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Single- and Multilevel Corpectomy and Vertebral body replacement for treatment of spinal infections. A retrospective single-center study of 100 cases

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ABSTRACT

Background: The optimal operative approach for treating spinal infections remains a subject of debate. Corpectomy and Vertebral Body Replacement (VBR) have emerged as common modalities, yet data on their feasibility and complication profiles are limited.

Methods: This retrospective single-center study examined 100 consecutive cases (2015–2022) that underwent VBR for spinal infection treatment. A comparison between Single-level-VBR and Multi-level-VBR was performed, evaluating patient profiles, revision rates, and outcomes.

Results: Among 360 cases treated for spinal infections, 100 underwent VBR, located in all spinal regions. Average clinical and radiologic follow-up spanned 1.5 years. Single-level-VBR was performed in 60 cases, Two-level-VBR in 37, Three-level-VBR in 2, and Four-level-VBR in one case.

Mean overall sagittal correction reached 10° (range 0–54°), varying by region. Revision surgery was required in 31 cases. Aseptic mechanical complications (8% pedicle screw loosening, 3% cage subsidence, 6% aseptic adjacent disc disease) were prominent reasons for revision. Longer posterior constructs (>4 levels) had significantly higher revision rates ($p < 0.01$). General complications (wound healing, hematoma) followed, along with infection relapse and adjacent disc infection (9%) and neurologic impairment (1%).

Multilevel-VBR (≥2 levels) displayed no elevated cage subsidence rate compared to Single-level-VBR. Three deaths occurred (43–86 days post-op), all in the Multi-level-VBR group.

Conclusion: This study, reporting the largest number of VBR cases for spinal infection treatment, affirmed VBR's effectiveness in sagittal imbalance correction. The overall survival was high, while reinfection rates matched other surgical studies. Anterior procedures have minimal implant related risks, but extended dorsal instrumentation elevates revision surgery likelihood.

1. Introduction

Spinal infection is a very heterogeneous disease in regard of its extent and localization, as well as clinical findings and patients' characteristics. The infection may affect each component of the vertebral column and the paravertebral tissue and therefore present with varying manifestations and degree of severity (Tsantes et al., 2020; Pingel, 2021). The infection can be specific (Tuberculosis, Brucellosis or fungal infections) or unspecific with bacterial infections, which is more common nowadays in Europe (Khanna and Sabharwal, 2019; Thavarajasingam et al., 2023). While in primary spinal infections the pathogen is transmitted hematogenous, secondary infections are conducted locally by medical interventions or penetrating injuries.

The incidence of spinal infections is growing and still we recognize high morbidity and mortality rates up to 20% related to the disease (Thavarajasingam et al., 2023; Heuer et al., 2022; Kehrer et al., 2015). This might be explained by an aging society and growing incidence of multimorbid patients.

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Although the evidence for adequate treatment is still very limited, many treatment options are available nowadays. For many practitioners conservative treatment is still the first line of treatment (Rutges et al., 2016; Lener et al., 2018). Indications for surgery are (impending/prolonging) neurological deficits, septical course, instability, de novo deformity or conservative treatment failure (Herren et al., 2017).

Posterior and anterior approaches are suitable, depending on the location, the radiological signs of instability and extent of destruction or deformity (Tani et al., 2022; Akbar et al., 2011). While moderate infections with surgical indications can mostly be treated by microinvasive procedures like percutaneous stabilization, microsurgical decompression or even endoscopic approaches, severe destruction with instability, loss of sagittal balance or even deformity need abscess drainage, debridement of the disc and bone, anterior release and/or reconstruction to rebuild the spinal alignment (Ackshota et al., 2019; Abreu et al., 2022).

In these cases, vertebral body replacement is sufficient as proper treatment because it brings a wide exposure of the anterior column with the ability to address multiple levels, to release kyphotic deformity, to restabilize and to achieve fusion. For the cervical subaxial spine the anterior approach is the most suitable. Interbody fusion is the more common way, but for similar reasons as for the thoracolumbar spine a corpectomy might be necessary (Burkhardt et al., 2019) (Walker et al., 2018; Schwendner et al., 2023; Wipplinger et al., 2022).

The number of recorded procedures in the literature is small; hence we conducted this retrospective monocentric analysis to get a better understanding of risk profile and achievement of surgical goals for this particular pathology.

2. Methods

A retrospective analysis was conducted at a single center, covering the period from 2015 to 2022. Cases were screened using the ICD-10 Code M 46, and patients who had received primary treatment were included while duplicates and those not treated surgically were excluded. The study focused on patients who underwent surgical intervention involving mono- or multilevel corpectomy and vertebral body replacement (VBR).

