



Clinical and radiological outcomes in thoracolumbar fractures using the SpineJack device. A prospective study of seventy-four patients with a two point three year mean of follow-up

Gael Kerschbaumer¹ · Benoit Gaulin¹ · Sébastien Ruatti¹ · Jérôme Tonetti^{1,2} · Mehdi Boudissa^{1,2} 

Received: 3 June 2019 / Accepted: 7 August 2019 / Published online: 15 August 2019
© SICOT aisbl 2019

Abstract

Purpose The aim of this study was to assess clinical and radiological results of SpineJack on the treatment of vertebral body fractures in a continuous prospective series of patients.

Material and methods Between May 2012 and April 2015, all patients operated using the SpineJack device were prospectively included in this monocentric study. Demographic data, clinical, and radiological results were recorded. Complications and surgical managements were recorded.

Results At a mean follow-up of 2.3 years, 74 patients with 77 fractured vertebrae were included. The stand-alone SpineJack group comprised 60 patients with 63 fractured vertebrae (group 1) and the group with additional posterior fixation 14 patients with 14 fractured vertebrae (group 2). The average initial vertebral wedge angle was 13.3 ± 6.1 degrees for group 1 and 15.3 ± 5.7 degrees for group 2 ($p = 0.25$). Post-operative values were 6.5 ± 4.6 degrees for group 1 and 5.1 ± 3.9 degrees for group 2 ($p = 0.31$). The differences within the same group were highly significant ($p < 0.0005$). The loss of reduction at last follow-up was 0.8 ± 1.6 degrees in group 1 and 0.6 ± 2.0 degrees in group 2 ($p = 0.77$). Subjective results were considered as very good or good for 57 patients (95%) in group 1 and for 11 patients (79%) in group 2, $p = 0.07$.

Conclusion The SpineJack seems to be a promising tool in the treatment of traumatic vertebral fractures with a correction in the sagittal plane comparable with what can be found in the literature.

Keywords SpineJack · Vertebral augmentation · Vertebral compression fracture · Percutaneous surgery · Sagittal correction

Introduction

The treatment of thoracolumbar vertebral fractures has always been a topic of controversy. Classification and treatment recommendations have evolved over time, but an international consensus still does not exist, especially for burst fractures [1]. With the recent advances in the field of sagittal balance of the spine, with most of the research focusing on degenerative problems, a lot of surgeons are now less inclined to accept traumatic sagittal deformity even if the fracture is stable. All

treatment options are usually evaluated with regard to complications, pain relief, and functional results, but increasingly, surgeons are also looking at which techniques give the best reduction in terms of vertebral and regional kyphotic deformity [1–3]. In an effort to minimize surgical trauma and post-operative opioid administration, minimally invasive surgical techniques are increasingly being used to treat vertebral fractures [4, 5]. Pedicle screw fixation seems to give satisfactory results in terms of sagittal deformity reduction; however this involves blocking at least two intervertebral discs and often leads to secondary surgery for hardware removal [4, 5].

Vertebroplasty and kyphoplasty are alternative techniques with injection of acrylic bone cement through a transpedicular minimally invasive approach. This technique has since been validated to treat osteoporotic vertebral compression fractures and has been shown to be beneficial when used in carefully selected patients [6–8]. One of the problems with vertebroplasty is the relative lack of reduction in case of important kyphotic deformity. One problem with kyphoplasty

✉ Mehdi Boudissa
mboudissa@chu-grenoble.fr

¹ Service de Chirurgie Orthopédique et Traumatologique, CHU Grenoble, Hôpital Nord, Université Grenoble Alpes, Boulevard de la Chantoume, 38700 La Tronche, France

² Laboratoire TIMC-IMAG, CNRS UMR 5525, Université Grenoble Alpes, Pavillon Taillefer, 38700 La Tronche, France

can be the loss of reduction observed when the balloons are deflated before injecting the cement [6–9].

