 10 years, which revealed nearly 1200 studies [12–15]. As long as life exists, traumatic injuries are inevitable, and natural disasters will continue to manifest in various ways. It is therefore crucial to be prepared to respond effectively when such events occur.

In the treatment of traumatic vertebral fractures, the minimally invasive techniques employed in recent years are highly effective and easy to perform. These approaches are also faster and less invasive. Herein, we present our cases and experiences and share our insights with the wider medical community.

2. Materials and methods

The study was conducted retrospectively. Ethical approval for this study was obtained by the Ethics Committee of Nuh Naci Yazgan University on 01 June 2023 (Approval No. 2023/006-007). The study was carried out at the Neurosurgery Clinic of Kayseri City Education and Research Hospital following the diagnosis of thoracolumbar vertebral burst fracture and fractures sustained as a result of the earthquake.

The study participants were patients who had sustained a thoracolumbar vertebral burst fracture and fractures due to the earthquake and had been admitted to the emergency room. The patients were triaged and grouped according to the surgical method to be applied.

Inclusion criteria: Thoracolumbar vertebral burst fractures due to earthquake trauma were included in the study.

Exclusion criteria: non-earthquake traumatic fractures, fractures due to infection, osteoporosis and malignancy were excluded from the study.

The study included 42 patients with thoracolumbar vertebral burst fractures. Two surgical techniques were employed: classical open surgery with screws and rods (Fig. 1A) was performed on 25 patients, while minimally invasive vertebroplasty-balloon kyphoplasty (VP-BK) was conducted on 15 patients (Fig. 1B). Two patients underwent vertebral cementoplasty in conjunction with open surgery due to the presence of multiple fracture levels.

After the initial evaluation at the emergency department, three treatment modalities were applied:

- Patients with vertebral burst fractures and neurological deficits were taken to surgery as quickly as possible.
- Patients with vertebral burst fractures and no neurological deficits were taken to surgery as soon as possible.
- Patients with intra-abdominal injuries, lung injuries or concomitant diseases, especially renal dysfunction, were treated in the wards and elective surgery was planned after stabilisation.

2.1 Conducting VP or BK

The patient is placed in the prone position and anaesthetised with sedoanalgesia. The requisite distance is determined by fluoroscopy and subsequently marked on the skin with a skin marker. Once the surgical area has been cleaned with povidone iodide and closed, the relevant vertebra is accessed through

