Single stage corpectomy and instrumentation in the treatment of pathological fractures in the lumbar spine

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Abstract

Purpose Corpectomy and implantation of titanium cages is standard in pathological fracture treatment but additional single ventral instrumentation remains controversial with regard to rotational stability.

Methods This study included 45 patients suffering from vertebral metastases with spinal stenosis, instability and/or neurological deficits secondary to pathological lumbar spine fractures and bone mineral density (BMD) ≥ 1.20 g/cm². The clinical results of a single stage anterior decompression with corpectomy defect restoration with titanium cage and single double rod system in patients were evaluated at mean 36 months postoperatively with follow-up neurological and radiological exams at three months then every six months.

Evaluation of neurological recovery included grading following a modified Frankel scale. Contentment, disability and actual pain were evaluated using the visual analogue scale (VAS) and Oswestry disability index (ODI). BMD was measured using dual-energy X-ray absorptiometry (DXA).

Results Postoperative neurological evaluations showed improvement in all patients. In the radiological follow-up in 40 patients (89%) findings were similar compared to the postoperative control. In five patients (11%) a loss of

correction at a mean of 8° degrees (Cobb angle) secondary to cage subsidence occurred. No breakage of the device or displacement of the instrumentation was seen. Overall the Frankel scale improved 0.65 points ($p < 0.05$) and the ODI improved 40.69 points ($p < 0.05$).

Conclusions In lumbar spine fractures of metastatic origin with stenosis, instability and/or neurological deficit, a single stage ventral decompression and instrumentation in patients with BMD ≥ 1.20 g/cm² should be considered.

Introduction

Spinal metastases are most common in the vertebral body and often lead to vertebral body fracture. Treatment of pathological fractures in the lumbar spine associated with instability, and/or spinal stenosis and/or neurological deficit remains controversial (Fig. 1). Prior to the introduction of vertebral cages, treatment was conservative including spinal orthosis and radiation [1]. Later, operative restoration of stability and early decompression in certain cases was proposed [2–5].

Simple laminectomy is ineffective in restoration of the spinal canal and improvement of neurological function [6].

Recent reports suggested that decompression by removal of dorsally displaced vertebral body or disc or tumour fragments using thoracoabdominal or abdominal retroperitoneal approaches can be more effective [7, 8]. The defect can be restored using bicortical bone graft or, in case of vertebral metastasis, with bone cement [9, 10].

Since 1990, titanium spacers for vertebral body restoration, and now also in distractible form [11], are available. These can be filled either with cancellous bone or bone cement.

To accomplish maximal stability following restoration, the gold standard includes fixation of a ventral instru-

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Fig. 1 **a, b** Pathological fracture of L3 with occlusion of the spinal canal caused by a dorsal fragment (*arrow*)

mentation in the single rod technique and, as this instrumentation alone does not provide sufficient rotational stability, additional dorsal transpedicular instrumentation [12–15].

Single ventral double rod instrumentations have also been claimed to achieve satisfactory rotational stability, permitting omission of additional dorsal transpedicular instrumentation [16–18].

However, single ventral instrumentation is controversial, as cases of breaking out of the instrumentation have been documented. Some authors recommend a single double rod system following corpectomy; others report insufficient stability and tend towards an additional dorsal instrumentation [12, 13, 15, 18, 19].

Biomechanical studies have documented adequate stability provided by single ventral double rod instrumentation under the condition of a BMD $>1.20 \text{ g/cm}^2$ [20].

In this study we sought to evaluate the single stage anterior decompression technique (with defect restoration using expandable titanium mesh spacer and a ventral double rod system) under the condition of a BMD $>1.20 \text{ g/cm}^2$ in patients with unstable pathological lumbar fractures and/or compromise of the bony canal and/or neurological deficit.

Material and methods

All patients treated for pathological fractures of the lumbar spine from February 2000 to April 2004 were located by medical record indexes or computer files. DXA measurement of BMD had been performed on the lumbar spine (L1–L4) and the femoral neck. During this period only patients with a BMD $>1.20 \text{ g/cm}^2$ were operated upon using the single stage anterior decompression technique upon using double rod system.