Several other techniques have since been described, one of them is the SpineJack (Vexim, France). It consists of a small titanium implant resembling a jack used to lift cars when changing tires. The implant is placed inside the vertebral body through a minimally invasive transpedicular approach and deploys in a strictly craniocaudal plane instead of expanding in a multidirectional way such as kyphoplasty balloons. The implants remain in place with the cement injected around them to solidify the construct. Supposed advantages are the craniocaudal expansion as well as possibly more force being applied when compared with kyphoplasty or stenting which could in turn theoretically lead to better reduction of kyphotic deformity [10]. We have been using the SpineJack since 2012 and have prospectively collected our results when using this implant.

The aim of this study was to assess clinical and radiological results of SpineJack on the treatment of vertebral body fractures in a continuous prospective series of patients. Our hypothesis was that our results were comparable with the other published studies about this device.

Material and methods

Patient population and assessment

All patients included in this study were treated for vertebral fractures at the University Hospital Grenoble. Between May 2012 and April 2015, 103 patients were operated upon using the SpineJack device. All variables studied were collected prospectively at each of the following time points: patient admittance to our hospital, post-operatively while still in the orthopaedic surgery ward, at three months, six months, one year, and at each subsequent follow-up visit.

We recorded demographic data such as age and sex, the Visual Analog Pain (VAS) scores at each time point, Oswestry Disability Index (ODI) at the final follow-up, subjective result as reported by the patient (very good, good, average, or bad), level of physical activity compared with before the accident, and if the patient was able to return to work.

All patients had a CT scan before and after surgery and plain radiographs at each follow-up visit.

We calculated the wedge angle for the fractured vertebra as well as the regional kyphotic angle at each time point. Additional variables included presence of cement leakage, fracture type using the Magerl classification, level of fracture, additional posterior fixation using percutaneous screw and rod constructs, time to surgery, duration of surgery, complications other than cement leakage, and revision surgery [11].

Operative technique

All patients were operated using a posterior percutaneous approach in the ventral decubitus position.

We used the 5-mm SpineJack (Vexim, France) for most cases; some patients were operated using the 4.2-mm SpineJack if the pedicle size was insufficient for the 5-mm model.

An image intensifier was used to check for the correct level of surgery with an anteroposterior as well as a lateral view.

A 3-mm trocar (Thiebaud, France) was positioned at the outer limit of the projected pedicle circle on an AP view. The trocar was then carefully advanced until the point reached the medial limit of the pedicle. The image intensifier was then switched to a lateral view to make sure that the point of the trocar had passed the posterior wall of the vertebral body. If correctly positioned, the trocar was then advanced to the mid-point of the vertebral body.

Guidewires were inserted into the trocars under fluoroscopic guidance, and the trocars were removed while keeping the guide wires in place.

A 5-mm skin incision around the guidewire permitted the introduction of the hand reamer and working cannula.

The hand reamer was advanced to the anterior third of the vertebral body before being removed while leaving the working cannula in place.

The SpineJack reduction device was then inserted and checked for positioning on the lateral view.

With the image intensifier still in a lateral view, we then deployed the SpineJack progressively while checking the reduction by way of fluoroscopy.

Once the reduction was satisfactory or the maximum distraction height was reached, the handle was removed and high viscosity cement injected around the reduction device (Cohesion cement, Vexim, France).

The working cannula was then removed, and the skin was closed using non-resorbable monofilament sutures.

For some patients, additional percutaneous pedicular screw and rod systems were used with one instrumented level above and one below the fractured vertebra. The additional use of this screw and rod system (Longitude, Medtronic France) was left to the appreciation of the surgeon according to the initial kyphosis. An additional fixation was used on all B-type fractures.

Analysis

Our goal was to assess the gain in vertebral wedge angle and to check for loss of reduction on the subsequent radiographs. We divided the patients into two groups, those with additional posterior fixation (group 2) and those without (group 1).

Radiographic variables were recorded by using the angle calculation tools on the PACS software of our hospital while

working on the digital CT scans and radiographs. All data were recorded by the two main investigators.

