The Safety and Efficacy of Cadaveric Allografts and Titanium Cage as a Fusion Substitutes in Pyogenic Osteomyelitis

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Objective: The safety and efficacy of various fusion substitutes in pyogenic osteomyelitis has not been investigated. We evaluated and compared the cadaveric allograft and titanium cages used to reconstruct, maintain alignment and achieve fusion in the management of pyogenic spinal infection.

Methods: There were 33 patients with pyogenic osteomyelitis underwent fusion in this study. Fifteen of the 33 patients were operated on by fusion with allografts (cadaveric patella bones) and 18 of those were operated with titanium mesh cages filled with autologous cancellous iliac bone. After the affected disc and vertebral body resection with pus drainage, cadaveric allograft or titanium cages were inserted into the resected space. Posterior transpedicular screw fixation and rod compression in resected space, where cadaveric allograft or titanium cages were inserted, was performed to prevent the malposition in all patients except 1 case. Recurrent infection was identified by serial erythrocyte sedimentation rate and cross reactive protein follow-up. Osseous union and recurred infection available at a minimum of 2 years following operation was identified. The amount of kyphosis correction and the subsidence were measured radiographically.

Results: Spinal fusion was achieved in 29 of 33 patients. In the cadaveric allograft group, 93.3% of patient (14 of 15) showed the osseous union while 83.3% of patient (15 of 18) in the titanium cage group showed union. Subsidence was noted in 12 of the patients. Twelve patients (36.3%) showed unsettling amounts of subsidence postoperatively whereas 46.6% of patients in the cadaveric allograft group and 37.7% of patients in the titanium cage group showed similar subsidence, respectively. There were statistical difference in the fusion rate ($p=0.397$) and subsidence rate ($p=0.276$) between the two groups. There was significant statistical difference in the postoperative improvement of segmental kyphosis between the two groups ($p=0.022$), that is the improvement in sagittal alignment was greater in the titanium cage group than in the cadaveric allograft group. There was no case of recurred infection.

Conclusion: The cadaveric allograft and titanium cages are effective and safe in restoring and maintaining sagittal plane alignment without increased incidence in infection recurrence in pyogenic osteomyelitis. The postoperative improvement of segmental kyphosis was better in the cage group.

Key Words: Allograft · Fusion · Spinal infection · Titanium cage.

INTRODUCTION

The incidence of pyogenic osteomyelitis is increasing significantly in recent years as the number of spinal procedures for either diagnostic or therapeutic purposes has increased significantly and immune-compromised patients has increased. The incidence of pyogenic lumbar spondylodiscitis after discectomy has been reported to be 0.7% to 0.8% even when prophylactic antibiotic treatment is given\textsuperscript{22,23}.

Management of pyogenic osteomyelitis is medical in most cases\textsuperscript{25,29,30}, but there are cases in need of surgical management. Operative management may be required for those who do not respond to antibiotic treatment and have a spinal deformity or an epidural abscess with neurological deficits. Although various approaches to the surgical management of pyogenic osteomyelitis have been introduced, the golden standard technique is debridement, followed by an autologous bone fusion with internal fixation. Most papers have suggested that fusion with an autologous iliac crest bone graft is satisfactory in bony union and spinal alignment maintenance. Other authors have suggested that the foreign substitutes may be used in active spinal infection in the respect of subsidence rate and easy feasibility to use. There are many concerns using cadaveric allografts and titanium cages, but few reports in the treatment of pyogenic osteomyelitis have been reported.
We compared the safety and efficacy of cadaveric allograft and titanium cages in spinal infections.

MATERIALS AND METHODS

Patient selection
Between April 1998 and March 2005, there were 33 patients with postoperative pyogenic osteomyelitis at our institution. We defined the pyogenic osteomyelitis as either presence of back or neck pain unrelieved by rest or analgesics, or fever and/or neck/back pain with neurological deficit on physical examination, together with laboratory (elevated values for erythrocyte sedimentation rate and C-reactive protein) and magnetic resonance image (MRI) abnormalities. An etiological diagnosis of pyogenic osteomyelitis was confined through identification of the causative microorganism from culture of a spine sample obtained by a surgical sample from paravertebral sites. Intraoperative specimens were obtained in all patients. All specimens were sent for Gram staining, aerobic and anaerobic cultures and sensitivity tests, fungal cultures, and acid-fast staining.

