Percutaneous internal fixation combined with kyphoplasty for neurologically intact thoracolumbar fractures: A prospective cohort study of 24 patients with one year of follow-up

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Summary

Introduction and hypothesis: Neurologically intact lumbar and thoracolumbar fractures are frequent but their treatment is not codified. The purpose of this study was to evaluate the effectiveness of minimally invasive treatment of such fractures by percutaneous fixation associated with balloon kyphoplasty.

Patients and methods: Between November 2008 and July 2010, 24 patients were treated. There were 12 men and 12 women, with a mean age of 53 years (range 20–88 years). Fractures were classified as one Magerl lesion type A1, one type A2, 19 A3 (five A31, 10 A32, four A33), and three type B2. The treatment was kyphoplasty of the fractured vertebra followed by percutaneous fixation of the vertebra above and below the fracture. Patient follow-up included an analysis of pain using the visual analogic score, the Oswestry score, and functional X-ray and CT analysis.

Results: Surgery lasted a mean 99 minutes. At the last follow-up, the mean pain was scored at 0.9 and the Oswestry score was 13.2. Reduction of vertebral kyphosis was 8.6° and reduction of the corrected regional angle was 7.1°. The gain in vertebral height was 17%. All pedicle screws were positioned correctly and no neurological, septic, or thromboembolic complications were observed.
Introduction

Neurologically intact lumbar or thoracolumbar fractures (T11–L2) are very frequent, but their management has not yet been codified. Orthopaedic treatment gives interesting results in certain indications [1]. However, it shows its limits in unstable fractures (Magerl type A3 and type B [2]) and in lumbar fractures, with poorer functional and radiological results over the long-term [3]. Surgery via the posterior approach with short-term osteosynthesis has been shown to be superior for this type of fracture [4,5]. Some authors combine posterior and anterior stabilization [6], but this is major surgery with high risks and longer hospitalization.

New minimally invasive techniques have appeared over the past few years. Their objective is to improve patient comfort by reducing postoperative pain and the duration of hospitalization [7]. Percutaneous osteosynthesis of spinal fractures was also the subject of a round table of the French spinal surgery society (la Société française de chirurgie rachidienne) in June 2009. As shown by the recent work by Fuentes et al. [8,9], percutaneous posterior osteosynthesis is possible and can be associated with anterior reduction with balloon kyphoplasty.

The objective of the present study was to assess this percutaneous technique in traumatology. This article presents the preliminary results of a prospective series of 24 patients who presented a lumbar or thoracolumbar fracture without neurological involvement, treated by the association of percutaneous osteosynthesis and kyphoplasty.

Patients and methods

Patients

Between November 2008 and July 2010, 24 patients (12 females and 12 males) were included in this prospective, observational, non-randomized, level IV study. All of them presented a fracture of the lumbar spine or at the thoracolumbar junction treated with percutaneous osteosynthesis associated with kyphoplasty of the fractured vertebra. All the patients were treated at the Poitiers university hospital (France).

The patients’ mean age was 53-years (range 20–88 years). Eight (33%) were retired and 16 (67%) had an occupation before injury. The mean body mass index was 24.3 (range 18.8–30.1). Nine patients were classified ASA 1 (37%), 13 ASA 2 (54%), one ASA 3 (4%), and one ASA 4 (4%). The fracture was secondary to a fall from a ladder in nine cases (37%), a traffic accident in eight cases (33%), a fall from a height in four cases (17%), and to a sports accident in three cases (13%), with two falls from horseback and one parachute fall. Eleven patients (46%) presented associated lesions: five in the limbs and six in the thoracic or lumbar spine. None of the patients presented neurological signs and all were classified Frankel stage E [10]. The mean time from injury to surgery was 2.4 days (range 1–7 days).

Lesions

The radiological explorations systematically included standard AP and lateral thoracolumbar X-rays of the spine as well as a CT-scan with sagittal, frontal, and three-dimensional reconstructions. The fractures were classified according to the classification by Magerl et al. [2]. The series included one type A1 lesion, one type A2, 19 type A3 (five A31, 10 A32, four A33), and three type B2 lesions. Half of the fractures were located in L1 (Fig. 1).