Preoperatively, all patients were checked following the criteria of Tokuhashi-score [21] in case of metastatic pathological fracture.

Only in patients with an acceptable life expectancy and without rapidly progressive cancer with a Tokuhashi-score above 5, were major reconstructive procedures such as corpectomy and single ventral instrumentation were planned. Each patient completed a questionnaire regarding presence of pain, present activity status or limitations, bowel or bladder dysfunction and overall satisfaction with the operation. On return for evaluation each patient had a detailed examination including documentation of the neurological state and radiological examination in two planes.

Patients' charts and operative notes were reviewed, and radiographs, magnetic resonance tomography (MRT), myelograms or computer tomograms (CT) were analysed with respect to the preoperative occlusion of the spinal canal as determined by the frontal and sagittal diameter. Only if the adjacent vertebrae were inconspicuous, was surgical treatment performed. In patients with renal metastases, preoperative angiography and embolisation were performed to prevent intraoperative bleeding.

Preoperative and final fracture angulation was measured from the anterior-posterior (AP) and lateral radiographs. Radiographs were reviewed with regard to potential postoperative complications.

A total of 45 patients (21 men and 24 women) with an average age of 61 years (range 22–83 years) met our inclusion criteria (see below). The causative primary tumours of the patients are shown in Table 1; the fracture levels and the percentage of spinal canal occlusion are shown in Table 2.

Indications for surgery

Only patients with pathological fractures following malignant disease with instability, compromise of the bony canal

Table 1 Diagnosis of the patients treated with corpectomy ($n=45$)

Diagnosis	Number of patients
Metastasis breast cancer	7
Metastasis sigma carcinoma	1
Metastasis colon carcinoma	4
Metastasis rectal carcinoma	1
Metastasis renal carcinoma	6
Metastasis bladder carcinoma	1
Metastasis liposarcoma	1
Metastasis carcinoma floor of the mouth	1
Metastasis yolk sac tumor	1
Metastasis hypopharygocarcinoma	2
Plasmacytoma	3
Metastasis carcinoma neck of uterus	3
Non Hodgkin lymphoma	1
Metastasis bronchial cancer	7
Metastasis prostate carcinoma	4
Metastasis liver cancer	1
Metastasis plasmacytocyte of the heel	1

and/or neurological deficit were operated upon. In all patients with constriction of the spinal canal due to pathological fracture (as demonstrated in CT or MRT) with a static or progressive neurological deficit, surgery was performed immediately. In absence of neurological deficit the intervention was scheduled in the routine program.

Determination of bone mineral density (BMD)

All patients indicated for surgery had a BMD measurement using PA-DXA (DPX-L; Lunar Corporation, Madison, Wisconsin, USA). Only in patients with $BMD \geq 1.20 \text{ g/cm}^2$ was a single ventral procedure was planned. In patients with rapidly progressive neurological deficit, ventral encroachment of the spinal canal ventral and unaffected adjacent vertebrae decompression and instrumentation was carried out immediately and BMD measurement was performed post-operatively. If BMD then turned out to be below 1.20 g/cm^2 additional dorsal transpedicular instrumentation was carried out. These patients were not included in the study.

Table 2 Level and number of corpectomies, percentage of spinal occlusion

Level (range)	Number of vertebral bodies ($N=45$)	Spinal occlusion (%)
L1	9	26.1 (17–31)
L2	11	30.6 (21–35)
L3	13	30.5 (21–40)
L4	12	28.5 (11–49)

Surgical procedure Patients were placed in the direct lateral position with the pelvis and shoulder perpendicular to the operating table to provide orientation to the spine. An abdominal retroperitoneal approach to the affected vertebra was performed, as described previously [22]. To reach the vertebrae of L1 and L2 thoracophrenicumbotomy was avoided and instead a retroperitoneal approach below the 12th rib was chosen; the diaphragm was incised at the part attached at the spine.