Resolution of infection was defined by normalization of the ESR, CRP levels and MRI finding. The mean follow-up period was 41.2 months (range 29-65 months).

Study design

Pre & postoperative evaluation

Clinical evaluation
The clinical evaluation of pain was graded using the visual analogue pain score (VAS) score and neurological outcomes were assessed by lower extremity motor deficit and bladder dysfunction. Motor deficit was graded by manual muscle testing (MMT) (Table 1). The patients’ scores were assessed by reviewing the medical records and office interviews conducted at the last follow-up visit.

Radiologic evaluation
Preoperative standing lateral radiographs, and magnetic resonance (MR) images were obtained in all patients. The patients’ conditions were classified into 3 grades based on the severity of bone and soft-tissue destruction as found on preoperative imaging studies\(^{27}\). Grade I represents isolated discitis or discitis with minor destruction of endplates. Grade II represents discitis with moderate endplate destruction. Grade III represents discitis with destruction of the VB. The differentiation between “minor destruction” and “moderate destruction” to the endplate was based on destruction of the vertebral body (VB) adjacent to the endplate noted on computed tomography (CT) scans and plain radiographs. If there was destruction in endplate only, we classified it as “minor destruction”. If there was destruction in endplate and also the portion of the body adjacent to the endplate without destruction of the anterior or posterior cortical margin of the VB, it was classified as “moderate destruction”. In cases in which there was destruction of the anterior or posterior margin of the VB or the pedicle, we classified it as destruction of the VB.

Postoperatively, radiological studies with dynamic views were obtained during follow-up. Last follow-up studies were obtained 24 months after the surgery to determine the imaging-documented fusion, subsidence, and degree of kyphosis.

Successful imaging-documented fusion was confirmed according to the following criteria: 1) the absence of radiolucent lines covering more than 50% of either implant, 2) translation of 3 mm or less and a range of motion of less than 5 degrees, 3) absence of halo, and 4) formation of anterior sentinel bone, or formation of the contiguous bony bridge between the upper and the lower vertebral bodies\(^{4,17}\). The successful fusion was considered if more than 3 conditions were met. The definition of subsidence was >5 mm of sinking of graft material under the endplates, with >5 mm of disc space collapse compared with immediate postoperative radiographs. The height of the disc space was evaluated by measuring the average of anterior, posterior, and median disc space heights. Immediate postoperative or 1-day postoperative radiographs were available for all patients who exhibited subsidence, and follow-up X-ray studies were obtained at 1 week, 1 month, 6 months, 1 year and 2 years. The last follow up X-ray studies were obtained 24 months after the surgery. The change in degree of kyphosis of each fusion level was assessed by the Cobb angle measurement comparing preoperative and last follow-up radiographs.

Infection management
At first, all patients were treated preoperatively with IV antibiotics. Then, assessment of clinical outcomes by VAS score, lower extremity motor grade by MMT, bladder dysfunction, ESR and CRP were evaluated at 1, 2, 4, and 6 weeks. The therapy period of antibiotics was discussed with the infection specialist. Postoperatively, all patients were treated with a minimum of 6 weeks of intravenous antibiotics, followed by 6 weeks of oral antibiotics or up to the time until ESR and CRP levels re-

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**Table 1. Manual muscle testing grading (MMT)**

| Grade | (%)  | Qualitative value                      | Muscle strength                          |
|-------|------|---------------------------------------|------------------------------------------|
| 5     | 100  | Normal                                | Complete range of motion (ROM) against gravity, with full resistance |
| 4     | 75   | Good                                  | Complete ROM against gravity; with some resistance |
| 3     | 50   | Fair                                  | Complete ROM against gravity; with no resistance |
| 2     | 25   | Poor                                  | Complete ROM with a gravity omitted |
| 1     | 10   | Trace                                 | Evidence of slight contractility, with no joint motion |
| 0     | 0    | Zero                                  | No evidence of muscle contractility |

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and 2 had thoracolumbar lesions. Sixteen patients had undergone operations before they experienced infection and 9 patients had undergone invasive procedures such as root block or discography. The source of infection could not be identified in the remaining 8 patients. A positive culture was obtained in 25 patients. The most common causative organism was Staphylococcus epidermidis, which was positive in 11 patients. Other organisms were Staphylococcus aureus in 9 patients, Acinetobactor baumannii, and Corynebacterium species in each of the 2 patients. Fifteen patients were operated on by interbody fusion with cadaveric allografts and the other patients with a titanium cage followed by posterior transpedicular screw fixation.