Demographic information, infection location, microbiological and laboratory results were collected for the patients. Images such as MRI, CT, and X-ray were evaluated to identify radiological features, including the site of infection, abscess, fractures, and deformities.

De novo deformity was defined as a de novo delta-kyphosis (delta: measured angle - physiological angle) exceeding 20° or de novo scoliosis exceeding 10°.

The Cobb angle (CA) was measured preoperatively using CT images and postoperatively using standing X-rays. The number and levels of segments included in the Cobb angle depended on the number and levels of the treated segments (e.g., one-level VBR = bisegmental CA, two-level VBR = trisegmental CA). See image 1 for visual example.

The chosen outcome measures included sagittal correction (preoperative - postoperative CA), intra- and postoperative complications, and mortality.

Multilevel-VBR (≥2-level) were analyzed separately and compared to single-level-VBR using chi square test.

Aseptic mechanical complications were defined as aseptic screw loosening, posterior implant failure or adjacent disc disease. They were analyzed in relation to the length of the posterior construct.

3. Surgical procedures/medical management

Spine surgeons specializing in neurosurgery or orthopedics performed the approach, debridement of disc and bone, and instrumentation in a single spine department.

Thoracolumbar infections were initially stabilized with a pediclescrew-rod system via a percutaneous or midline approach. In a

