Anterior Column Reconstruction Using Titanium Ring Cages in Severe Vertebral Osteomyelitis

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Abstract

Background and Purpose: The use of instrumentation in spinal infections is still a controversial issue. The aim of the present study was to evaluate the efficiency of titanium cages in the surgical treatment of severe vertebral osteomyelitis (synonym spondylodiscitis) concerning eradication of the infection as well as biomechanical aspects.

Materials and Methods: The peri- and postoperative data of 43 consecutive patients with vertebral osteomyelitis who underwent single-stage posterior stabilization, anterior debridement including decompression, and anterior column reconstruction using modular titanium ring cages filled with autologous bone were analyzed retrospectively. In 29 cases, a clinical and radiological follow-up of on average 2.5 years (median 2.2 years) was available. To assess the course of spinal alignment, a detailed radiometric analysis was performed.

Results: The time of symptoms prior to surgery averaged 4.6 months. Preoperatively, 37% of the patients showed neurologic compromise with partial or complete recovery in 88% after surgery. In 25 patients (58%), a germ was isolated with Staphylococcus aureus being the most frequent pathogen (44%). Except for one patient with anterior revision and exchange of the cage for persistent infection, primary eradication of the infection was accomplished in all patients. At follow-up, all infections were eradicated, and all cages appeared radiographically fused. The present loss of correction in the sagittal plane amounted 1.5° at the affected segment(s) reconstructed by cage interposition and 4.4° at posterior fusion levels.

Conclusion: Single-stage posterior instrumentation and fusion combined with anterior debridement and anterior column reconstruction using modular titanium ring cages represent a safe and efficient strategy in cases of severe vertebral osteomyelitis necessitating surgery. The use of titanium cages guarantees long-term maintenance of correction without increased risk of persistent or recurrent infection.

Key Words
Vertebral osteomyelitis · Spondylodiscitis · Spinal infection · Cage · Spinal instrumentation

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Introduction

Vertebral osteomyelitis (synonym spondylodiscitis) is an infectious disease at the vertebral endplates with affection of the disc and subsequent involvement of adjacent vertebrae, surrounding soft tissues, and the spinal canal. Due to its non-specific character of symptoms and rare incidence vertebral osteomyelitis is often diagnosed with a delay of several weeks or even months [1–13]. In up to 50% of patients, neurologic deficits are present at the time of diagnosis [3].

In most patients, early stages of the disease respond well to conservative treatment including long-term antibiotic therapy, and spinal immobilization. More advanced conditions might comprise progressive osseous destructions with unstable mechanical

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deformity, neurologic impairment, extensive abscess formation, septicemia, and medically intractable pain, which are generally accepted indications of surgery.

The surgical techniques range from anterior debridement and interbody fusion [1, 2, 5, 14–17], posterior debridement with internal fixation [6] to combined single-session or sequential procedures with posterior instrumentation, anterior debridement, and anterior column reconstruction using autologous bone grafts [3, 4, 7–10, 13, 18–23]. Anterior instrumentation in the presence of infection has been reported [21, 24, 25] but still remains controversial due to the risk of bacterial adherence and biofilm formation on foreign bodies leading to persistent or recurrent infection [4, 26–29]. On the other hand, primary stability, which can be achieved by hardware placement, is essential for healing and rapid mobilization. Review of the literature revealed a small but recently increasing number of studies presenting excellent results with the use of anterior instrumentation in pyogenic vertebral osteomyelitis after radical debridement and latterly titanium cages as an alternative to structural bone grafts to rebuild the anterior column [9, 11–13, 24, 30–35].

In the authors' department, surgical treatment of severe vertebral osteomyelitis, consists in posterior instrumentation, anterior debridement, and anterior column reconstruction by interposition of titanium cages since 1998. The present study was undertaken to demonstrate our mid- and partially long-term results with this technique.

Materials and Methods

Between 1998 and 2004, 23 female and 20 male patients with vertebral osteomyelitis, ranging in age from 39 to 85 years (mean 66 years; standard deviation (SD) ± 11 years), were surgically treated in our department. All patients underwent single-stage posterior stabilization, anterior debridement with decompression, and reconstruction of the anterior column using modular titanium ring cages. Indications of surgery in these cases were failed conservative treatment with progressive osseous destruction, unstable mechanical deformity, extensive abscesses, especially epidural abscess formation, as well as imminent or present neurologic impairment.

Evaluation of Data

Collection of data comprised a mainly retrospective analysis of medical records, which were available in every case. Ten patients deceased, two of them within the first month postoperatively (pneumonia with multiorgan failure 2 weeks and asystole 4 weeks after surgery). Three patients died within the first postoperative year, five patients more than 1 year after surgery. In these cases, death was neither related to surgery nor persisting or recurrent infection. Up to now, eight patients did not meet the routine follow-up investigation 1 year postoperatively. In 29 cases, a clinical and radiological examination with a mean follow-up period of 2.5 years (median 2.2 years; range 1–5.6 years; SD ± 1.4 years) could be obtained. Neurologic function was assessed according to the Frankel score [36]. Moreover, a blood test was performed to measure the C-reactive protein (CRP) level as laboratory-chemical parameter. A radiometric analysis (see below) was possible in 28 patients.

Clinical data included: time of complaints associated with spinal infection prior to surgery, location of infection, number of affected segments, preoperative and follow-up neurologic status and CRP levels, potential source of infection, predisposing conditions, concomitant medical disorders as well as the preoperative ASA score (American Society of Anesthesiologists risk score) to describe patients' physical fitness ranging from ASA 1 (healthy patient) to ASA 5 (moribund patient who is not expected to live 24 h with or without surgery). Besides, time of surgery, blood loss, presence of epidural or paraspinal abscess formation, length of posterior instrumentation, isolated germs, time of parenteral antibiotic therapy, use of braces postoperatively, intra- and postoperative complications were evaluated.