Operative technique

The patient was installed in the ventral decubitus position, under general anesthesia, on a spinal surgery table, with blocks under the thorax and the iliac crests to allow reduction of the fracture by putting the spine in lordosis. Lateral X-ray guidance made it possible to identify the fractured vertebra. The first operative phase involved balloon kyphoplasty of the fractured vertebra using material from Kyphon Inc. The cannulae were inserted via a pedicular approach following a converging, slightly descending direction; then the balloon trajectories were drilled through the cannulae. The balloons were expanded intravertebrally under X-ray guidance with a contrast agent. Pressure and volume were checked using the Kyphon ancillary instrumentation. After having deflated and removed the balloons, the cavity left free in the vertebra body was filled with either Biomet

Figure 1 Distribution of fractures according to lesion location.
Bone Cement V® from Biomet, or with Kyphos® phosphocalcic cement from Kyphon, always progressively and with X-ray guidance. The second operative phase involved percutaneous osteosynthesis with Sextant® ancillary instrumentation from Medtronic. Polyaxial pedicular screws were placed in the adjacent vertebrae under X-ray guidance after the trocar, the threaded pin, the dilators, and then the graduated screw tap. The sextant-shaped ancillary was then attached to the screw holder so as to insert the two prebent stems in the screw heads and block them with bolts after the distractive reduction manoeuvre. Finally, the skin incisions were sutured using separated stitches. It should be noted that in two cases, the kyphoplasty procedure was carried out after percutaneous osteosynthesis with no particular complications.

Verticalization and ambulation were authorized beginning the day after surgery in absence of associated pelvic or lower limb lesions. Each patient left with a prescription for step 2 painkillers for two weeks, preventive anticoagulation for 45 days, and isometric rehabilitation with a physical therapist. Sick leave for 45 days was also prescribed and an appointment for consultation on the 45th postoperative day was scheduled for radiological and clinical follow-up. No external contention was prescribed.

**Evaluation methods**

Pain was evaluated pre- and postoperatively using the visual analogic scale (VAS). Functional incapacity was also assessed using the French version of the Oswestry disability index [11].

The radiographic analysis (Fig. 2) was performed on plain lateral X-rays in the preoperative consultation, immediately postoperative, then at three months, six months, one year, and two years for the longest follow-up. Measurements of vertebral kyphosis (VK) and regional kyphosis (RK) were taken on each standard lateral X-ray. The corrected regional angle (CRA) was calculated by subtracting the regional kyphosis measured from the regional physiological kyphosis using the abacus concept reported by Stagnara et al. [12]. Vertebral height was measured according to the vertebral height index (VHI) comparing the height of the anterior side of the vertebral body to the height of the body of the adjacent vertebra [13]. A CT-scan at three months postoperative (Fig. 3) evaluated the deformity in the sagittal plane, height restoration, and cement distribution in the body of the fractured vertebra as well as the position of the pedicular screws in the subjacent and superjacent vertebrae.

**Results**

**Surgery**

The mean duration of surgery was 99 minutes (range 68–182 min). The mean scars measured 1 cm (1.5 cm for the incisions for the pedicular screws, 1 cm for the incisions required for passing the prebent stems, and 5 mm for the incisions corresponding to the kyphoplasty trocar).

The mean quantity of cement injected into the vertebral body was 7.6 cc (range 4–10 cc). Eight cases (33%) of cement leakage were noted intraoperatively with no clinical consequences. Three were observed along the trocar trajectory, two in the subjacent and superjacent discal space, and three others in the lateral vertebral space. No intramedullary leakage was observed.

Radioscopy lasted a mean 179 s (range 123–203 s).

**Postoperative recovery**

Hospitalisation lasted a mean nine days (range 4–44 days). One patient was hospitalised 44 days for traction treatment of an associated acetabulum fracture. The duration of hospitalisation was six days (range 4–17 days) for the 13 patients with no associated lesions. No septic or thromboembolic complications were observed.

Three patients (12%) presented a postoperative hematoma at the scar, one of which had to be reviewed in
Clinical results

The mean follow-up was 12.5 months (range 3–24 months). One patient was lost to follow-up at three months (he returned to his native country).

Preoperative pain was high in all patients, with the mean VAS evaluated at 7.7/10 (range 6–10), decreasing to 1.9/10 (range 0–8) upon discharge. The mean VAS was 1.1/10 (range 0–4) at three months and 0.9 (range 0–3) at the last follow-up.