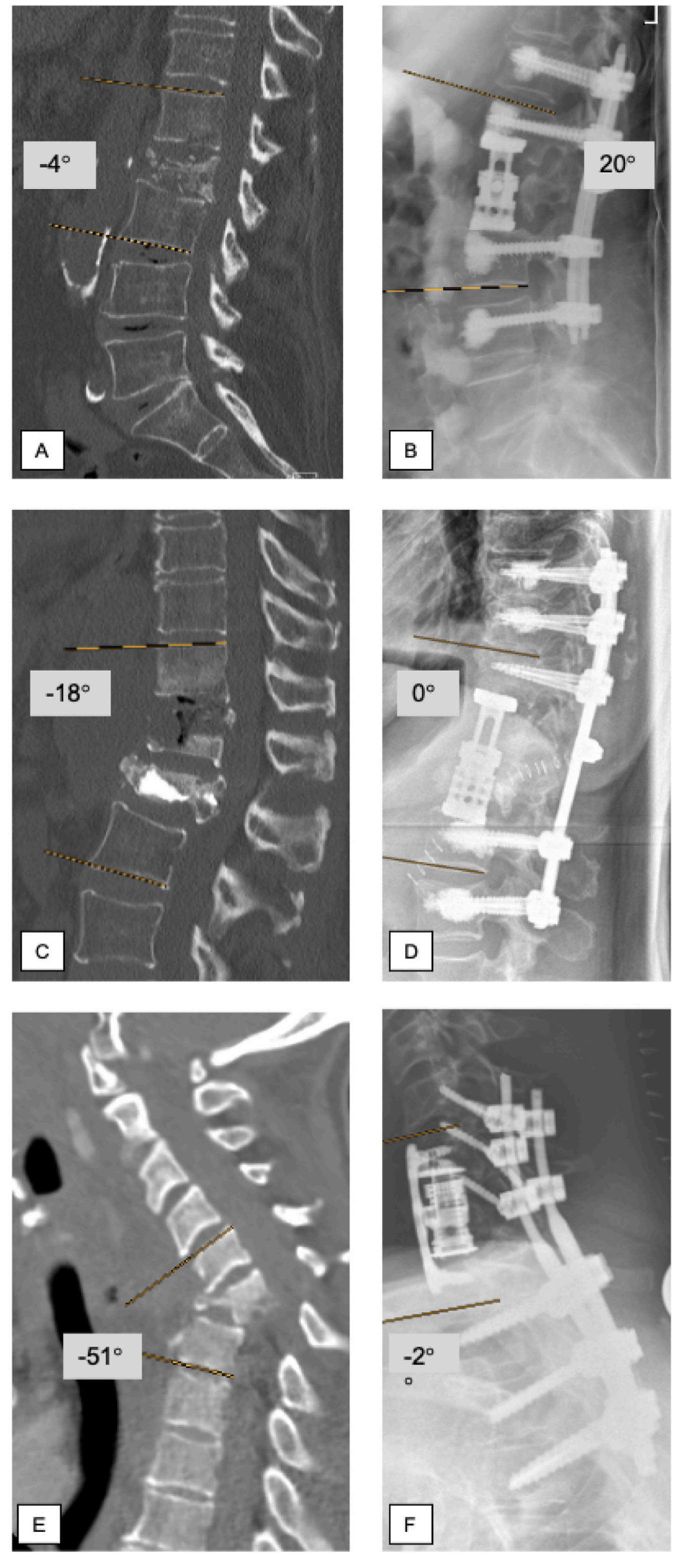

Image 1. A. Infectious destruction of L2, bi-segmental CA = −4° (kyphosis). B. postoperative image after 1-level-VBR and posterior instrumentation, postop CA = 20° (lordosis). C Spondylodiscitis and frature of T11, tri-segmental CA = −18°, D. postoperative image after 2-level-VBR and posterior instrumentation, postop CA = 0°. E Cervical kyphotic deformity due to infection, bi-segmental CA = −54°. F. postoperative image after combined reconstruction, postop CA = −2°.

second stage surgery, different anterior approaches were used based on the location of the infection: anterior retroperitoneal (ALIF) approach for lumbosacral (L5/S1) lesions, lateral mini-open retroperitoneal anteroinferior psoas approach (XLIF) for lower lumbar segments (L2-L4), left-sided endoscopic-assisted transpleural approach for the thoracolumbar region (Th10-L1), and right-sided for mid-thoracic infections (Th5-9). In all cases involving thoracolumbar lesions, an expandable titanium cage with rectangular footprint (obelisc™, Ulrich medical) was used for anterior column reconstruction.

Cervical corpectomy was performed using a standard left-sided anterolateral approach with the implantation of an expandable implant (Fortify®, Globus medical) and anterior plating.

Calculated antibiotics were given based on the patients' risk profile, type of spinal infection and accompanying infectious focus and changed to a specific regimen after positive microbiological results. Antibiotics were admitted for at least 6 weeks.

4. Results

A total of 360 cases of acute, subacute, or chronic spinal infection treated between 2015 and 2022 were identified. Among these cases, 100 underwent single- or multilevel corpectomy and vertebral body replacement (VBR). The indications for VBR included severe destruction of the vertebral body, pathologic fracture, or deformity that required correction.

The mean age of the patient cohort was 68 years, ranging from 28 to 89 years. Out of the 100 cases, 56 were male and 44 were female.

The most common location of the spinal infection was the lumbar region (L2-L5) with 48 cases, followed by the thoracolumbar junction (T11-L2) with 27 cases, cervical (C1-7) with 14 cases, main thoracic (T1-10) with 10 cases, and lumbosacral (L5-Sacrum) with 1 case. Multilocular infections were observed in 12 cases. Among the cases, 59 were primary pyogenic infections, 39 were secondary infections, 1 was fungal, and 1 was parasitic.

Preoperative MRI with gadolinium enhancement was available in 88 out of 100 cases, while CT scans were available in all cases. In 99% of cases, the disc space and in 98%, the vertebral body was affected. Additionally, 24% of cases had infections in the bi- or unilateral facet joints. Paravertebral tissue infection was associated with 56% of cases, while infection in the spinal canal (epidural abscess) was also observed in 54% of cases. Pathologic fracture was present in 27% of cases, and 18% exhibited de novo deformities.

Please refer to Table 1 for preoperative Cobb angle (CA) measurements.

For thoracolumbosacral infections (86 cases), dorsal pedicle screw instrumentation was performed prior to VBR in all cases. The mean number of dorsally instrumented levels was 4, ranging from 2 to 9 (see Table 2). Cement augmented screws were used in 48 cases (55.8%) to enhance stability. Dorsal decompression was performed in 58 cases.

10 out of 14 cervical cases (71%) received additional dorsal instrumentation.

Single-level (bisegmental) VBR was performed in 60 patients, two-level VBR (trisegmental) in 37 patients, three-level VBR in 2 cases, and four-level VBR in 1 case (see Table 1).

The mean follow-up time was 509 days, ranging from 9 to 2509 days. Of these cases, 79 were followed up for more than 3 months, and 31 cases were followed for more than a year. The follow-up period included clinical and radiologic examinations, with X-rays performed in 85% of cases, CT scans in 45% of cases, and repeated MRI in 28% of cases.

The mean overall sagittal correction achieved was 10°, ranging from 0 to 54°. Location-specific results can be found in Table 1.

In terms of complications, 31 out of 100 patients required unplanned revision surgery. Among the revisions, 25 were posterior-only, 5 were anterior-only, and one involved combined approaches.