Radiographic and Radiometric Analysis

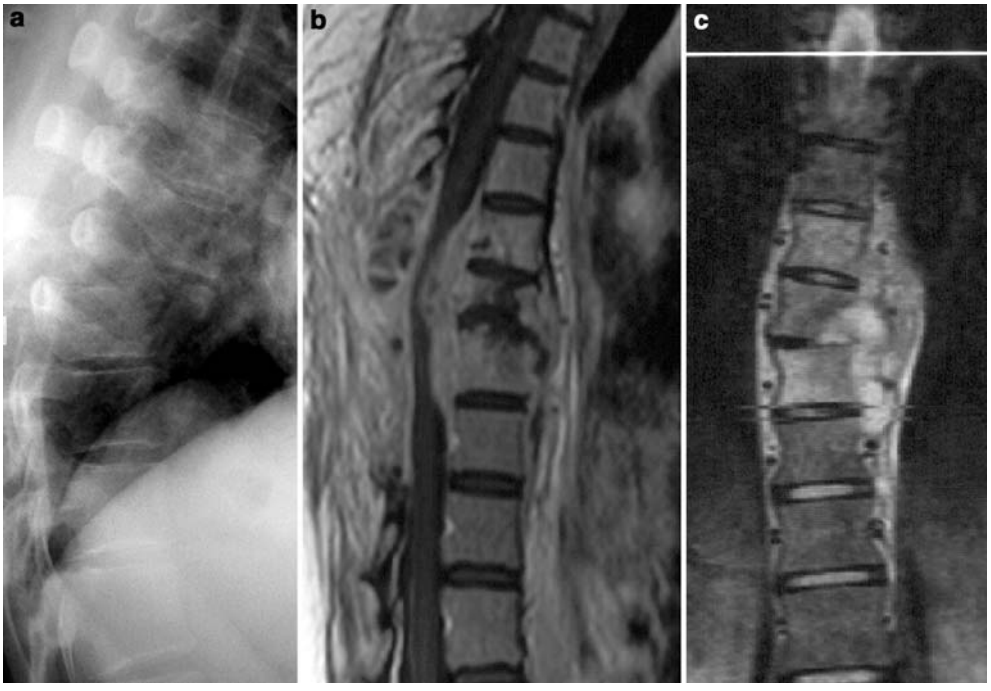
On follow-up coronal and sagittal standardized radiographs in standing posture, bony integration of the cage was assessed. This was judged as complete if a continuous bony fusion mass had formed either anterior or lateral to the cage, and graded as incomplete if there was no 'bridging' but the interfaces between bone and cage had disappeared [30]. Furthermore, any lucency around the pedicle screws, loosening, dislocation, and breakage of implants as well as subsidence of the cage were recorded.

The radiometric analysis comprised measuring of the preoperative, postoperative, and follow-up sagittal regional spinal profile at the level of infection (thoracic kyphosis T4–T12, thoracolumbar junction T10–L2, and lumbar lordosis L1–L5) and alignment at fusion levels in the coronal plane according to Cobb [37].

Additionally, kyphosis and lordosis, respectively, of the affected segment(s) and at posterior fusion levels were measured to determine the postoperative correction and the present loss of correction with regard to the pathologic kyphosis as a result of anterior column destruction.

Surgical Technique

All patients underwent single-stage surgery (Figures 1, 2, 3). Initially, a multisegmental posterior stabilization with fusion was performed mainly using transpedicular fixation techniques (Micomed Posterior Dual Rod System, micomed Ortho, Unteraegeri, Switzerland) and cancellous autologous bone from the posterior iliac crest. Patient positioning/ligamentotaxis and adequate rod bending corrected sagittal plane deformities. Length of instrumentation depended on the extent of anterior column destruction and the quality of bone. Usually, fusion involved two segments above and below the infected ones. If an epidural abscess was present, it was decompressed, irrigated, and drained from posterior. Afterwards, the patient was placed in a lateral position to allow for a thorough debridement of all infected and necrotic tissue by discectomy and partial or complete corpectomy. Most commonly, infection of the midthoracic spine was managed by a right lateral approach whereas thoracolumbar and lumbar segments were addressed from the left. In cases of extensive paraspinal abscess formation, its side was selected for the approach. Sufficient tissue specimens were sent for microbiological and histopathological analysis. The spinal canal was decompressed completely and cleared of any debris by repeated irrigation with diluted povidon iodine. Anterior column reconstruction was performed using a modular titanium ring cage (Vertebral Body Replacement, Ulrich medical GmbH, Ulm, Germany) filled with morsellized autologous bone to support its osseous integration. The cage was introduced into the defect and expanded until securely locked. Additionally, autologous bone was placed anterior and lateral to the cage and surrounded by antibiotic sponges (Sulmycin Implant, Nycomed Pharma, Unterschleissheim, Germany) to create an effective antimicrobial milieu. Finally, deep drains were inserted.