Ligation of segmental vessels was followed by corpectomy to the posterior margin of the vertebral body. The final decompression was accomplished using straight and angled curettes to elevate displaced bony fragments away from the dorsal longitudinal ligament.

The defect was restored by insertion of a titanium SynExTM cage (Stratec Medical, Oberdorf, Switzerland) in all patients. The cage between the adjacent vertebrae was stabilised with a ventral double rod system (VentroFixTM, Stratec Medical, Oberdorf, Switzerland). In all patients the cage was filled with bone cement (CMW, DePuy, Warsaw, IN, USA) in order to increase stability (Fig. 2).

Postoperative management

Postoperative management consisted of early ambulation on the first postoperative day without spinal orthosis. Patients were discharged from the hospital after complete wound healing and mobilisation.

During hospital care re-treatment was planned. In all patients postoperative local radiation was initiated. Depending on the primary tumour, radiation was combined with chemotherapy or, in case of thyroid carcinoma, with radioiodine therapy.

Clinical and radiological follow-up was three months after surgery and then every six months.

Measurement of spinal canal occlusion

Determination of the occlusion of the spinal canal was done by measurement of the longitudinal and sagittal diameter of the cranial and caudal unchanged canal in relation to the occlusion at the injury level (Fig. 3).

Statistical evaluation

Descriptive statistics during follow-up (arithmetic mean, standard deviation, range) were calculated using standard formulae.

Baseline clinical scores were compared with follow-up data by paired Wilcoxon tests for the Frankel score, ODI score, the visual analogue scale and the radiological evaluation. Radiological angle measurement and clinical

Fig. 2 a, b Corpectomy, titanium-cage, double rod instrumentation

scores were compared using the Spearman coefficient of correlate. A p -value < 0.05 was considered significant.

Results

Patients and hospital stay

The mean follow-up was 36 months (range 14–60 months). Mean duration of postoperative hospitalisation was 13 days (range 9–24 days).

Fig. 3 Measurement of spinal occlusion (a). Position of the vertebral screws (b)

Radiological results

For the final postoperative evaluation the last available radiograph was used. The average BMD was 1.30 g/cm^2 (range 1.20 – 1.63 g/cm^2). In 40 patients (89%) radiological measurement did not show a difference between preoperative and final fracture angulation. In five patients, a clinically silent loss of correction occurred and was observable in the three months postoperative radiological assessment. The degree of angulation then did not change in the further course. There was no statistically significant difference between the BMD in this group of patients and that of patients with identical preoperative and postoperative fracture angulations. Mean BMD in patients with and without loss of correction was 1.30 g/cm^2 in both groups; there was no statistical difference.

Pre- and postoperative neurological status

At time of admission, patients showed the following neurological status, graded in a modified Frankel scale (Tables 3 and 4) (25). In 21 patients no disturbances were found. Five patients presented with a spinal claudication due to spinal stenosis caused by the pathological fracture; in the rest no neurological deficit could be found. Nine patients had normal motor function and voluntary bowel and bladder function as a result of nerve root compression only under load. Six patients retained motor function at medium grade and/or suffered from bowel and bladder

Table 3 Modified Frankel scale (25)

Classification	Description
F1	Complete motor and sensory lesion
F2	Sensibility intact, no voluntary motor function
F3	Poor motor function, no movement
F4	Reduced motor activity (3+/5+), bowel/bladder paralysis
F5	Reduced motor activity (4+/5+), bowel/bladder dysfunction
F6	Slight motor dysfunction (4+–5+/5+), bowel/bladder function
F7	No neurological deficit

dysfunction. Four patients exhibited motor function at lowest grade and/or had bowel and bladder paralysis.

Postoperative findings are summarised in Table 4.

Following surgery no iatrogenic neurological deficit occurred. All patients presenting with spinal claudication had full neurological recovery after surgery. Nineteen (79%) of these 24 patients showed improvement in neurological function at least one Frankel subgrade or better, with seven patients becoming neurologically normal. Overall the Frankel score improved 0.65 (range 0–3) points ($p<0.05$). One patient requires a wheel chair (2%), and seven patients (15%) require crutches for longer walks.