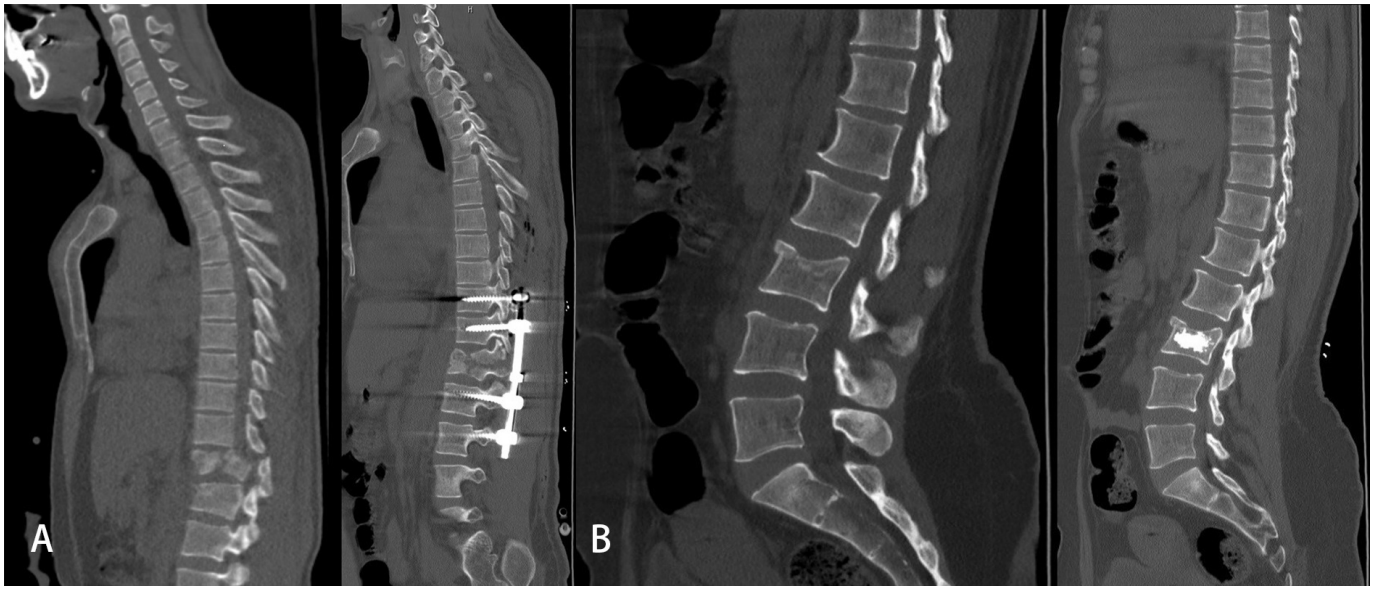

FIGURE 1. Sagittal computerized tomography images of the patient who underwent surgery with conventional method as screws and rods. (A) Preoperative and Postoperative sagittal section CT image showing surgery with screws and rods. (B) Preoperative and Postoperative sagittal section CT image showing of minimally invasive cementoplasty.

its pedicle using the guides included in the BK kit, with the assistance of fluoroscopy. If BK is to be performed, the balloon is inflated with radiopaque material and subsequently filled with cement (Fig. 2). Each stage is then confirmed by fluoroscopy (Fig. 3). If the procedure is to be performed at two levels, the process is repeated.

Postoperatively, patients with good general conditions and no accompanying pathology were transferred to the ward and mobilised quickly. Patients with poor general condition, especially those with impaired renal function, were transferred to intensive care units. Once their condition improved, they were moved to the ward.

2.2 Statistical analyses

The data were analysed using the SPSS 22 program (IBM, Armonk, NY, USA). Descriptive statistics, including frequencies, percentages and means, were used alongside Fisher's exact test due to the presence of values below five in the tables and Yates' correction (continuity correction) due to expected values below 25. Additionally, the Kolmogorov-Smirnov test was employed to assess the suitability of the data for normal distribution. As the data were not following a normal distribution, the Mann-Whitney U test was applied. A p-value of less than 0.05 was considered statistically significant.

3. Results

A total of 42 patients were included in the study, comprising 23 females (54.8%) and 19 males (45.2%). The mean age of the patients was 47.95 (SD (standard deviation): 17.79, range: 22–86, median: 43.5) years. The mean age of the female cohort was 52.86 (SD: 16.51, range: 24–86, median: 53.0), while the mean age of the male cohort was 42.00 (SD: 17.86, range: 22–78, median: 37.0). The mean age of the female cohort was found to be significantly higher ($p = 0.032$, Mann-Whitney U test, $Z = -2.150$). Of the patients, 28 (66.7%) underwent surgery at the lumbar level, 19 (45.2%) at the thoracic level and 5 (11.9%) at the thoracolumbar level. A minimally invasive procedure was performed in 25 patients (59.5%), an instrumental procedure in 15 patients (35.7%) and a combination of both in two patients (4.8%). A total of 15 patients (only screw patients), representing 40.5% of the total sample, underwent screw fixation. Among the 17 patients (with two patients who underwent combined procedures), 13 (76.5%) had one to three segment screws, while four (23.5%) had four to six segment screws.

Table 1 and Fig. 4 illustrate the correlation between surgical procedures and gender. No significant correlation was identified between the occurrence of a lumbar-level fracture and gender ($p = 0.584$). At the thoracic level, no significant relationship was observed between gender and fracture occurrence ($p = 0.192$), although the procedure was more common in females. Minimally invasive surgery was performed more frequently on women ($p = 0.267$), while instrumental surgery was more common in men. However, this difference was not statistically significant ($p = 0.076$). No statistically significant difference was observed between the sexes with regard to the number of screw levels ($p = 1.000$).