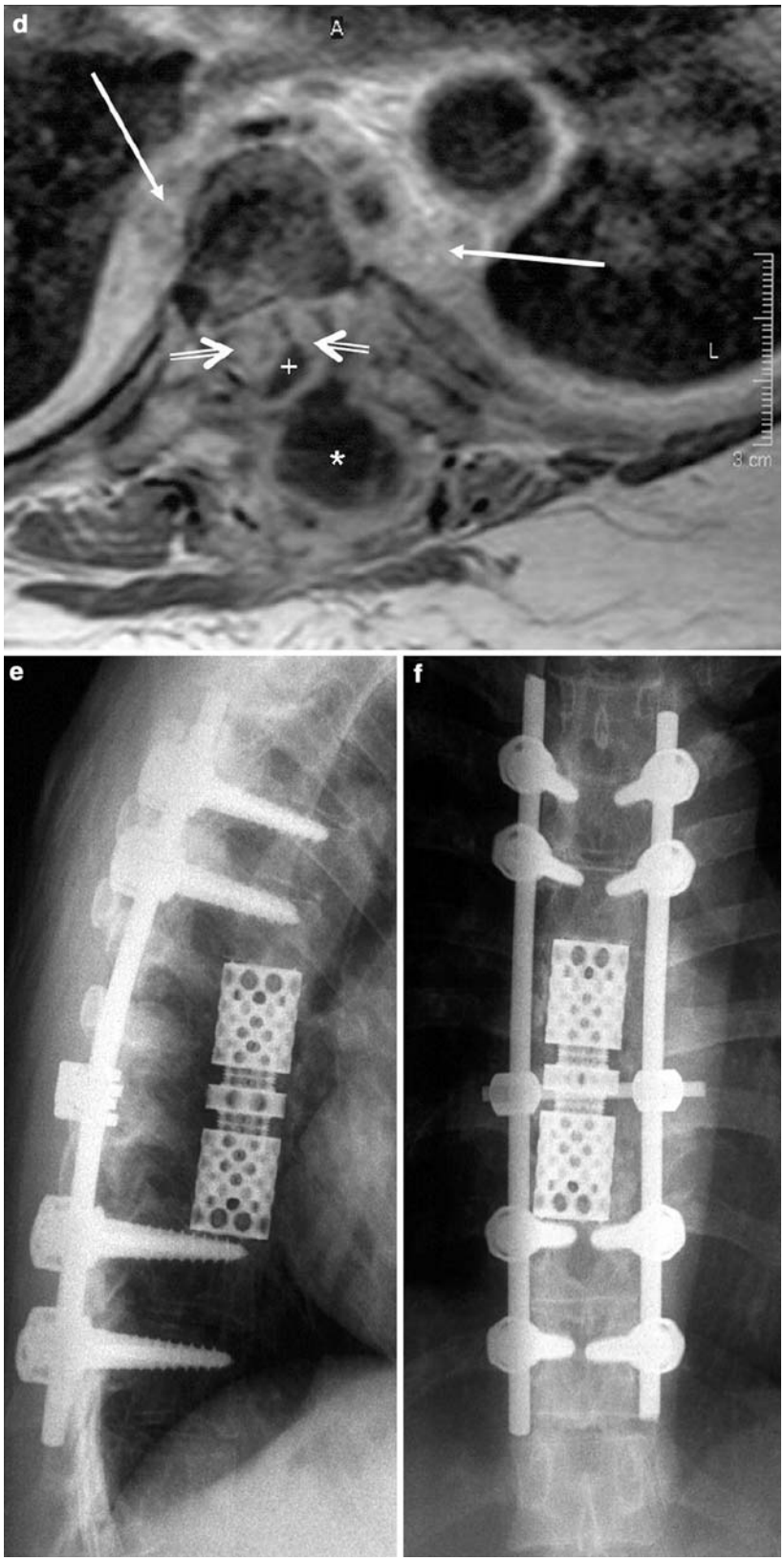
Figures 1a to 1f. Thirty nine-year-old male Indian with tuberculous vertebral osteomyelitis from T7 to T9, incomplete paraparesis (Frankel C), and high-grade instability T7/8 after urgent hemilaminectomy from T7 to T9 before transferring to our department (a). Magnet resonance imaging showed extensive osseous destructions and epidural as well as paraspinal abscess formation (b–d: long arrows = paraspinal abscess; short arrows = epidural abscess; plus = high-grade compressed spinal cord; asterisk = abscess cavity after hemilaminectomy). Prior to anterior debridement with corpectomy of vertebral bodies T7–T9 and anterior column reconstruction using an expandable titanium cage, reposition and posterior stabilization from T5 to T11 were performed (e, f: 18 months postoperatively). No neurologic impairment at follow-up.

Results

Clinical Results of All 43 Consecutive Patients

Diagnosis of vertebral osteomyelitis was often delayed. As an indirect parameter the mean duration of symptoms before surgery amounted 4.6 months (range 1 week to 2 years; SD ± 4.6 months).

Predominantly, infection affected the lower spinal regions with involvement of the lumbar spine in 16 patients (37%) and the thoracolumbar junction in 13 cases (30%; Figure 4). The mid- and upper thoracic segments were involved in 30%. Only one patient showed affection of the cervical spine. In the majority of



Figures 1. Continued

patients (67%), vertebral osteomyelitis was limited to one segment (range 1–4); two segments were infected in 11 patients (26%; Figure 5).

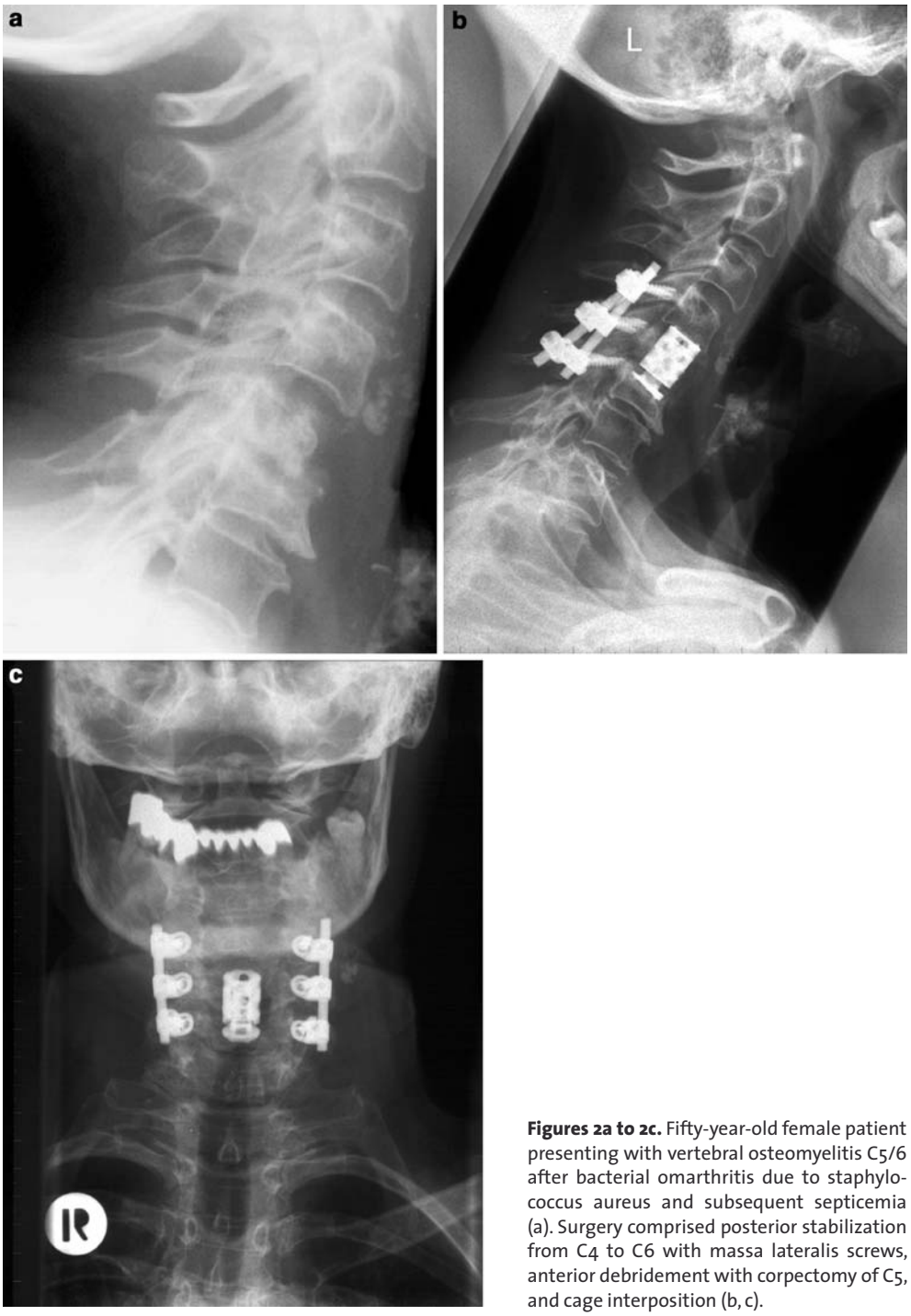
Preoperative neurologic impairment was present in 16 patients (37%), ranging from Frankel B to D (Figure 6). Postoperatively and at latest follow-up, respectively, neurologic status improved in 14 patients (88%): Frankel B to C n = 1, B to D n = 2, B to E n = 3, C to E n = 2, and D to E n = 6. In one case, neurologic compromise remained Frankel D. One patient with Frankel B preoperatively could not be assessed in the course. In three patients (7%), neurology deteriorated from Frankel E to D, which was related to surgery in two cases (see complications).