Of the 16 patients who were working before injury, 13 were able to return to work (81%), one patient returned via occupational rehabilitation (7%), and two stopped working completely (13%).

At the last follow-up, The Oswestry disability index score [11] was a mean 13.2% (range 0–54%). The patient with the highest score (54%) was a farmer who had nevertheless returned to work. Twenty patients were very satisfied (83%) with the surgery and four (17%) moderately satisfied. None of the patients were dissatisfied or very dissatisfied with the intervention.

Radiological results

The preoperative, immediate postoperative, and last follow-up VK, CRA, and VHI results are given in relation to the lesion location (Tables 1–3). A gain in correction was observed after treatment on the three radiological criteria, but a loss of correction reappeared over time (Figs. 4 and 5) for all locations and types of fracture and for all ages. As

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Changes in vertebral kyphosis in degrees.</th>
</tr>
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<tbody>
<tr>
<td>Level</td>
<td>n</td>
</tr>
<tr>
<td>T12</td>
<td>2</td>
</tr>
<tr>
<td>L1</td>
<td>12</td>
</tr>
<tr>
<td>L2</td>
<td>5</td>
</tr>
<tr>
<td>L3</td>
<td>2</td>
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<td>L5</td>
<td>1</td>
</tr>
<tr>
<td>Series</td>
<td>24</td>
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</tbody>
</table>

IVK: initial vertebral kyphosis; pVK: postoperative vertebral kyphosis; fUK: vertebral kyphosis at last follow-up; GpC: gain in postoperative correction; GfuC: gain in correction at last follow-up; LfuC: loss in correction at last follow-up.
Table 2  Changes in corrected regional angle in degrees.

<table>
<thead>
<tr>
<th>Level</th>
<th>n</th>
<th>iCRA</th>
<th>poCRA</th>
<th>CRAfu</th>
<th>GCpo</th>
<th>GCfu</th>
<th>LCfu</th>
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<tbody>
<tr>
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<td>2</td>
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<td>14.6</td>
<td>16</td>
<td>0.5</td>
<td>15.5</td>
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<tr>
<td>L1</td>
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<td>−1.1</td>
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<tr>
<td>L2</td>
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<td>17.6</td>
<td>3.6</td>
<td>8.6</td>
<td>14</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>L3</td>
<td>2</td>
<td>13</td>
<td>7</td>
<td>7.5</td>
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<td>5.5</td>
<td>0.5</td>
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<tr>
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<tr>
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<td>12</td>
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<td>6.4</td>
<td>11.8</td>
<td>7.1</td>
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</table>

iCRA: initial corrected regional angle; pCRA: postoperative corrected regional angle; CRAfu: corrected regional angle at last follow-up; GCpo: gain in postoperative correction; GCfu: gain in correction at last follow-up; LCfu: loss of correction at last follow-up.

Table 3  Changes in vertebral height index in percentage.

<table>
<thead>
<tr>
<th>Level</th>
<th>n</th>
<th>iVHI</th>
<th>poVHI</th>
<th>VHIfu</th>
<th>GCpo</th>
<th>GCfu</th>
<th>LCfu</th>
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<td>86</td>
<td>84</td>
<td>34</td>
<td>32</td>
<td>2</td>
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<tr>
<td>L1</td>
<td>12</td>
<td>66</td>
<td>87</td>
<td>84</td>
<td>21</td>
<td>18</td>
<td>3</td>
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<tr>
<td>L2</td>
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<td>93</td>
<td>87</td>
<td>27</td>
<td>22</td>
<td>5</td>
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<tr>
<td>L3</td>
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<td>91</td>
<td>87</td>
<td>16</td>
<td>12</td>
<td>4</td>
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<td>L4</td>
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<td>102</td>
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<tr>
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<td>84</td>
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<td>90</td>
<td>86</td>
<td>22</td>
<td>18</td>
<td>4</td>
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</tbody>
</table>

iVHI: initial vertebral height index; poVHI: vertebral height index; VHIfu: vertebral height index at last follow-up; GCpo: gain in postoperative correction; GCfu: gain in correction at last follow-up; LCfu: loss of correction at last follow-up.