The most common reasons for revision surgery were wound healing

Table 2
Number of levels of posterior instrumentation and the corresponding dorsal revisions performed due to aseptic mechanical complications in cases of vertebral body replacement (VBR) for spinal infection treatment.

Instrumented levels	Cases	Dorsal revisions
0	4	0
2	6	0
3	8	0
4	45	4 (8,9%)
5	13	2 (15,4%)
6	10	3 (30,0%)
7	7	1 (14,2%)
8	5	3 (60%)
9	2	0

Table 1
Vertebral-Body-Replacement (VBR) by number of levels and location. Sagittal correction (Cobb angle post-preoperative) achieved thru surgery. CA = Cobb angle, <0° = kyphosis, >0° = lordosis. Cause for revision surgery. WHD = Wound healing disorder, ant. = anterior, post. = posterior, Neuro-Deficit = Neurological impairment, ADD = adjacent disc disease, Removal = Shortening/Removal of pedicle screw-rod-construct.

	TOTAL	cervical	Thoracal	Thoraco-lumbar	lumbar	Lumbo-sacral
		C0–C7	Th1-TH10	Th11-L2	L3-5	L5-Sacrum
VBR level						
All	**100**	14	10	27	48	1
1-level	**60**	8	3	13	35	1
2-level	**37**	6	5	14	12	0
3-level	**2**	0	1	0	1	0
4-level	**1**	0	1	0	0	0
Preoperative Cobb angle						
mean	**1,4°**	−14°	−20°	−10°	16°	31°
range	**−56° – 42°**	−56°- 7°	−39° -3°	−56°- 11°	−9° - 42°	
Sagittal Correction (pre-postoperative CA)						
mean	**10°**	14°	13°	16°	8°	0°
Cause for reoperation						
Relapse	**9**	1	1	3	4	0
WHD ant.	**3**	1	0	0	2	0
WHD post.	**9**	2	1	1	5	0
Neuro-Deficit	**1**	0	0	0	1	0
Implant failure ant.	**3**	1	0	0	2	0
Implant failure pos.	**8**	0	0	4	4	0
ADD	**6**	0	0	1	5	0
Removal	**6**	0	1	1	3	1
Approach related complication	**2**	1	0	0	1	0

disorders (12 out of 100 cases), with 9 cases requiring posterior revision and 3 cases requiring anterior revision. The study revealed two reports of anterior approach related complications, one cervical with injury of the esophagus and one postoperative bleeding in the psoas muscle through the retroperitoneal approach.

Implant failure was the second most common reason, occurring in 11 out of 100 cases. Posterior pedicle screw loosening was more frequent (8 out of 100 cases) than anterior cage subsidence (3 out of 100 cases). Infection-related complications, such as ongoing infection, relapse, or adjacent disc infection, occurred in 9 out of 100 cases. Aseptic adjacent disc disease was observed in 6 out of 100 cases. Neurologic impairment due to posterior surgery occurred in one case.

Aseptic mechanical complications were associated with long pedicle-screw constructs involving more than 4 instrumented levels. 63 cases had shorter posterior constructs (0–4 instrumented levels), while 37 cases had longer posterior (5–9 instrumented levels) constructs. The rate of aseptic mechanical complications was significantly lower for shorter constructs ($p < 0.01$). Further details can be found in Table 2.

Three patients died within 43–86 days (mean 53 days) after the initial hospital admission. The causes of death were sepsis and multi-organ failure in two cases and pulmonary exhaustion in one case.

In 6 out of 100 cases, shortening or removal of the dorsal instrumentation was performed after recovery and healing of the infection. The planned procedure was performed 177–242 days (mean 202 days) after the initial admission to the hospital.

The subgroup analysis of Multi-level-VBR (≥2 levels) revealed no significant differences compared to Single-level-VBR with respect to patient characteristics such as diabetes, renal failure, hepatopathy, i.v. drug abuse, immunosuppression, or malignoma. However, the Multi-level-VBR subgroup was significantly older on average ($p = 0.04$). Parameters like WCC, CRP, septic condition, and neurologic status upon admission did not exhibit significant differences between the two groups. While the Multi-level-VBR group showed a notably higher number of deformities ($p = 0.02$), the occurrences of facet involvement, epidural abscess, paravertebral abscess, and fractures did not significantly differ between groups.