Preoperative magnet resonance imaging showed epidural abscess formation in seven patients (16%) and paraspinal abscesses in 14 cases (33%).

CRP level averaged 11.1 mg/dl (range 0.7–55.1 mg/dl; SD ± 10.9 mg/dl; norm < 0.5 mg/dl) immediately before surgery. In 23 of the 29 patients (79%) with a follow-up of more than 1 year, CRP was slightly elevated being 1.8 mg/dl on average, ranging from 0.7 to 4.3 mg/dl. In these cases, concomitant medical disorders such as rheumatoid arthritis, lupus erythematosus, monoclonal gammopathy, renal insufficiency as well as diabetes mellitus existed.

Preoperative ASA-score to demonstrate patients' health status before surgery was three on average: ASA 4 n = 7 (16%), ASA 3 n = 32 (74%), ASA 2 n = 3 (7%), and ASA 1 n = 1 (2%). Predisposing conditions and concomitant medical disorders of all 43 patients are listed in Table 1. A potential source of vertebral osteomyelitis was recorded in 26 cases (60%).

Two surgeons performed surgery (surgeon A n = 30; surgeon B n = 13). Total time of surgery including patient positioning and if necessary changeo-



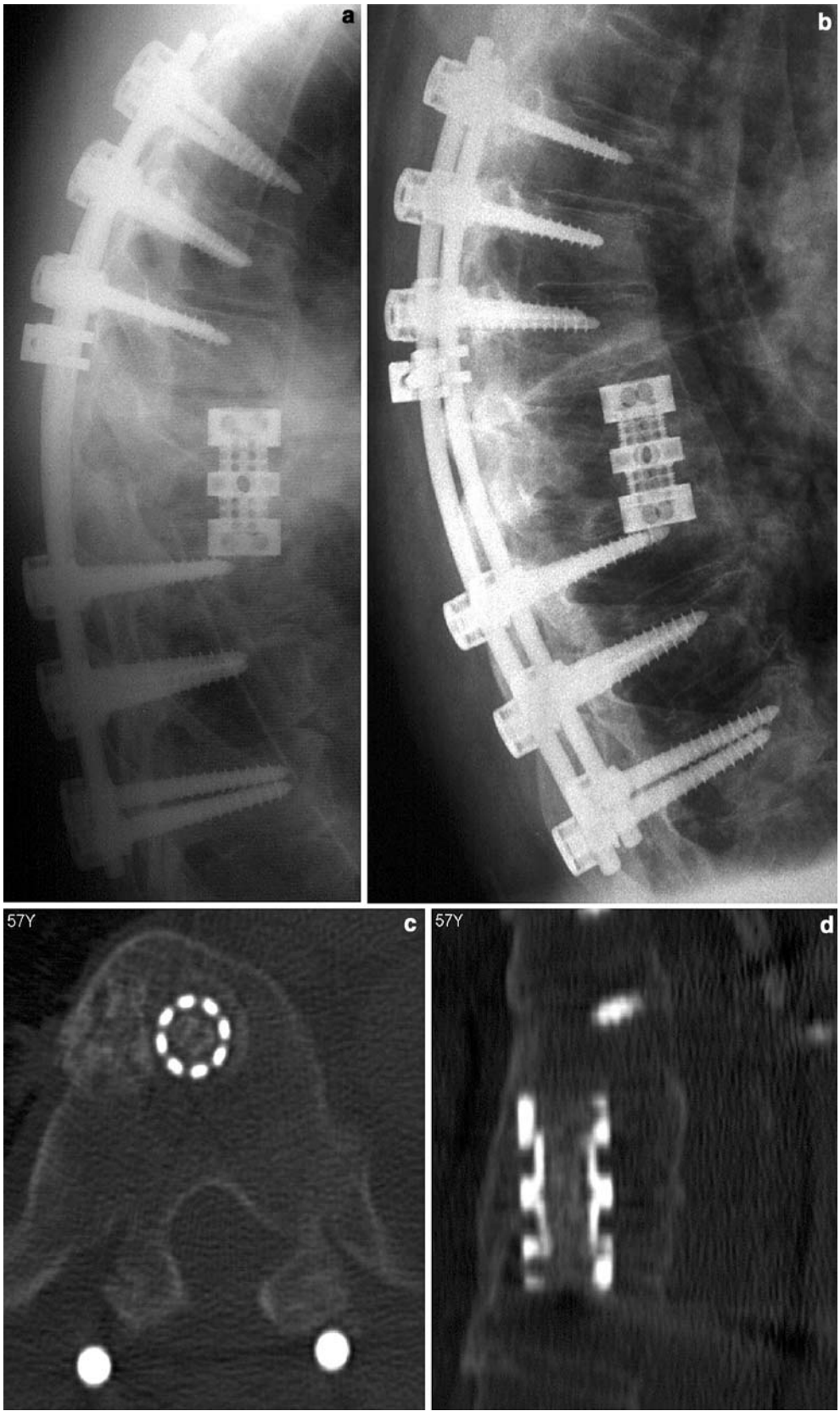
Figures 2a to 2c. Fifty-year-old female patient presenting with vertebral osteomyelitis C5/6 after bacterial omarthritis due to staphylococcus aureus and subsequent septicemia (a). Surgery comprised posterior stabilization from C4 to C6 with massa lateralis screws, anterior debridement with corpectomy of C5, and cage interposition (b, c).

ver to single-lung ventilation averaged 311 min (range 152–540 min; SD ± 73 min). Mean intraoperative blood loss amounted 1,558 ml (range 380–9,600 ml, see complications; SD ± 1,503 ml). Average length of posterior instrumentation was four segments (1–8 segments).