Table 4  Mean postreduction loss in VK, CRA, and VHI in relation to cement used.

<table>
<thead>
<tr>
<th>Cement</th>
<th>n</th>
<th>VK (◦)</th>
<th>CRA (◦)</th>
<th>VHI</th>
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<td>Acrylic</td>
<td>20</td>
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<td>3.5</td>
</tr>
<tr>
<td>Phosphocalcic</td>
<td>4</td>
<td>2.8</td>
<td>4.3</td>
<td>4.0</td>
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</tbody>
</table>

for VK, the mean postreduction loss was 1.6° and the mean final gain was 8.6°. For CRA, the mean postreduction loss was 4.7° for a final gain of 7.1°. As for VHI, the mean loss was four points and the mean final gain was 18 points.

The loss in reduction can also be compared in relation to the cement used, phosphocalcic or acrylic (Table 4). Phosphocalcic cement was used in the young patient because of its biocompatibility and its biomechanical properties, making it close to normal cancellous bone. Four patients with a mean age of 26 were treated with phosphocalcic cement and 20 patients (mean age 58 years) with acrylic cement.

On the postoperative CT, eight cases of cement leakage into the adjacent discal space, surrounding the vertebra, or on the trocar trajectory, were observed, with no intramedullary leakage. All the pedicular screws were properly positioned.

Discussion

Treatment of thoracolumbar fractures with no neurological involvement has not yet been codified. It can be orthopaedic or surgical. Recent studies [14,15] have not found one method statistically superior to any other. Nevertheless, according to Thomas et al. [15], surgery may reduce pain more quickly and may allow earlier mobilization and return to work. In 2008, Freslon et al. [16] found a correlation between vertebral kyphosis and functional score, which could mean that reinforcing the anterior column could improve this functional result. This is why it may be advantageous to associate percutaneous osteosynthesis with kyphoplasty.

The data reported in the literature [17,18] have already demonstrated the efficacy of balloon kyphoplasty in recent vertebral fractures with significant improvements in terms of pain, function, and quality of life. It corrects kyphosis, stabilizes the fracture, and allows early mobilization, even in cases of A3 burst fractures [19]. The association with short-term osteosynthesis via the posterior approach can restore traumatic kyphosis and vertebral height on a long-term basis without the more invasive anterior approach [20]. Nevertheless, rare but potentially serious complications exist with kyphoplasty: a severe reaction to the cement, pulmonary embolus, and intramedullary extravasation of the cement. In a study published in 2009 on 1150 kyphoplasty procedures, McArthur et al. [21] found six cases of postoperative complications (0.5%), including one case of permanent monoplegia of the left leg, two cases of transitory neurological deficits, two cases of hemorrhage, and one of asymptomatic pulmonary embolus. In the present series, we did not observe any of these complications despite eight cases (33%) of cement leakage, all extramedullary.

We used phosphocalcic cement in the four youngest patients (mean age, 26 years) because of its excellent bio-
compatibility and its ability to be resorbed and replaced by newly formed bone tissue, which seems to be a major advantage in young patients with a long life expectancy [22,23]. Comparing the radiological results in relation to the cement used (phosphocalcic or acrylic), it would seem that the loss of reduction observed would be slightly higher for VK and VHI in the phosphocalcic cement group (Table 4). The number of patients and the length of follow-up are insufficient to bring out a significant difference in this series. Nevertheless, recent studies have found significantly greater loss of correction, for the most part in burst fractures, challenging the use of phosphocalcic cement in kyphoplasty [24,25].

Sextant™ is an ingenious osteosynthesis technique that allows percutaneous surgical treatment. The objective here is to reduce operative morbidity (intraoperative bleeding, postoperative pain, length of hospital stay), while maintaining results that are similar to conventional techniques [26,27]. On the other hand, percutaneous osteosynthesis associated with kyphoplasty requires a precise and rigorous technique with a long learning curve. In our series, the mean duration of the intervention was 160 min for the two patients operated on in 2008, 111 min for the 12 patients operated on in 2009, and 88 min for the ten patients operated on in 2010. The data reported in the literature show that there is a risk of error in the pedicular screw fixation on the order of 6 to 7% in conventional surgery [15,28]. In the present study, all of the pedicular screws were properly positioned on CT verification, undoubtedly because of the radioscopic guidance used during screw fixation [29]. Use of radioscopic guidance (mean, 179 s in this study) definitely induces irradiation, but it would seem that computer-assisted navigation significantly reduces this duration [30,31], for both the patient and the personnel.