All quantitative variables were recorded in an Excel spreadsheet and the average, median, and standard deviation were calculated. For quantitative data, a paired Student *t* test was used to check for significant differences between groups. For qualitative data, we used Fisher’s exact test. Significance was set at $p < 0.05$.

Results

During the inclusion period, 103 patients for 106 fractured vertebrae were operated using the SpineJack device. We were unable to retrieve the initial CT scan for nine patients which were excluded from the study. Twenty patients were lost to follow-up with the remaining 74 patients for 77 fractured vertebrae completing the follow-up to at least one year. The mean follow-up was 2.3 years \pm 0.8 (1–4).

The stand-alone SpineJack group comprised 60 patients with 63 fractured vertebrae (group 1) and the group with additional posterior fixation 14 patients with 14 fractured vertebrae (group 2).

Demographic data

Demographic characteristics were comparable for both groups with an age average of 42.9 \pm 11.7 years for group 1 and 47.7 \pm 16.8 for group 2 with no significant difference ($p = 0.23$). The sex ratio was 42 males in group 1 (67%) and nine males in group 2 (64%) with no significant difference ($p = 0.73$). The fracture levels are summed up in Figs. 1 and 2.

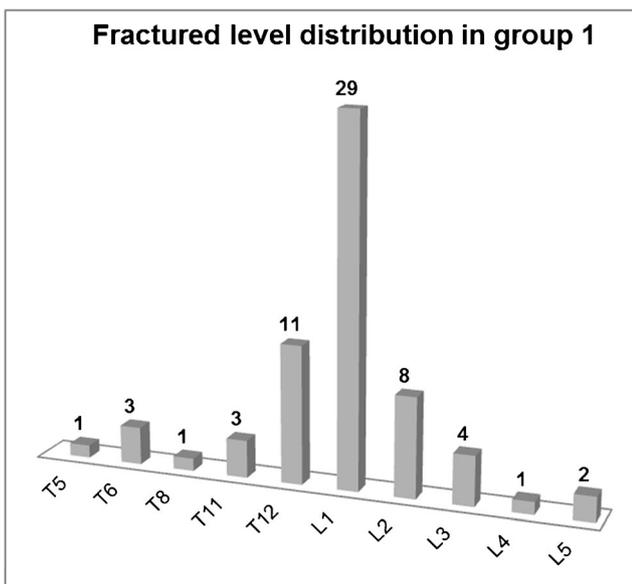


Fig. 1 Fractured level distribution in group 1 (stand-alone SpineJack)

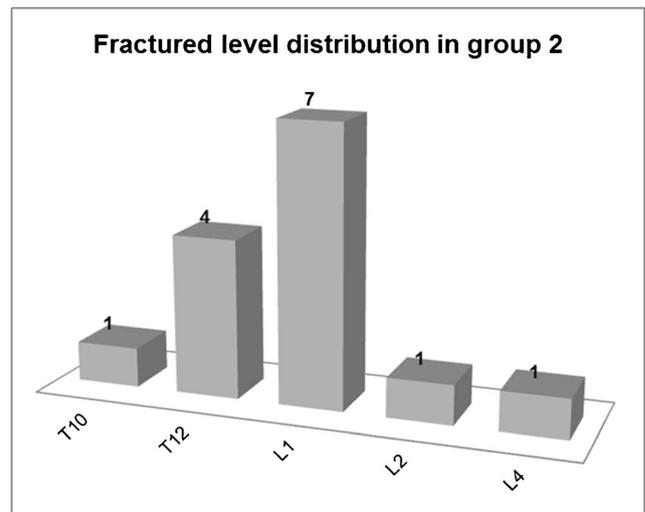


Fig. 2 Fractured level distribution in group 2 (SpineJack and percutaneous screw fixation)

Types of fracture according to the Magerl classification are summed up in Figs. 3 and 4.

Average time from trauma to surgery was three \pm six (1–42) days in group 1 versus 17 \pm 55 (1–210) days in group 2, $p = 0.07$.

The surgical time was 36 \pm 12 minutes in group 1 versus 81 \pm 22 minutes in group 2, $p < 0.0005$.