Isolation of organisms based on specimens taken intraoperatively was successful in 25 patients (58%) with Staphylococcus aureus being the most common pathogen identified (44%). Mycobacterium tuberculosis was found in four patients (16%). A detailed overview is given in Table 2.

Postoperative Management

After intensive care, a prompt mobilization of the patients was aspired to avoid the typical complications associated with prolonged bed rest such as pneumonia and deep vein thrombosis. Mobilization supported by physiotherapists started on average 12 days after surgery (range 1–26 days; SD ± 7 days). In 16 patients (37%), a brace was applied for mean 6 months because of osteoporotic bone conditions. Postoperatively, parenteral antibiotics were applied until significant decrease in CRP, 23 days on average, and thereafter administered orally for up to 3 months. Initial broad-spectrum antibiotic therapy consisted in a combination of clindamycin and ceftriaxone or ceftazidime and was modified in dependence on the sensitivity of the isolated germs. In the four cases with tuberculous vertebral osteomyelitis, a combined treatment including rifampicin, isoniazide, ethambutol, and pyrazinamide for 4 months and rifampicin together with isoniazide for another 4 months was conducted.



Figures 3a to 3d. Fifty two-year-old male patient with vertebral osteomyelitis T7/8 due to Staphylococcus aureus and extensive epidural abscess formation with paraparesis (Frankel B) who had undergone laminectomy from T5 to T9 before surgical intervention in our department. He was treated with posterior stabilization from T4 to T11, anterior debridement with corpectomy T7 and T8 as well as anterior column reconstruction by cage interposition (a). Radiographs and computed tomography scans, 62 months postoperatively, show a complete bony integration of the cage with a continuous anterior and lateral bridging and bone mass formation in the cage itself (b–d). Complete recovery of neurologic function at follow-up.

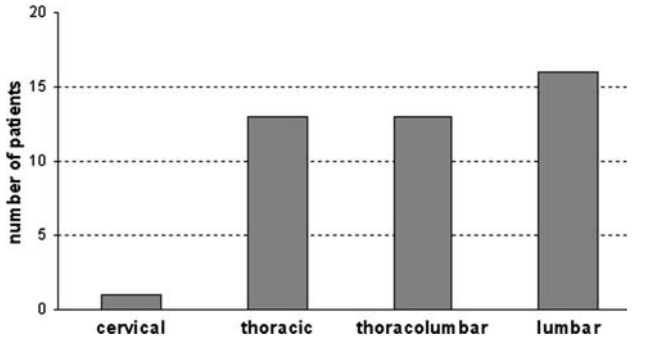


Figure 4. Localization of infections in all 43 patients.

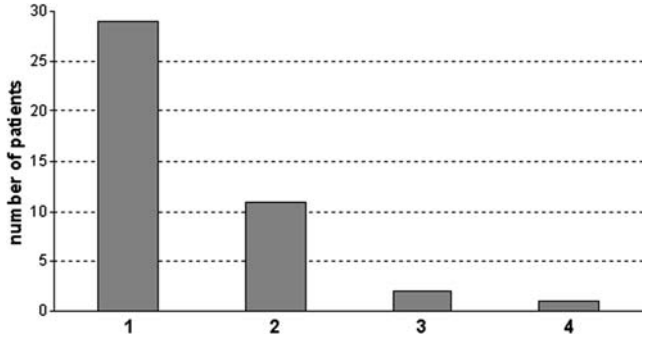


Figure 5. Number of affected segments in all 43 patients.

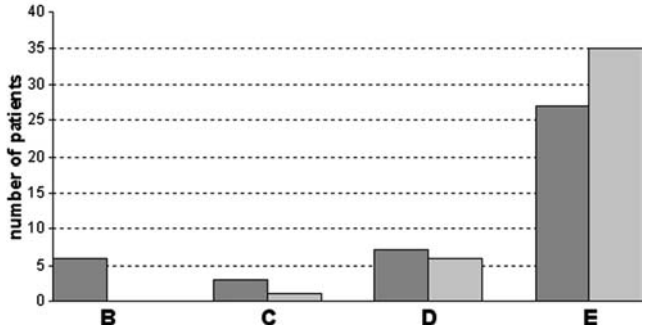


Figure 6. Neurologic function preoperatively (dark gray), after surgery and at follow-up, respectively, (light gray) in each case of all 43 patients according to the Frankel score (A–E). In one patient with Frankel B preoperatively, assessment of the postoperative neurologic status was not possible.

Surgery and Infection Related Complications

In one patient, intraoperative injury of the common iliac vein accounted to a high total blood loss of 9,600 ml during surgery.

Concerning early postoperative complications (< 4 weeks) one cage had to be exchanged because of posterolateral malposition with L5 radix compression. Despite soon revision a mild one-sided weakness of the foot extensor muscles remained (motor strength grade 4 of 5). In another case, anterior decompression and replacement of the cage had to be performed within the early postoperative course due to newly arising one-sided paresis of the quadriceps muscles on the basis of nerve root compression by hematoma. Also in this

Table 1. List of predisposing conditions and concomitant medical disorders of all 43 patients.

	n
Potential focus/infection preop. including among others	26
Discectomy in the affected segment(s) (< 12 months preop.)	6
Spinal infiltration (< 12 months preop.)	2
Urinary tract infection	5
Pneumonia	4
Prior surgery due to spinal infection in the affected segment(s)	7
Renal insufficiency	18
Diabetes mellitus: IDDM, NIDDM	10, 4
Malignant tumor	5
Rheumatoid arthritis	3
Alcohol abuse	3
Lupus erythematosus	1
Monoclonal gammopathy	1
Myelodepression	1
Chronic pancreatitis	1
Arterial hypertension	28
Coronary heart disease	13
Cardiac arrhythmia	10
Cardiac insufficiency	8
Chronic obstructive pulmonary disease	6