In the 1995 Sofcot symposium series [32], the mean VK decreased from 17° to 5.9°, for a final gain of 11.1° for posterior surgery. In the series reported at the 2007 Sofcrot round table [16], the mean VK decreased from 18.1° to 12.5° for all surgeries, for a final gain of 5.6°. In our series, the mean VK decreased from 15.2° to 6.6°, for a mean final gain of 8.6°. It is clear that percutaneous osteosynthesis alone has already demonstrated interesting results [33]. In 2008, Pelegri et al. [34], reported a series of 13 patients treated with percutaneous osteosynthesis alone with a mean VK decreasing from 16° to 8.1° at the last follow-up (for an absolute gain of 7.9°). The CRA decreased from 12° to 2.5° at the last follow-up (for an absolute gain of 9.5°), whereas it decreased from 13.5° to 6.4° at the last follow-up (for an absolute gain of 7.1°) in the present study. Our results seem to be similar even though we did not investigate the same population. Our study included 19 A3 fractures (79% of the patients) versus seven (54%) in the study reported by Pelegri et al. [34]. Our mean age was 53-years versus 36-years. Yet if the corrections are compared in relation to age, the immediate gains in reduction were poorer and the postreduction losses greater in the older subject, in particular for the CRA (Table 5). This rapid reappearance of kyphosis involves RK more than VK. Collapse may therefore be mainly in the suprajacent disks whose quality may be poorer in the older subject (degenerative discopathy). Pelegri et al. [34] prescribed a corset after surgery in nine of their 13 patients (69%), lasting from 30 to 90 days. In our series, no external corset contention was prescribed, explaining why the percutaneous osteosynthesis—kyphoplasty association seems advantageous.

However, there was inevitably loss of reduction during kyphoplasty balloon deflation. To limit this in conventional surgery, the authors performed the osteosynthesis procedure first with the “redactor” material, i.e., with monaxial screws, distractors, and prebent stems. The ligamentotaxis produced by the first instrumentation increases reduction during kyphoplasty and lowers the loss of reduction during balloon deflation. In our series, kyphoplasty was carried out before osteosynthesis so as not to interfere with the Sextant™ during fixation of the pedicular screws and trocar setup. Actually, it is possible to perform kyphoplasty after placing the Sextant™ with no particular problems, and we are currently moving in this direction. Moreover, intravertebral stent systems have recently been developed to control the loss in reduction related to kyphoplasty. The idea is to leave a metallic stent in place in the fractured vertebra to maintain reduction after balloon deflation. A study is ongoing in our department (with the OsseoFix™ system from the Alphatec spine laboratory).

### Table 5

<table>
<thead>
<tr>
<th>Age group</th>
<th>n</th>
<th>GCpo</th>
<th>GCfu</th>
<th>LCfu</th>
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<td>20–29</td>
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<td>14</td>
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<td>30–49</td>
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<td>50–69</td>
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<td>70–89</td>
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<tr>
<td>Series</td>
<td>24</td>
<td>11.8</td>
<td>7.2</td>
<td>4.7</td>
</tr>
</tbody>
</table>

GCpo: gain in postoperative correction; GCfu: gain in correction at last follow-up; LCfu: loss in correction at last follow-up.

### Conclusion

Percutaneous osteosynthesis combined with balloon kyphoplasty is a valuable surgical technique for the treatment of types A and B lumbar and thoracolumbar fractures with no neurological injury. The clinical results are excellent in terms of pain, scarring, and overall patient satisfaction. Patients can return home quickly without having to wear a corset.

The radiological results are very encouraging, with similar corrections to classical surgery in terms of vertebral height. Primary instrumentation and the use of intravertebral stents may be able to limit the loss of correction observed during kyphoplasty balloon deflation.

The association of percutaneous osteosynthesis and kyphoplasty may be an alternative to conventional open surgery, but a longer follow-up and greater numbers of patients are required before this technique can be generalised.

### Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.
References