Clinical results

The average pre-operative VAS pain scale was at 7.3 \pm 1.1 (6–9) for group 1 and 7.1 \pm 0.8 (6–9) in group 2 without statistically significant difference ($p = 0.87$). After surgery, the score decreased to 1.7 \pm 1.2 (0–4) for group 1 and 2.0 \pm 1.2 (0–4) for group 2 ($p = 0.37$). Three months after surgery, VAS in group 1 was at 1.3 \pm 2.2 (0–4) and group 2 at 2.2 \pm 2.7 (0–4) ($p = 0.38$). The last follow-up yielding scores was of 0.7 \pm 1.6 (0–2) for group 1 and 1.6 \pm 2.4 (0–3) for group 2 ($p = 0.18$). The

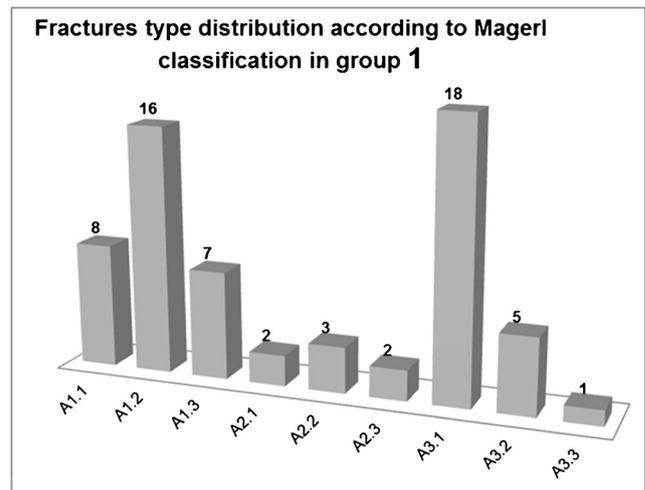


Fig. 3 Fractures type distribution according to Magerl classification in group 1 (stand-alone SpineJack) [11]

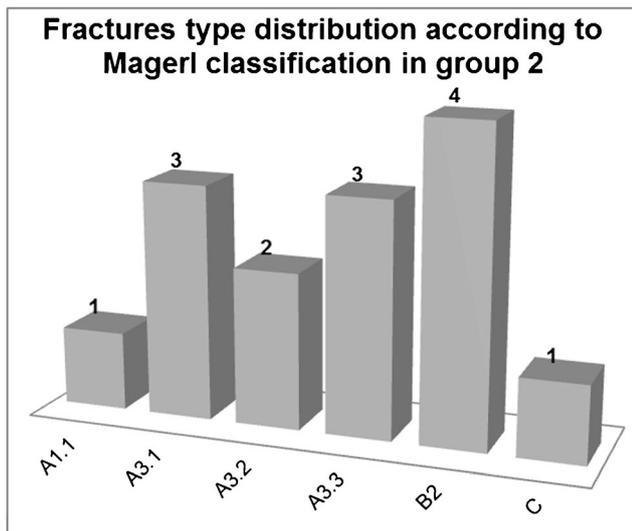


Fig. 4 Fractures type distribution according to Magerl classification in group 2 (SpineJack and percutaneous screw fixation) [11]

Oswestry Disability Index questionnaire was handed out to patients during the last follow-up visit with group 1 scoring an average of 5.7 ± 12.2 (2–60) and group 2 scoring at 11.6 ± 13.0 (0–36) with the difference not reaching statistical significance ($p = 0.19$).

At last follow-up in group 1, 49 patients (82%) reported being able to return to the same level of athletic or physical activity as before the fracture, the rate was at 56% (7 patients) in group two, without statistically significant difference ($p = 0.09$).

In group 1, 52 patients (87%) had been able to return to work at four to six months after surgery, in group two 79% (11 patients) had resumed work, ($p = 0.6$).