Table 2. List of isolated germs in all 43 patients without evidence of pathogen in 18 cases.

	n
Total	43
No evidence of pathogen	18
Isolation of two germs	1
Gram-positive bacteria	
Staphylococcus aureus	11
Enterococcus faecalis	3
Anaerobe[a]	1
Gram-negative bacteria	
Pseudomonas aeruginosa	1
Escherichia coli	1
Serratia marcescens	1
Proteus mirabilis	1
Mycobacteria	
Mycobacterium tuberculosis	4
Mycobacterium fortuitum	1
Candida albicans	1
Aspergillus fumigatus	1

[a]Peptostreptococcus

patient, a mild motor deficit persisted (muscle grade 4 of 5). One patient with fusion from T1 to T8 and supralaminar hooks on top degraded from Frankel B before to Frankel A after surgery. Instant intervention exchanging the supralaminar hooks for transverse hooks led to complete neurologic recovery (Frankel E). Six patients needed superficial debridement and secondary suture of the posterior wound without removal of implants because of delayed wound healing, on average 3 weeks after surgery. In one case, this operation had to be performed twice.

Regarding infection related complications a 57-year-old male patient suffering from alcohol abuse and diabetes mellitus who was treated with posterior instrumentation from L2 to L5, decompression by laminectomy, anterior debridement, corpectomy of vertebra L4, and cage interposition due to vertebral osteomyelitis with extensive epidural and paraspinal abscess formation required repeated revision (four times) for persistent infection: the first revision, 2 weeks postoperatively, consisted in posterior debridement and wound closure. The second operation, 1 week later, encountering also psoas abscesses, comprised dorsoventral revision with complete hardware removal, reinstrumentation from L2 to S1, and again interposition of a titanium cage. After 2 and 4 weeks, respectively, posterior revision leaving the implants in place was performed. Eight months later, posterior reinstrumentation with fusion was required because of rod breakage between L5 and S1 as a result of pseudarthrosis. At the latest follow-up 22 months after the initial surgery, the patient had improved significantly being nearly pain-free without any neurologic compromise and presenting a sound implant situation.

Radiological (n = 29) and Radiometric Results (n = 28)

At latest follow-up, a continuous bony bridging indicating a complete integration of the cage was found in 15 cases whereas the integration was judged as incomplete in 14 cases. In all patients, posterior fusion appeared radiographically whole without any evidence of pseudarthrosis.

In nine cases, lucencies around a total of 25 pedicle screws, mostly the lower ones, including screw dislocation in two patients were recorded: in the first case with instrumentation from T4 to T9 and high-grade osteoporosis, all pedicle screws had penetrated the upper vertebral endplates, and the cage had subsided into the upper vertebra to a minor degree. After the first postoperative year (6/04), there was no further dislocation and no indication of back pain at follow-up (1/06). In the second case with fusion from L1 to L4, both pedicle screws in L4, of which the upper third had been resected, and the cage showed migration down to the lower endplate slightly penetrating it. This occurred within the first 6 months after surgery and led to loss of correction (see below). Thirty months postoperatively no progress of implant migration was found while back pain was tolerable. In three more patients, there was also minor subsidence of the cage into the upper vertebra, of which the lower end plate had been resected in one case. No major dislocation of cages or breakage of implants was observed.

Mean segmental kyphosis (of the affected segment(s)) could be corrected from 9.9° (range -26° – 64°) by 11.5° on average to 1.4° (range -33° – 40°) postoperatively and lost 1.5° (range -3° – 13°) during follow-up. The maximum loss of correction of 13° was observed in the patient with migration of the pedicle screws at L4 and subsidence of the cage. The preoperative angle of kyphosis at posterior fusion levels averaged 3.1° (range -51° – 74°); it measured –5.1° (range -54° – 58°) after surgery and lost 4.4° in the postoperative course, leaving a final correction of 0.7° (range -52° – 58°). The complete radiometric data concerning the sagittal profile is given in Table 3.

Spinal deformity in the coronal plane was only minimal, measuring 5.9° (range 0°–18°) on average before surgery, 2.5° (range 0°–8°) postoperatively, and 2.6° (range 0°–8°) at follow-up.

Discussion

Whereas conservative treatment comprising long-term antibiotic therapy and spinal immobilization is appropriate for early stages of vertebral osteomyelitis, surgery is clearly indicated when encountering marked osseous destructions, neurologic deficits, or extensive abscess formation [1–3, 5–13, 15, 17–23, 25, 30–35].

Since Hodgson & Stock [14] reported in 1960 on the anterior approach to permit a radical debridement in tuberculous spinal infections, this procedure has been established as essential element of surgery for vertebral osteomyelitis. The surgical techniques reported in the literature range from anterior debridement and interbody fusion [1, 2, 5, 15–17], debridement from posterior with internal fixation [6] to combined single-stage or two-stage operations including posterior instrumentation, anterior debridement, and anterior column

Table 3. Radiometric results of 28 patients concerning the sagittal spinal profile in the course. Minus means lordotic angles; SD: standard deviation.

	Preoperative	Postoperative	Follow-up	Loss of correction
Mean angle of segmental kyphosis/lordosis	9.9°	–1.4°	0.1°	1.5°
Min– max	–26° to 64°	–33° to 40°	–32° to 42°	–3° to 13°
SD	± 20.3°	± 17.7°	± 18.7°	± 3.4°
Mean angle of kyphosis/lordosis at fusion levels	3.1°	–5.1°	–0.7°	4.4°
Min– max	–51° to 74°	–54° to 58°	–52° to 58°	–5° to 16°
SD	± 32.4°	± 29.3°	± 30.2°	± 4.2°
Mean angle at T4–T12	48.3°	36.1°	41.1°	n = 8
Mean angle at T10–L2	13.8°	12°	15.5°	n = 4
Mean angle at L1–L5	–25.4°	–32.7°	–28.1°	n = 16

restoration by interposition of bone grafts [3, 4, 7–10, 13, 18–23]. To reconstruct the frequently present anterior loss of substance, autologous strut grafts have traditionally been advocated as well as additional extrafocal posterior instrumentation to recover spinal alignment, prevent graft complications, and to allow for rapid mobilization [2, 3, 5, 7, 8, 10, 13, 16–22].