Pain / disability / contentment

Preoperative and postoperative pain was measured using the visual analog scale (VAS). Pain (which was likely to be caused by instability) was reduced from a preoperative average of 4.56 (range 2–8) to an average postoperative of 3.82 (range 2–6) ($p=0.004$) at a mean follow-up of three years after surgery. The results are summarised in Fig. 4.

In Fig. 5 pre- and postoperative activity is shown using the Oswestry disability index (ODI). The ODI improved significantly from an average of 55.87 (range 38–77) preoperative to an average of 15.18 (range 5–40) after three years ($p<0.01$).

Table 4 Pre- and postoperative neurological evaluation. The overall improvement of 0.65 (range 0–3) points was statistically significant ($p<0.05$)

Modified Frankel scale preoperative	Modified Frankel scale postoperative
10 x F4	1 x F4 / 3 x F5 / 4 x F6 / 2 x F7
9 x F5	4 x F5 / 5 x F6
5 x F6	5 x F7
21 x F7	21 x F7

Most of the patients were content with the surgical result, which was judged “good” by 40 patients, “satisfactory” by three patients and “poor” by two patients.

Complications

In five patients (11%), the cage subsided into the end plate of an adjacent vertebra without clinical signs or symptoms. Overall the loss of correction in the postoperative follow-up was 0.92° (angle range $0-8^\circ$) and not statistically significant ($p=0.16$). Furthermore the loss of correction was not associated with clinical symptoms. The Spearman coefficient of correlation between radiologically measured loss of correction and Frankel/ODI score was $-0.11/-0.16$ and not significant ($p=0.49 / 0.29$). No further therapy was necessary. Two patients (4.4%) with wound infections required revision surgery.

Discussion

The aim of this paper was to evaluate single stage surgical procedures following corpectomy in patients suffering from pathological fractures in the lumbar spine secondary to vertebral metastases in patients with BMD $>1.20 \text{ g/cm}^2$.

Indications for surgery were pathological fractures with:

1. Neurological deficit and/or
2. Bony encroachment of the spinal canal and/or
3. Instability
4. BMD $\geq 1.20 \text{ g/cm}^2$.

A ventral decompression was chosen because of a primary ventral event. Dorsal decompression is a common therapy in occlusion of the spinal canal, but increased instability can occur in these patients [6]. Indirect dorsal procedures exerting ligamentotaxis by distraction are indicated in burst fractures, but contraindicated in meta-static fractures.

Although vertebroplasty and recently kyphoplasty [23] have been introduced in the therapy of pathological fractures, it is generally accepted that the method, at least as sole treatment, is contraindicated in patients with neurological deficit or posterior edge involvement or spinal canal stenosis [24].

Direct ventral decompression of the spinal canal can be achieved using a dorsal or ventral procedure.

Transpedicular resection of bony fragment can be done mono- or bilateral. This method is controversial because a complete decompression is not guaranteed and neural structures can be damaged [25]. Bilateral decompression can cause instability or increase existing instability [6]. A single dorsal instrumentation does not provide enough

Fig. 4 Pre- and postoperative pain rating on the visual analog scale (VAS). The patients improved 0.36 points (range 0–5) between preoperative and three months after surgery. This improvement is found to be significant ($p=0.006$). However from the third month on no significant improvement occurred ($p>0.05$)

stability and material breakage as well as loss of correction are described [15].

With a direct ventral decompression using a retroperitoneal approach decompression can be accomplished more effectively by means of corpectomy with removal of dorsally displaced vertebral body or disc fragments [7].

Defect-restoration with bone cement or a cage is an accepted method [2, 9, 10, 11, 23]; however, the instrumentation needed to achieve sufficient stability following lumbar corpectomy is controversial. Biomechanical studies revealed that the highest achievable stability is provided by dorso-ventral instrumentation [11, 15], but it remains unclear what degree of stiffness is needed to provide osseous healing. Following corpectomy and ventral instrumentation a second surgical procedure with increased physiological burden on the patient due to additional instrumentation would be necessary.