The length of stay was significantly longer ($p = 0.02$) in the Multilevel-VBR group compared to the Single-level-VBR group. However, the rates of bedridden patients and those with major neurological impairments did not display significant differences. Moreover, the revision rate was not higher in the Multilevel-VBR (≥2 levels) subgroup.

All recorded deaths were observed within the Multilevel-VBR group, with a mortality rate of 7.5%, significantly higher ($p = 0.03$) in this subgroup.

For further details, refer to Table 3.

Table 3
This table presents a comparison between patients who underwent Single-Level-VBR and Multi-Level-VBR(≥2-level) for spinal infection treatment. The table provides patients' characteristics, laboratory and radiologic findings on admission, and outcome data. Significant differences with p-values <0.05 are highlighted with an asterisk (*).

	Single-level-VBR		Multi-level-VBR		p =
n°	60		40		* (<0.05)
ADMISSION Status					
Diabetes	12	20,0%	10	25,0%	0,55
cRF	8	13,3%	5	12,5%	0,90
Hepatopathy	7	11,7%	2	5,0%	0,25
Immunosuppression	4	6,7%	3	7,5%	0,87
Malignoma	6	10,0%	6	15,0%	0,45
Facet joint involvement	14	23,3%	11	27,5%	0,64
Paravertebral abscess	36	60,0%	20	50,0%	0,32
Epidural abscess	30	50,0%	24	60,0%	0,33
Fracture (pathologic)	17	28,3%	11	27,5%	0,93
Deformity	6	10,0%	**11**	27,5%	**0,02***
Neurological deficit	19	31,7%	13	32,5%	0,93
Age	66,2		71,35		**0,04***
WCC	9,73		9,14		0,72
CRP	7,88		7,16		0,68
GFR	86,10		75,10		0,12
OUTCOME					
Bedridden	8	13,3%	8	20,0%	0,37
Neurological impairment	13	21,7%	11	27,5%	0,50
Revision Total	22	36,7 %	9	22,5%	0,13
Revision anterior	4	3,4%	2	5,0%	0,73
Cage subsidence	1	1,7%	2	5,0%	0,34
Death	0	0%	3	7,5%	**0,03***
Days in Hospital	27,07		48,73		**0,02***

5. Discussion

In this retrospective cohort study, the authors aimed to evaluate the risk profile and outcomes of vertebral body replacement (VBR) for the treatment of spinal infection and compare Single-level- to Multi-level-VBR. To date, this study reported the highest number of VBR cases for spinal infection treatment.

Corpectomy and vertebral body replacement is used as a surgical tool for more than 20 years to treat different spine pathologies like (burst-) fractures, tumors, adult or posttraumatic deformities and spinal infections (Tarhan et al., 2015). While in the beginning bone grafts were used to restore the spinal alignment, nowadays there are various implants on the market and especially expandable cages offer various surgical advantages (Kasapovic et al., 2021; Kandziora et al., 2004).

Spinal infections are relatively rare but have heterogeneous manifestations. Indications for VBR in spinal infection cases include severe destruction of the vertebral body, pathologic/septic fracture, and kyphotic or scoliotic deformity (Akbar et al., 2011; Ärzteblatt DÄG Redaktion Deutsches). The advantages of the anterior approach in treating spinal infections include wide exposure of the infection site, thorough debridement, stable anterior mechanical support, correction of deformities, and achieving fusion in the long term (Ruf et al., 2007).

In terms of sagittal correction, there was a limitation in this study due to the use of preoperative supine position CT scans and postoperative standing X-rays for assessment. This may have led to an underestimation of the preoperative kyphotic angle and the achieved sagittal correction. However, the overall correction achieved was more than 10°, which can be considered effective in preserving or restoring sagittal balance in spinal infection cases (Robertson et al., 2004; Le Huec et al., 2019; Scheer et al., 2021).

The study did not evaluate fusion outcomes due to the limited long-term follow-up and inconsistent radiological data.

The study identified and categorized disease-related surgical complications into three distinct groups. The first group encompassed general complications and complications related to the surgical approach. The second group comprised septic complications, while the third group included aseptic mechanical complications.

The anterior approach is generally considered safe, only for the upper thoracic spine the anterior access is limited. As expected, general complications were a major reason for revision surgery, while anterior approach related wound healing disorders were less (3%) common than for the posterior approach (9%).

In comparison to the posterior approach, the anterior approach allows for a wider exposure of the disc space and vertebral body (Ruf et al., 2007). Besides a frequently seen psoatic abscess formation can be drained easily. Surgical debridement aims to decrease the infectious load and therefore may lower the rate of infection recurrence. While other studies show very diverse results concerning relapse rate, the rate of recurrence and relapse in this surgical cohort was 9% (Shiban et al., 2014; Sanda et al., 2021).