Extensive osseous destructions, however, require a suitable amount of autologous bone, which is not available in every patient. Moreover, harvesting of huge strut grafts is associated with a significantly increased risk of donor site morbidity [38, 39]. Another problem consists in the small weight bearing surface and structural weakness of rib or fibula grafts. These tend to subsidence, slippage, or fracture, particularly if the graft bridged more than two disc spaces, and often failed to incorporate [14–16]. Even in cases with added posterior instrumentation, Sundararaj et al. [32] reported on graft related problems in up to 6.5%.

Thus, there is need of a durable, in any case suitable, and anytime available anterior column support such as a metal cage, which has been proven to be highly efficient in spinal destructions caused by tumor or fracture. However, anterior instrumentation in pyogenic vertebral osteomyelitis is still a controversial issue due to the understandable concerns regarding persistence or recurrence of infection [4, 26–29].

Nevertheless, a small but increasing number of authors presented excellent results using anterior instrumentation at debrided segments in pyogenic vertebral osteomyelitis and latterly titanium ring cages for anterior column reconstruction without increased risk of persistent or recurrent infection [9, 11–13, 24, 30, 31, 33–35]. In 1996, Eysel et al. [24] reported as one of the first authors on the successful use of anterior dual rod instrumentation in 23 patients with vertebral osteomyelitis after radical debridement. At follow-up, all infections were eradicated, and the mean loss of correction at instrumentation amounted 2.7° [24].

In the present study, modular titanium ring cages were used to rebuild anterior column defects in combination with initial posterior instrumentation to restore spinal alignment. After 2.5 years mean follow-up, the infection was eradicated in all investigated 29 patients. However, in one patient, eradication of the infection was accomplished by repeated revision exchanging the cage one time. The same patient experienced a pseudarthrosis with rod breakage, which could be managed by reinstrumentation and fusion. Furthermore, all cages appeared radiographically fused, and no dislocation or breakage of implants was recorded at follow-up. The present loss of correction in the sagittal plane amounted 1.5° at the affected segment(s) and 4.4° at posterior fusion levels.

Beside earlier published data of our department concerning the use of cages in spinal infections [13, 30], review of the literature revealed only a few and recently published studies which all described a profitable use of titanium ring cages in addition with posterior instrumentation in the surgical treatment of pyogenic vertebral osteomyelitis [9, 11, 33–35]. An increased risk of persistence or early recurrence of infection using titanium cages compared to autologous bone grafts could not be found. Regarding the loss of correction over time Ulmar et al. [35] reported a value of 1.1°, which was similar to our findings at the affected segments rebuilt by cage interposition. For strut grafts combined with posterior fixation the loss of correction amounted on average 5°, as given in the literature [13, 23, 32].

In the present study, subsidence of the cage associated with a segmental loss of correction of up to 13°

was recorded in two patients of whom the endplates had been resected. Thus, the surgeon should avoid placing the cage into the cancellous vertebral bone. We recommend either to place the cage onto the scraped endplates or directly onto previously inserted pedicle screws to prevent any subsidence. Moreover, cages should not be used as stand-alone devices but combined with initial posterior fixation. This enables restoration of the sagittal alignment, minimizes the risk of cage dislocation, and creates the necessary stability to promote bony integration of the cage.

In addition to a radical debridement and stability as basic requirements of healing, the excellent vertebral perfusion and soft tissue coverage (including immunocompetent structures such as the peritoneum and the pleura) [30, 40] as well as appropriate local and systemic antibiotic treatment contribute to the successful use of titanium cages in the presence of infection. Moreover, the material of the cage itself may be an important factor. Due to its porous nature titanium may facilitate soft tissue attachment delivering sufficient concentrations of antimicrobial substances [34]. Compared to stainless steel titanium implants are supposed to have a lower bacterial adherence because of their less electromechanically active surface [28].

With regard to single-stage or two-stage surgery the authors advocate a single-stage procedure. This allows for early mobilization and consequently shorter hospital stays and less costs. A second intervention represents an additional risk of anesthesia and surgery in these elderly and sick patients. This recommendation correlates well with the excellent results of other studies on single-stage maneuvers [19].

The authors are aware that the extent of fusion and bony integration of cages can better be evaluated by computed tomography compared to plain radiographs (Figure 3). Therefore, further studies including standardized computed tomography are desirable to optimize visualization of bone mass formation, in particular around and in the cage.

Conclusion

To our experience indications of surgery in cases of vertebral osteomyelitis are failed conservative treatment with progressive osseous destructions resulting in unstable deformity, neurologic impairment, extensive abscess formation, and septicemia. Concerning biomechanical aspects the use of titanium cages in combination with posterior instrumentation provides primary stability with immediate strong anterior column support and therefore early mobilization, avoiding complications, which are related to long-term bed rest. The use of titanium implants at debrided spinal structures bore no increased risk of persistent or recurrent infection.