Biomechanical studies revealed that, based on a BMD $>1.20 \text{ g/cm}^2$, single ventral double rod instrumentation can achieve sufficient stability following corpectomy in the lumbar spine [20].

Clinically we found a rapid postoperative improvement of the impairment due to instability or neurological deficit. Because of immobilisation preoperative, VAS pre- and postoperative does not reveal big differences. The reason for surgery was to restore or assure stability rather than pain reduction.

Even in 11% of all patients with radiological loss of correction no significant deterioration of scores could be detected compared to patients without any radiological change over time ($p>0.05$). It can be assumed that subsidence of cage can occur as a consequence of impairment of the stability of the end plates during preparation. The BMD in patients with radiological loss

Fig. 5 Oswestry disability index (ODI) preoperative and in the follow-up. The ODI improved significantly in all time intervals between preoperative and three months, one year, two and three years after surgery ($p^* < 0.05$)

of correction showed no statistically significant difference to that of patients with identical preoperative and postoperative fracture angulations. Thus, we conclude that loss of correction does not occur as a consequence of decreased BMD.

Our previous biomechanical studies have shown that in patients with BMD $<1.20 \text{ g/cm}^2$, due to axial rotational instability, loosening of instrumentation can occur. Therefore these patients in our hospital underwent additional dorsal, transpedicular instrumentation to achieve the maximum obtainable stability with a 360° fusion. These patients however were not analysed.

In the patients in our study no resections of the vertebra L5 were performed, although we treated patients with pathological fractures of L5. Due to the iliac crest a fixation of the ventral double rod instrumentation was not possible in these patients, as an orthodromic entrance of the screws is obligatory for the fixation.

Conclusion

For pathological fractures in the lumbar spine above L5 compromising the bony canal with or without neurological deficit or pathological fracture with instability an anterior decompression and a ventral instrumentation is recommended. Generally, dorso-ventral instrumentation following corpectomy in the lumbar spine is required to achieve maximum stability, but with good bone quality ($\text{BMD} \geq 1.20 \text{ g/cm}^2$) single ventral double rod instrumentation provides sufficient stability and lowers the surgical impact on the patient and obviates the costs for an additional dorsal instrumentation.