The end result of the surgery was judged to be very good by 48 patients (80%) in group 1 and 11 patients (79%) in group 2 ($p = 0.86$), good by nine patients (15%) in group 1 and no patient in group 2 ($p < 0.0005$), average by no patient in group one and three patients (22%) in group two ($p < 0.0005$), and poor by three patients (5%) in group 1 and no patient in group 2 ($p = 0.06$).

Radiological results

The average initial vertebral wedge angle was 13.3 ± 6.1 degrees for group 1 and 15.3 ± 5.7 degrees for group 2 with the difference not reaching statistical significance ($p = 0.25$).

The post-operative values for vertebral wedge angle were 6.5 ± 4.6 degrees for group 1 and 5.1 ± 3.9 degrees for group 2 ($p = 0.31$).

The differences between pre-operative and post-operative values within the same group were highly significant ($p < 0.0005$).

The average gain in vertebral wedge angle for group 1 was 6.8 ± 4.9 degrees and 10.1 ± 5.0 in group 2 with a significant difference between the two groups ($p = 0.025$).

The loss of reduction at three months was 0.8 ± 1.6 degrees in group 1 and 0.6 ± 2.0 degrees in group 2 ($p = 0.77$). There was no further loss of reduction after three months for both groups.

The average pre-operative regional kyphotic angle for group 1 was 8.3 ± 7.2 degrees and 10.6 ± 5.6 degrees for group 2, with the difference not reaching statistical significance ($p = 0.25$).

For the post-operative regional kyphotic angle, the average was 6.3 ± 6.9 degrees for group 1 and 2.9 ± 4.7 degrees for group 2 with the difference being non-significant ($p = 0.08$).

The gain in regional kyphotic angle was 2.6 ± 3.7 degrees in group 1 and 7.7 ± 7.9 degrees in group 2, again the difference in gain between the two groups reaches statistical significance ($p = 0.0007$).

The loss of reduction at three months was 0.6 ± 2.1 degrees in group 1 and 1.8 ± 4.5 degrees in group 2 ($p = 0.12$). No further loss of reduction was observed after three months for both groups.

Table 1 sums up the radiological results and cement leakages respectively for the immediate post-operative and follow-up period.

Complications

The post-operative CT scan showed 28 cases of cement leakage for group 1 (44% leakage rate) and seven cases for group 2 (50% leakage rate), $p = 0.71$.

As far as other complications are concerned, we noted one case of dura leak which resolved spontaneously with 72 hours of bed rest and one late complication of vertebral body collapse which required secondary posterior fixation and anterior corpectomy, both patients were from group 1.

Six patients out of group 2 have had elective secondary surgery to remove the screw and rod constructs.

Discussion

Since the first published studies on short-segment pedicle screw instrumentation, there has been a progressive shift towards less invasive techniques using either pedicle screws or cement as direct anterior column support because these techniques have been shown to give similar results to the classic open techniques with less surgical approach-related morbidity [5, 12]. The goal of surgical treatment has always been fracture stabilization to permit fracture consolidation and also to limit secondary deformity. Most vertebral fractures present with a more or less pronounced kyphotic deformity and our goal is to reduce and then fix the fracture.

According to some studies, more severe cases of residual kyphotic deformity are associated with worse functional outcomes than the patients with the least amount of residual kyphotic wedge angles [2, 13]. Balloon Kyphoplasty has shown its superiority in correcting kyphosis when compared with

Table 1 : Radiological results and cement leakage distribution

| | Group 1 (n = 63) | Group 2 (n = 14) | p |
|-------------------------------|------------------|------------------|----------|
| Wedge angle (degrees) | | | |
| Pre-operative | 13.3 ± 6.1 | 15.3 ± 5.7 | < 0.0005 |
| Post-operative | 6.5 ± 4.6 | 5.1 ± 3.9 | < 0.0005 |
| Gain | 6.8 ± 4.9 | 10.1 ± 5.0 | 0.025 |
| Loss of reduction at 3 months | 0.8 ± 1.6 | 0.6 ± 2.0 | 0.77 |
| Regional angle (degrees) | | | |
| Pre-operative | 8.3 ± 7.2 | 10.6 ± 5.6 | 0.25 |
| Post-operative | 6.3 ± 6.9 | 2.9 ± 4.7 | 0.08 |
| Gain | 2.6 ± 3.7 | 7.7 ± 7.9 | 0.0007 |
| Loss of reduction at 3 months | 0.6 ± 2.1 | 1.8 ± 4.5 | 0.12 |
| Cement leakage | | | |
| Cranial | 2 | 1 | 0.49 |
| Caudal | 3 | 0 | 1 |
| Posterior | 1 | 0 | 1 |
| Anterior | 4 | 1 | 1 |
| Lateral | 18 | 5 | 1 |
| Total | 28 | 7 | 0.71 |