References

1. Emery SE, Chan DP, Woodward HR. Treatment of hematogenous pyogenic vertebral osteomyelitis with anterior debridement and primary bone grafting. Spine 1989;14:284–91.
2. Krodel A, Sturz H. Differentiated surgical and conservative treatment of spondylitis and spondylodiscitis. Z Orthop Ihre Grenzgeb 1989;127:587–96.
3. Stoltze D, Bohm H, Harms J. Operative Behandlung bei bakterieller Spondylitis undSpondylodiszitis. Fortschritte in der Unfallchirurgie - 10. Steglitzer Unfalltagung. Berlin Heidelberg New York: Springer, 1992.
4. Oga M, Arizono T, Takasita M, et al. Evaluation of the risk of instrumentation as a foreign body in spinal tuberculosis. Clinical and biologic study. Spine 1993;18:1890–4.
5. Fang D, Cheung KM, Dos_Remedios ID, et al. Pyogenic vertebral osteomyelitis: treatment by anterior spinal debridement and fusion. J Spinal Disord 1994;7:173–80.
6. Rath SA, Neff U, Schneider O, et al. Neurosurgical management of thoracic and lumbar vertebral osteomyelitis and discitis in adults: a review of 43 consecutive surgically treated patients. Neurosurgery 1996;38:926–33.
7. Arnold PM, Baek PN, Bernardi RJ, et al. Surgical management of nontuberculous thoracic and lumbar vertebral osteomyelitis: report of 33 cases. Surg Neurol 1997;47:551–61.
8. Przybylski GJ, Sharan AD. Single-stage autogenous bone grafting and internal fixation in the surgical management of pyogenic discitis and vertebral osteomyelitis. J Neurosurg 2001;94:1–7.
9. Hee HT, Majd ME, Holt RT, et al. Better treatment of vertebral osteomyelitis using posterior stabilization and titanium mesh cages. J Spinal Disord Tech 2002;15:149-56; discussion 56.
10. Dimar JR, Carreon LY, Glassman SD, et al. Treatment of pyogenic vertebral osteomyelitis with anterior debridement and fusion followed by delayed posterior spinal fusion. Spine 2004;29:326–32; discussion 32.
11. Lee MC, Wang MY, Fessler RG, et al. Instrumentation in patients with spinal infection. Neurosurg Focus 2004;17:E7.
12. Linhardt O, Krüger A, Krödel A. First results of anterior versus posterior instrumentation-fusion in the treatment of spondylodiscitis. Z Orthop 2004;142:73–8.
13. Lerner T, Hackenberg L, Rosler S, et al. Surgical therapy of unspecific and specific Spondylodiscitis. Z Orthop Ihre Grenzgeb 2005;143:204–12.
14. Hodgson A, Stock F. Anterior spine fusion for the treatment of tuberculosis of the spine. J Bone Joint Surg Am 1960;42-A:295–310.
15. Kemp HB, Jackson JW, Jeremiah JD, et al. Anterior fusion of the spine for infective lesions in adults. J Bone Joint Surg Br 1973;55:715–34.
16. Rajasekaran S, Soundarapandian S. Progression of kyphosis in tuberculosis of the spine treated by anterior arthrodesis. J Bone Joint Surg Am 1989;71:1314–23.
17. Matsui H, Hirano N, Sakaguchi Y. Vertebral osteomyelitis: an analysis of 38 surgically treated cases. Eur Spine J 1998;7:50–4.
18. Moon MS, Woo YK, Lee KS, et al. Posterior instrumentation and anterior interbody fusion for tuberculous kyphosis of dorsal and lumbar spines. Spine 1995;20:1910–6.

19. Safran O, Rand N, Kaplan L, et al. Sequential or simultaneous, same-day anterior decompression and posterior stabilization in the management of vertebral osteomyelitis of the lumbar spine. Spine 1998;23:1885–90.
20. Krodel A, Kruger A, Lohscheidt K, et al. Anterior debridement, fusion, and extrafocal stabilization in the treatment of osteomyelitis of the spine. J Spinal Disord 1999;12:17–26.
21. Faraj AA, Webb JK. Spinal instrumentation for primary pyogenic infection report of 31 patients. Acta Orthop Belg 2000;66:242–7.
22. Hadjipavlou AG, Mader JT, Necessary JT, et al. Hematogenous pyogenic spinal infections and their surgical management. Spine 2000;25:1668–79.
23. Klockner C, Valencia R. Sagittal alignment after anterior debridement and fusion with or without additional posterior instrumentation in the treatment of pyogenic and tuberculous spondylodiscitis. Spine 2003;28:1036–42.
24. Eysel P, Hopf C, Vogel I, et al. Primary stable anterior instrumentation or dorsoventral spondylodesis in spondylodiscitis? Results of a comparative study. Eur Spine J 1997;6:152–7.
25. Yilmaz C, Selek HY, Gurkan I, et al. Anterior instrumentation for the treatment of spinal tuberculosis. J Bone Joint Surg Am 1999;81:1261–7.
26. Gristina AG, Naylor PT, Myrvik QN. Mechanisms of musculoskeletal sepsis. Orthop Clin North Am 1991;22:363–71.
27. Chang CC, Merritt K. Infection at the site of implanted materials with and without preadgered bacteria. J Orthop Res 1994; 12:526–31.
28. Sheehan E, McKenna J, Mulhall KJ, et al. Adhesion of Staphylococcus to orthopaedic metals, an in vivo study. J Orthop Res 2004;22:39–43.
29. Ha KY, Chung YG, Ryoo SJ. Adherence and biofilm formation of Staphylococcus epidermidis and Mycobacterium tuberculosis on various spinal implants. Spine 2005;30:38–43.
30. Liljenqvist U, Lerner T, Bullmann V, et al. Titanium cages in the surgical treatment of severe vertebral osteomyelitis. Eur Spine J 2003;12:606–12.
31. Schinkel C, Gottwald M, Andress HJ. Surgical treatment of spondylodiscitis. Surg Infect (Larchmt) 2003;4:387–91.
32. Sundararaj GD, Behera S, Ravi V, et al. Role of posterior stabilisation in the management of tuberculosis of the dorsal and lumbar spine. J Bone Joint Surg Br 2003;85:100–6.
33. Fayazi AH, Ludwig SC, Dabbah M, et al. Preliminary results of staged anterior debridement and reconstruction using titanium mesh cages in the treatment of thoracolumbar vertebral osteomyelitis. Spine J 2004;4:388–95.
34. Hsieh PC, Wienecke RJ, O'Shaughnessy BA, et al. Surgical strategies for vertebral osteomyelitis and epidural abscess. Neurosurg Focus 2004;17:E4.
35. Ulmar B, Richter M, Kelsch G, et al. Distractible vertebral body replacement for the thoracic and lumbar spine. Acta Orthop Belg 2005;71:467–71.
36. Frankel HL, Hancock DO, Hyslop G, et al. The value of postural reduction in the initial management of closed injuries of the spine with paraplegia and tetraplegia. I. Paraplegia 1969;7:179–92.
37. Cobb J. Outline for the study of scoliosis. In: Instructional course letters. Ann Arbor: American Academy of Orthopaedic Surgeons, 1948:5.
38. Arrington ED, Smith WJ, Chambers HG, et al. Complications of iliac crest bone graft harvesting. Clinical Orthop Relat Res 1996;(329):300–9.
39. Bodde EW, de Visser E, Duysens JE, et al. Donor-site morbidity after free vascularized autogenous fibular tranfer: subjective and quantitative analyses. Plast Reconstr Surg 2003;111:2237–42.
40. Lehovsky J. Pyogenic vertebral osteomyelitis/disc infection. Baillieres Best Pract Res Clin Rheumatol 1999;13:59–75.

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