No significant correlation was observed between age and fracture levels (lumbar/thoracic) ($p = 0.852/0.771$). Patients who underwent instrumental surgery were younger ($p = 0.001$), while patients who underwent minimally invasive surgery were older ($p = 0.001$). Patients with screw levels of 4–6 exhibited a higher mean age, yet no statistically significant difference was identified ($p = 0.296$). Please see Table 2 and Fig. 5 for additional details.

4. Discussion

In this study, the most common subtype of spine injury was burst fracture, which frequently occurred in the thoracolumbar

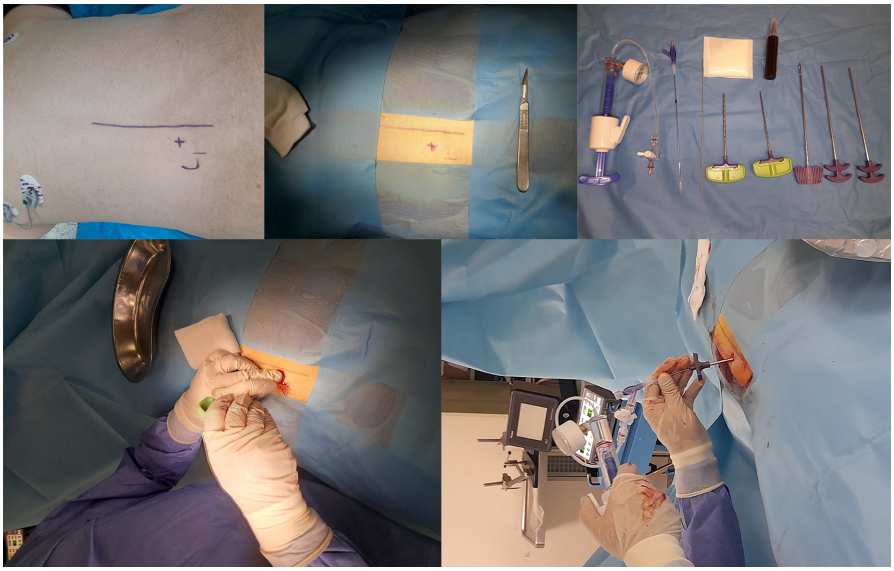

FIGURE 2. Demonstration of the surgical stages of balloon kyphoplasty and vertebroplasty.

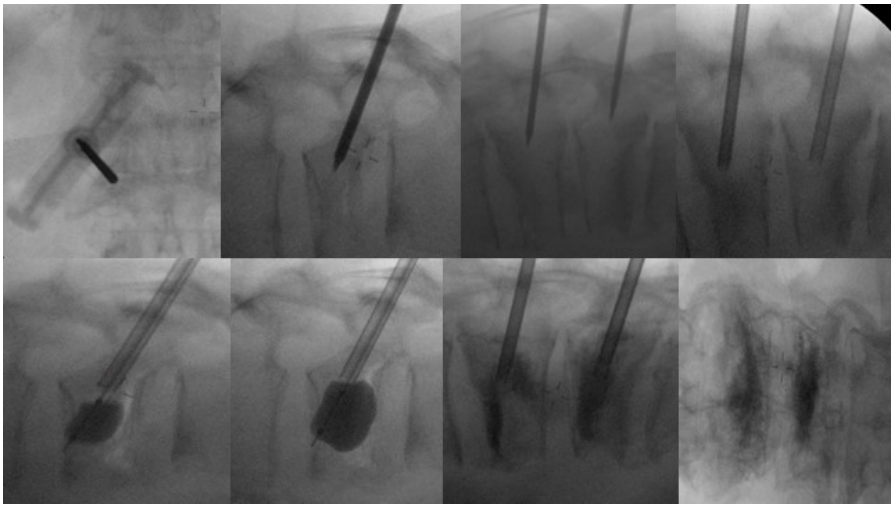

FIGURE 3. Demonstration of all stages of Balloon Kyphoplasty via fluoroscopy.