vertebroplasty [8, 9]. The variant technique of vertebral stenting has also been shown to give reliable results [14]. The SpineJack has been compared with balloon kyphoplasty on a cadaveric model and has been shown to give significantly better reductions in terms of angle as well as vertebral body height correction when compared with kyphoplasty with less cement volume required [10, 15]. There are also several studies on the clinical use of the SpineJack with most authors looking at the pain and functional scores as well as complications [16–21].

To our knowledge, only few series report clinical and radiologic results on a patient cohort with trauma and osteoporotic fractures treated by SpineJack [16–19]. There are other studies that looked exclusively at osteoporotic compression fractures with kyphotic wedge angle above 20 degrees, and the authors found a reduction from a mean of 24.4 degrees to 11.7 degrees. These patients had a significant delay before surgery of at least six weeks, and the average age at 73.2 years was well above the average age of our series, but the authors were able to demonstrate a significant reduction of kyphotic deformity by using the SpineJack which is consistent with our results [19]. When comparing our results to the other published reports, we can see that the patient populations are a little different. Our group tends to be younger with a majority of male patients when compared with the other series in the literature [16–21]. Also most of our patients were treated immediately after their hospital admission for what were clearly identified traumatic fractures rather than osteoporotic fractures first treated medically.

Our results concerning the correction of the wedge angle seem consistent with what most authors find for their trauma

series when using pedicle screws; however, the secondary loss of correction seems to be less pronounced with the SpineJack [22, 23]. We do note that care should be taken when comparing different series of patients as local habits as well as differences in patient populations can make comparisons difficult. The absolute numbers in terms of reduction gain must be seen in the context of the initial type of fracture and initial wedge angle. Comminuted type A3 fractures with important wedge angles will usually show a more important gain than A1 type fractures with less comminution, as comminuted fractures are usually easier to reduce. On the other hand, these comminuted fractures are more at risk of secondary loss of reduction when compared with less comminuted fractures, and this aspect is one of the criteria used in McCormack's load sharing classification [24]. We did not try to analyze the differences in our series between A3 type fractures and the other types as our case numbers are not sufficient to reliably deduce a difference. When looking at the averages between our two groups, we see significant differences when looking at regional kyphotic angle correction as well as the wedge angle gain. Our explanation for this is the difference in fracture type between the two groups with group 2 having more burst fractures than group 1 and possibly a more important initial wedge angle even though the difference was not significant. The difference in regional kyphotic angle gain is most likely due to the better correction with pedicle screws even though this most likely takes place in the adjacent disc spaces, and some of this correction is subsequently lost during follow-up, as previously described in most series using pedicle screws [22, 23].

Our clinical results seem comparable with other published studies using minimally invasive surgical techniques for

thoracolumbar fractures, but it is difficult to draw conclusions when comparing studies that differ in aim and patient population [16–23]. The rate of patients with a very good or good subjective result as well as return to physical activity and return to work does seem satisfactory.

Regarding complications, our rate of cement leakage seems to be a little higher than what other authors found when using the SpineJack; however, there is no way to know if these differences are significant, and none of our patients with cement leakage were symptomatic or required revision surgery [16–21].