References

1. Eble MJ, Eckert W, Wannenmacher M (1995) Value of local radiotherapy in treatment of osseous metastases, pathological fractures and spinal cord compression. *Radiologe* 35(1):47–54
2. Kostuik JP, Errico TJ, Gleason TF, Errico CC (1988) Spinal stabilization of vertebral column tumors. *Spine* 13(3):250–256
3. Buchelt M, Windhager R, Kiss H, Schneider B, Lack W, Kotz R (1996) Surgical treatment of spinal metastases. *Z Orthop Ihre Grenzgeb* 134(3):263–268
4. Dominkus M, Krepler P, Schwameis E, Kotz R (1998) Surgical therapy of spinal metastases. *Orthopade* 27(5):282–286
5. Oda I, Cunningham BW, Abumi K, Kaneda K, McAfee PC (1999) The stability of reconstruction methods after thoracolumbar total spondylectomy. An in vitro investigation. *Spine* 24(16):1634–1638
6. Quint U, Wilke HJ, Loer F, Claes LE (1998) Functional sequelae of surgical decompression of the lumbar spine—a biomechanical study in vitro. *Z Orthop Ihre Grenzgeb* 136(4):350–357
7. Siegal T, Robin G, Lubetzki-Korn I, Fuks Z (1982) Anterior decompression of the spine for metastatic epidural cord compression: a promising avenue of therapy? *Ann Neurol* 11(1):28–34. doi:10.1002/ana.410110106
8. Harrington KD (1984) Anterior cord decompression and spinal stabilization for patients with metastatic lesions of the spine. *J Neurosurg* 61(1):107–117
9. Scoville WB, Palmer AH, Samra K, Chong G (1967) The use of acrylic plastic for vertebral replacement or fixation in metastatic disease of the spine. Technical note. *J Neurosurg* 27(3):274–279
10. Harrington KD (1981) The use of methylmethacrylate for vertebral-body replacement and anterior stabilization of pathological fracture-dislocations of the spine due to metastatic malignant disease. *J Bone Joint Surg Am* 63(1):36–46
11. Knop C, Lange U, Bastian L, Blauth M (2000) Three-dimensional motion analysis with Synex. Comparative biomechanical test series with a new vertebral body replacement for the thoracolumbar spine. *Eur Spine J* 9(6):472–485
12. Kanayama M, Ng JT, Cunningham BW, Abumi K, Kaneda K, McAfee PC (1999) Biomechanical analysis of anterior versus circumferential spinal reconstruction for various anatomic stages of tumor lesions. *Spine* 24(5):445–450
13. Vahldiek MJ, Panjabi MM (1998) Stability potential of spinal instrumentations in tumor vertebral body replacement surgery. *Spine* 23(5):543–550
14. Wilke H (1996) Möglichkeiten und Grenzen der biomechanischen in vitro Testung von Wirbelsäulenimplantaten. Habilitationsschrift, Universität Ulm
15. Wilke HJ, Kemmerich V, Claes LE, Arand M (2001) Combined anteroposterior spinal fixation provides superior stabilisation to a single anterior or posterior procedure. *J Bone Joint Surg Br* 83(4):609–617
16. Kaneda K, Taneichi H, Abumi K, Hashimoto T, Satoh S, Fujiya M (1997) Anterior decompression and stabilization with the Kaneda device for thoracolumbar burst fractures associated with neurological deficits. *J Bone Joint Surg Am* 79(1):69–83
17. Zdeblick TA, Shirado O, McAfee PC, deGroot H, Warden KE (1991) Anterior spinal fixation after lumbar corpectomy. A study in dogs. *J Bone Joint Surg Am* 73(4):527–534
18. Lack W, Eyb R, Ramach W, Kotz R, Salzer M, Wagner O, Sunder-Plassmann M, Braun O (1987) Experiences with ventral stabilization in vertebral metastases in the area of the thoracic and lumbar spine. *Z Orthop Ihre Grenzgeb* 125(3):268–274
19. Knöller S, Haag M (2001) Mittelfristige Ergebnisse nach ventraler Spondylodese mit dem Doppelstabsystem “Ventre-Fix”. *Osteologie* 10(S2):88
20. Knoller SM, Meyer G, Eckhardt C, Lill CA, Schneider E, Linke B (2005) Range of motion in reconstruction situations following corpectomy in the lumbar spine: a question of bone mineral density? *Spine* 30(9):E229–E235
21. Tokuhashi Y, Matsuzaki H, Toriyama S, Kawano H, Ohsaka S (1990) Scoring system for the preoperative evaluation of metastatic spine tumor prognosis. *Spine* 15(11):1110–1113
22. Mirbaha MM (1978) Exposure of the vertebral bodies of the proximal lumbar segments. Some anatomic points. *Spine* 3(4):329–335
23. Kluba T, Giehl JP (2004) Distractable vertebral body replacement in patients with malignant vertebral destruction or osteoporotic burst fractures. *Int Orthop* 28(2):106–109. doi:10.1007/s00264-003-0518-x
24. Rollinghoff M, Zarghooni K, Schluter-Brust K, Sobottke R, Schlegel U, Eysel P, Delank KS (2010) Indications and contraindications for vertebroplasty and kyphoplasty. *Arch Orthop Trauma Surg* 130(6):765–774. doi:10.1007/s00402-010-1083-6
25. Bradford DS, McBride GG (1987) Surgical management of thoracolumbar spine fractures with incomplete neurologic deficits. *Clin Orthop Relat Res* 218:201–216