TABLE 1. Gender and patients' fracture levels and surgical procedures.

Surgical procedures and their features			Total	Gender				χ^2	*df*	*p*
				Female		Male				
				n	%	n	%			
Fracture Level (n: 42)	Lumbar	Yes	28	14	50.0	14	50.0	0.300	1	0.584*
		No	14	9	64.3	5	37.5			
	Thoracic	Yes	19	13	68.4	6	31.6	1.703	1	0.192*
		No	23	10	43.5	13	56.5			
Operation Type (n: 42)	Minimally invasive	Yes	27	17	63.0	10	37.0	1.230	1	0.267*
		No	15	6	40.0	9	60.0			
	Instrumental	Yes	17	6	35.3	11	64.7	3.149	1	0.076*
		No	25	17	68.0	8	32.0			
Screwing Level (n: 17)		1–3	13	5	38.5	8	61.5	0.243	1	1.000**
		4–6	4	1	25.0	3	75.0			

*Row Percentage Used *Yates's correction (continuity correction), **Fisher's Exact Test.*

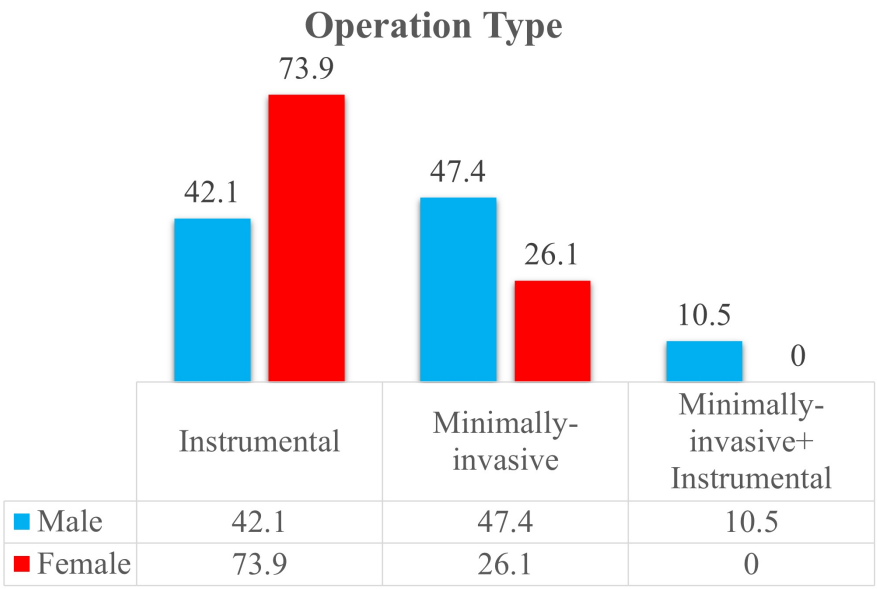

FIGURE 4. Graphical representation of gender, patients' fracture levels, and surgical procedures performed.

TABLE 2. Age and fracture levels of patients and surgical procedures.

Surgical procedures and their features			Age			*p**
			Mean ± SD	Min–Max	Median	
Fracture Level (n: 42)	Lumbar	Yes	48.39 ± 18.46	22–86	43.5	0.852
		No	47.07 ± 16.98	22–74	44.5	
	Thoracic	Yes	48.78 ± 17.39	22–86	45.0	0.771
		No	47.26 ± 18.46	22–78	43.0	
Operation Type (n: 42)	Minimally invasive	Yes	54.40 ± 17.31	22–86	56.0	0.001
		No	36.33 ± 12.05	22–72	35.0	
	Instrumental	Yes	36.82 ± 11.37	22–72	37.0	0.001
		No	55.52 ± 17.52	22–86	58.0	
Screwing Level (n: 17)		1–3	34.07 ± 7.51	22–44	35.0	0.296
		4–6	45.75 ± 18.02	31–72	40.0	