Conclusion

The SpineJack seems to be a promising tool in the treatment of traumatic vertebral fractures with a correction in the sagittal comparable to what can be found in the literature. Our rate of complications is comparable to what can be found in the literature without serious implant-related peri-operative complication.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

References

- Scheer JK, Bakhsheshian J, Fakurnejad S, Oh T, Dahdaleh NS, Smith ZA (2015) Evidence-based medicine of traumatic thoracolumbar burst fractures: a systematic review of operative management across 20 years. *Global Spine J* 5:73–82. <https://doi.org/10.1055/s-0034-1396047>
- Mayer M, Ortmaier R, Koller H, Koller J, Hitzl W, Auffarth A, Resch H, von Keudell A (2017) Impact of sagittal balance on clinical outcomes in surgically treated T12 and L1 burst fractures: analysis of long-term outcomes after posterior-only and combined posteroanterior treatment. *Biomed Res Int* 2017:1568258. <https://doi.org/10.1155/2017/1568258>
- Van Meirhaeghe J, Bastian L, Boonen S, Ranstam J, Tillman JB, Wardlaw D, investigators FREE (2013) A randomized trial of balloon kyphoplasty and nonsurgical management for treating acute vertebral compression fractures: vertebral body kyphosis correction and surgical parameters. *Spine (Phila Pa 1976)* 38:971–983. <https://doi.org/10.1097/BRS.0b013e31828e8e22>
- Zairi F, Court C, Tropiano P, Charles YP, Tonetti J, Fuentes S, Litrico S, Deramond H, Beaurain J, Orcel P, Delecrin J, Aebi M, Assaker R, French Society of Spine Surgery (2012) Minimally invasive management of thoraco-lumbar fractures: combined percutaneous fixation and balloon kyphoplasty. *Orthop Traumatol Surg Res* 98:S105–S111. <https://doi.org/10.1016/j.otsr.2012.06.004>
- McAnany SJ, Overley SC, Kim JS, Baird EO, Qureshi SA, Anderson PA (2016) Open versus minimally invasive fixation techniques for thoracolumbar trauma: a meta-analysis. *Global Spine J* 6:186–194. <https://doi.org/10.1055/s-0035-1554777>
- Ma XL, Xing D, Ma JX, Xu WG, Wang J, Chen Y (2012) Balloon kyphoplasty versus percutaneous vertebroplasty in treating osteoporotic vertebral compression fracture: grading the evidence through a systematic review and meta-analysis. *Eur Spine J* 21:1844–1859
- Papanastassiou ID, Filis A, Gerochristou MA, Vrionis FD (2014) Controversial issues in kyphoplasty and vertebroplasty in osteoporotic vertebral fractures. *Biomed Res Int* 2014:934206. <https://doi.org/10.1155/2014/934206>
- Garnier L, Tonetti J, Bodin A, Vouaillat H, Merloz P, Assaker R, Court C, French Society for Spine Surgery (2012) Kyphoplasty versus vertebroplasty in osteoporotic thoracolumbar spine fractures. Short-term retrospective review of a multicentre cohort of 127 consecutive patients. *Orthop Traumatol Surg Res* 98:S112–S119. <https://doi.org/10.1016/j.otsr.2012.03.018>
- Wang B, Zhao CP, Song LX, Zhu L (2018) Balloon kyphoplasty versus percutaneous vertebroplasty for osteoporotic vertebral compression fracture: a meta-analysis and systematic review. *J Orthop Surg Res* 13:264. <https://doi.org/10.1186/s13018-018-0952-5>
- Krüger A, Oberkircher L, Figiel J, Floßdorf F, Bolzinger F, Noriega DC, Ruchholtz S (2015) Height restoration of osteoporotic vertebral compression fractures using different intravertebral reduction devices: a cadaveric study. *Spine J* 15:1092–1098. <https://doi.org/10.1016/j.spinee.2013.06.094>
- Magerl F, Aebi M, Gertzbein SD, Harms J, Nazarian S (1994) A comprehensive classification of thoracic and lumbar injuries. *Eur Spine J* 3:184–201
- Li H, Yang L, Xie H, Yu L, Wei H, Cao X (2015) Surgical outcomes of mini-open Wiltse approach and conventional open approach in patients with single-segment thoracolumbar fractures without neurologic injury. *J Biomed Res* 29:76–82. <https://doi.org/10.7555/JBR.29.20140083>
- Wang XY, Dai LY, Xu HZ, Chi YL (2008) Kyphosis recurrence after posterior short-segment fixation in thoracolumbar burst fractures. *J Neurosurg Spine* 8:246–254. <https://doi.org/10.3171/SPI/2008/8/3/246>
- Disch AC, Schmoelz W (2014) Cement augmentation in a thoracolumbar fracture model: reduction and stability after balloon kyphoplasty versus vertebral body stenting. *Spine (Phila Pa 1976)* 39:E1147–E1153. <https://doi.org/10.1097/BRS.0000000000000470>
- Rotter R, Schmitt L, Gierer P, Schmitz KP, Noriega D, Mittlmeier T, Meeder PJ, Martin H (2015) Minimum cement volume required in vertebral body augmentation—a biomechanical study comparing the permanent SpineJack device and balloon kyphoplasty in traumatic fracture. *Clin Biomech* 30:720–725. <https://doi.org/10.1016/j.clinbiomech.2015.04.015>
- Baeesa SS, Krueger A, Aragón FA, Noriega DC (2015) The efficacy of a percutaneous expandable titanium device in anatomical reduction of vertebral compression fractures of the thoracolumbar spine. *Saudi Med J* 36:52–60. <https://doi.org/10.15537/smj.2015.1.9463>
- Noriega D, Krüger A, Ardura F, Hansen-Algenstaedt N, Hassel F, Barreau X, Beyerlein J (2015) Clinical outcome after the use of a new craniocaudal expandable implant for vertebral compression fracture treatment: one year results from a prospective multicentric study. *Biomed Res Int* 2015:927813. <https://doi.org/10.1155/2015/927813>
- Renaud C (2015) Treatment of vertebral compression fractures with the cranio-caudal expandable implant SpineJack®: technical note and outcomes in 77 consecutive patients. *Orthop Traumatol Surg Res* 101:857–859. <https://doi.org/10.1016/j.otsr.2015.08.009>