The rate of cage subsidence in the thoracolumbosacral subgroup was 3%, consistent with or lower than reported in the literature (Wipplinger et al., 2022; Lu et al., 2009). For the cervical spine, there was one case of cage subsidence related to recurrent infection and implant infection. In cases involving the thoracolumbosacral region, VBR was supplemented with posterior fixation to enhance stability, as longer anterior constructs may be prone to instability (Bayerl et al., 2019).

Aseptic complications such as adjacent disc disease (6%) and aseptic posterior implant failure (8%) accounted for the highest portion of revision cases (42% of revision cases). The mean number of instrumented levels was four, with pedicle screws placed two levels above and below the VBR to increase stability. Longer posterior instrumentation (5–9 instrumented levels) had significant higher rates of aseptic mechanical complications ($p < 0.01$). This raises questions about whether the instability in infectious cases is biomechanically comparable to other pathologies and if similar treatment approaches should be considered or shorter 360°-constructs may be safer.

The analysis of the multilevel VBR (≥2 levels) subgroup in comparison to the Single-level-VBR did not exhibit significant differences between the two groups in respect of patient characteristics, including factors such as Diabetes, renal failure, hepatopathy, i.v. drug abuse, immunosuppression, and malignoma. However, the Multilevel-VBR subgroup displayed a notably higher average age ($p = 0.04$). Additionally, parameters like WCC, CRP, and neurologic status upon admission were consistent across the two groups and did not show any significant differences. Though, within the Multilevel-VBR group, a significantly higher number of cases with deformities was observed ($p = 0.02$), occurrences of facet involvement, epidural abscess, paravertebral abscess, and fractures did not show significant differences between the Multilevel-VBR and Single-level-VBR groups.

The length of hospital stay was significantly prolonged in the Multilevel-VBR group compared to the Single-level-VBR group ($p = 0.02$), indicating potential complexities or additional requirements in the multilevel procedures that contribute to extended hospitalization. However, rates of bedridden patients and those with major neurological impairments did not significantly differ between the two groups.

Another notable finding was that the revision rate was not higher in the Multilevel-VBR (≥2 levels) subgroup. This implies that, despite the increased complexity of multilevel procedures, their revision rates remained comparable to those of single-level procedures (Ackshota et al., 2019).

Of particular concern is that, all instances of mortality occurred within the Multi-level-VBR group, with a subgroup mortality rate of 7.5%. This rate was found to be significantly higher ($p = 0.03$) compared to the Single-level-VBR group. One explanation might be the fact, that the cohort of Multi-level-VBR was significantly older. But this observation highlights the need for thorough consideration and potentially enhanced monitoring for patients undergoing multilevel VBR procedures, given their increased vulnerability.

The overall mortality rate (3%) in this cohort study was lower or in line compared to other reports (Ackshota et al., 2019; Shiban et al., 2014; Sanda et al., 2021; Vettivel et al., 2019; Zarghooni et al., 2012).

Future prospective trials comparing short and long anterior and posterior instrumentation may provide a better understanding of the biomechanical considerations and outcomes in the treatment of spinal infection.

6. Conclusion

In this retrospective cohort study, we investigated the efficacy of vertebral body replacement (VBR) for spinal infection treatment and compared Single-level-VBR with Multi-level-VBR. This study, encompassing the highest number of VBR cases for infection treatment to date, provided insights into the treatment landscape.

Our findings indicated that the anterior approach is generally safe, offering exposure advantages, effective debridement and correction of sagittal malalignment. Complications primarily stemmed from general factors rather than approach-related issues. Aseptic complications, including adjacent disc disease and aseptic posterior implant failure, were significant causes of revision surgery rather than septic complications.

Comparing the two approaches, we noted that the multilevel VBR subgroup had a higher mortality rate (7.5%) than the single-level group, potentially linked to its older average age. Notably, the number of implant related complications were not higher.

The study underscored the need for further research to compare short and long anterior and posterior instrumentation and evaluate the biomechanical considerations in treating spinal infections.

In a cohort with a low overall mortality rate (3%), our results contribute to understanding VBR's role in managing spinal infections. Prospective trials comparing various instrumentation approaches will refine our treatment understanding.

Conflict of interest

The corresponding author, on behalf of all co-authors, declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper. All authors have provided the relevant information to the corresponding author and have given their approval for this declaration.

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