**Mann-Whitney U test. SD: standard deviation; Min: minimum; Max: maximum.*

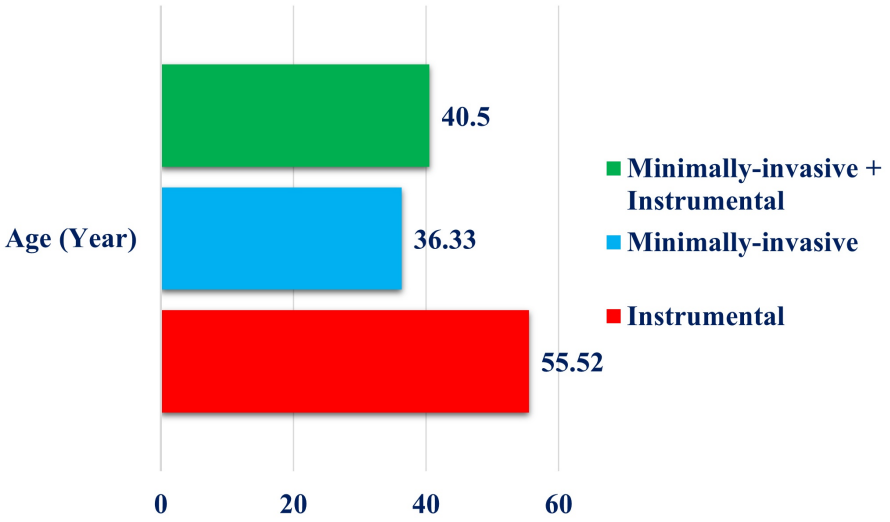

FIGURE 5. Graphical representation of the age and fracture levels of the patients and the surgical procedures performed.

region of the vertebral column. For the treatment of vertebral burst fractures, minimally invasive surgery using high-viscosity cement yielded good results, particularly in older patients, due to the shorter duration of surgery and rapid postoperative recovery.

The average hospital stay for patients operated on solely for vertebral burst fracture was observed to be two days. Those treated with the minimally invasive method were discharged on the first day. Fewer rest reports were issued, reducing potential economic loss. Patients who underwent either surgical method were mobilised at the sixth postoperative hour. Patients with neurological deficits were transferred to the physical therapy rehabilitation clinic after surgery. These positive outcomes can be attributed to the absence of pain and the rapid mobilisation observed during our short-term follow-up.

Patients who sustained thoracolumbar vertebral fractures following the devastating earthquake were treated with open surgery using pedicle screws and rods, as well as less invasive vertebral cementoplasty.

In their study, Adrian *et al.* [16] retrospectively analysed 129 patients who underwent surgery for thoracic or lumbar AO type A3 fractures at a Level 1 trauma centre in Germany between 2008 and 2020. They observed that the use of pedicle screws resulted in a higher degree of restoration and greater preservation of vertebral body height compared to percutaneous kyphoplasty and pedicle screw fixation. Nevertheless, no notable radiological distinction was observed between the surgical techniques at the 24-week follow-up. The postoperative outcomes were comparable to those reported by Wen *et al.* [17]. Our hospital was not located near the earthquake centre, so long-term follow-up was not feasible.

In a comparative study, Tang *et al.* [18] examined the efficacy of minimally invasive techniques and pedicle screw fixation in managing vertebral fractures associated with osteoporosis. A total of 51 patients with vertebral fractures were included in the study. Both methods were shown to be effective in relieving pain associated with non-union vertebral fractures. However, the minimally invasive approach offered several advantages over open surgery, including reduced operating time and hospital stay, decreased intraoperative blood loss and lower surgical costs [18]. In patients treated due to the earthquake, particularly those with multiple traumas (such as long bone fractures and abdominal trauma), vertebral cementoplasty was preferred more frequently.

It was also used as a feasible and appropriate option in elderly patients in whom surgical indications were contraindicated and the risk of surgical and anaesthesiologist intervention was significant [2]. In the context of a sudden natural disaster such as an earthquake, it is crucial to provide timely treatment and rehabilitation to trauma patients. In the present study, minimally invasive surgical techniques were used to treat elderly patients, with a focus on early mobilisation. It is particularly important to note that bone metabolism is significantly faster in younger individuals compared to older individuals [19]. In the younger female patient cohort, pedicle screws were utilised more frequently, aligning with the specific characteristics of the fracture. Therefore, patients should be promptly admitted and discharged as soon as advisable to ensure timely and effective care.