19. Noriega DC, Rodríguez-Monsalve F, Ramajo R, Sánchez-Lite I, Toribio B, Ardura F (2019) Long-term safety and clinical performance of kyphoplasty and SpineJack® procedures in the treatment of osteoporotic vertebral compression fractures: a pilot, monocentric, investigator-initiated study. *Osteoporos Int* 30:637–645. <https://doi.org/10.1007/s00198-018-4773-5>
20. Muñoz Montoya JE, Torres C, Ferrer ER, Muñoz Rodríguez EE (2018) A Colombian experience involving SpineJack®, a consecutive series of patients experiencing spinal fractures, percutaneous approach and anatomical restoration 2016-2017. *J Spine Surg* 4: 624–629. <https://doi.org/10.21037/jss.2018.07.08>
21. Premat K, Vande Perre S, Cormier É, Shotar E, Degos V, Morardet L, Fargeot C, Clarençon F, Chiras J (2018) Vertebral augmentation with the SpineJack® in chronic vertebral compression fractures with major kyphosis. *Eur Radiol* 28:4985–4991. <https://doi.org/10.1007/s00330-018-5544-6>
22. Yue JJ, Sossan A, Selgrath C, Deutsch LS, Wilkens K, Testaiuti M, Gabriel JP (2002) The treatment of unstable thoracic spine fractures with transpedicular screw instrumentation: a 3-year consecutive series. *Spine (Phila Pa 1976)* 27:2782–2787
23. Khare S, Sharma V (2013) Surgical outcome of posterior short segment trans-pedicle screw fixation for thoracolumbar fractures. *J Orthop* 10:162–167. <https://doi.org/10.1016/j.jor.2013.09.010>
24. McCormack T, Karaikovic E, Gaines RW (1994) The load sharing classification of spine fractures. *Spine (Phila Pa 1976)* 19:1741–1744

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.