In a study involving 12 patients with traumatic vertebral burst fractures, Moura demonstrated that minimally invasive kyphoplasty permitted the safe reconstruction of the vertebral body in a manner that was closer to its original anatomy. Furthermore, this approach resulted in clinical functional and imaging improvements over the medium-to-long term [20]. The techniques employed to treat spinal fractures have remained largely unchanged over time. However, there has been a notable decline in the invasiveness of these procedures and a concomitant improvement in safety.

Verlaan *et al.* [21] (2020) reported that the Cobb angle was significantly reduced and vertebral body height was restored in patients treated for burst fractures using percutaneous and minimally invasive surgery. This approach has the potential to minimise the disadvantages of traditional surgery, including the destruction of paravertebral muscle structure, bleeding, infection rates and postoperative pain. Recently, percutaneous pedicle screw fixation systems have been introduced as a treatment for spinal fractures, aiming to reduce the adverse effects associated with conventional open approaches. These include iatrogenic muscle denervation and pain. In the treatment of acute thoracolumbar fractures, the pedicle screw fixation technique appears to achieve similar results to those of the open technique in terms of neurological improvement and deformity correction [22, 23]. However, it is more accurate in placing the screws. Despite the advantages of percutaneous pedicle screws in terms of ease and speed of application, our clinic was unable to utilise this technique due to economic and social insurance constraints.

The successful execution of screw placement and vertebral cementoplasty hinges upon the practitioner's technical expertise and the quality of fluoroscopic imaging. Both procedures were successfully completed in our cases without any complications. Consequently, vertebral fractures induced by seismic activity and treated at our facility were stabilised using both vertebral cementoplasty and pedicle screw implantation. The patients were able to resume their normal activities without neurological deficits and were able to participate in social activities.

In treating patients with vertebral fractures, vertebral cementoplasty was preferred over open posterior vertebral fusion surgery due to its less invasive nature. On average, patients were able to return to work 15 days following the procedure. However, this period was extended for patients with comorbidities and additional trauma.

5. Limitations of the study

It should be noted that this study is subject to several limitations. The study was conducted retrospectively, with the radiographic and fluoroscopy images taken during surgery re-examined retrospectively. The study population comprised patients with vertebral fractures who were transported to our hospital in a stable condition following the earthquake. Regrettably, the number of patients who could be treated during the initial seven-day period after the earthquake was limited. Nevertheless, although the sample size was limited, it was sufficient compared to similar studies. As the majority of patients do not reside in the city where our hospital is located

and may have been referred to other cities, the postoperative follow-up was not sufficiently comprehensive. It should also be noted that this is a cross-sectional study, which may not be representative of the general population.

6. Conclusions

In the aftermath of the unforeseen and catastrophic earthquake, our team promptly addressed the medical needs of patients with vertebral fractures, utilising the resources at our disposal. Vertebral cementoplasty is a minimally invasive technique that has demonstrated efficacy in treating earthquake-related vertebral burst fractures. However, due to the unavailability of long-term follow-up, our preliminary outcomes align with those documented in the existing literature. In our short-term observations, rapid mobilisation and early postoperative return to work indicated that our surgery modality is effective and reliable.

AVAILABILITY OF DATA AND MATERIALS

The data produced for this study was collected and used only for the purpose of conducting this study and has not been published in any other database or elsewhere.

AUTHOR CONTRIBUTIONS

YG and ŞG—detailing the work; project preparation, data collection. BO—made the statistical analysis and contributed for writing the paper. ŞG and BO—made the last proof reading of the scientific paper in the project.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Ethical approval for this study was obtained by the ethics committee of Nuh Naci Yazgan University (Date of approval: 01 June 2023; number: 2023/006-007). Consent for participation was obtained from all subjects.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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