Clinical evaluation
The mean preoperative VAS scores of all patients were 8.84. In the cadaveric allograft group, the mean preoperative and postoperative VAS score were 9.04 and 4.70, respectively. The mean improvement of VAS score was 4.34±1.87. In the titanium cage group, the mean VAS score of the preoperative and postoperative period were 8.67 and 4.41, respectively. The mean improvement of VAS score was 4.26±1.54. The amount of postoperative VAS score improvement in two groups was not significantly different (p=0.436) (Table 3, 4).

Preoperative lower extremity motor deficits were noted in 27 out of 33 patients, 13 in the cadaveric allograft group and 14 in the titanium cage group respectively. In the cadaveric allograft group 3 (20.0%) patients were classified as grade 0, 1 (6.7%) as grade 1, 3 (20.0%) as grade 2, 3 (20.0%) as grade 3, 3 (20.0%) as grade 4. In the titanium cage group 1 (5.5%) patient was classified as grade 0, 3 (16.7%) as grade 1, 3 (16.7%) as grade 2, 4 (22.2%) as grade 3, 3 (16.7%) as grade 4. There was no statistical difference in preoperative motor grade between the two groups (p=0.741). Using MMT, 9 patients of the cadaveric allograft group and 7 patients of the titanium cage group have improved during the follow-up period. However 4 patients of the cadaveric allograft group and 7 patients of the titanium cage group remained within the same lower extremity motor grade since

Surgical indication
We confined the surgical indications, which included refractory to medical management, vertebral destruction causing instability or significant deformity, neurologic deficit by spinal cord compression, and abscess formation with spiking fever.

Surgical procedure
All patients were positioned in the prone position for the posterior approach. Infected bones or discs were removed as much as possible and posterior decompression was performed. Abscess was also removed and drained. Posterior pedicle screw fixation was performed under fluoroscopic guidance to prevent deformity or instability. All infected areas were irrigated with antibiotics mixed with normal saline, then cadaveric allograft was inserted into the disc space for osseous fusion (Fig. 1). The pedicle screw fixation was performed at the involved segment only, but sometimes extended to 1 or 2 upper and lower segments to obtain proper sagittal alignment. When using a titanium cages (Pyra MESH®, Medtronic Sofamor-Danek, Memphis, TN, USA), it was filled with autologous cancellous iliac bone (Fig. 2). Proper size and height was chosen to fit the defects and achieve sufficient stability and segmental lordosis. In cases of patients who underwent spinal surgery with implant devices, all implants were removed and abscess was drained.

Statistical analysis
Statistical analyses of the data were performed using SPSS statistical software (version 12.0). The independent two-sample t-test, Wilcoxon rank-sum test, Fisher exact test, and chi-square test were used for the statistical analysis. Statistical significance was set at a probability value of less than 0.05.

RESULTS
There were 33 patients in this study (16 men and 17 women, mean 53.9 years). Among these, 31 patients had lumbar lesions, and 2 had thoracolumbar lesions. Sixteen patients had undergone operations before they experienced infection and 9 patients had undergone invasive procedures such as root block or discography. The source of infection could not be identified in the remaining 8 patients. A positive culture was obtained in 25 patients. The most common causative organism was Staphylococcus epidermidis, which was positive in 11 patients. Other organisms were Staphylococcus aureus in 9 patients, Acinetobactor baumannii, and Corynebacterium species in each of the 2 patients. Fifteen patients were operated on by interbody fusion with cadaveric allografts and the other patients with a titanium cage followed by posterior transpedicular screw fixation.

The patient demography is summarized in Table 2.

Clinical evaluation
The mean preoperative VAS scores of all patients were 8.84. In the cadaveric allograft group, the mean preoperative and postoperative VAS score were 9.04 and 4.70, respectively. The mean improvement of VAS score was 4.34±1.87. In the titanium cage group, the mean VAS score of the preoperative and postoperative period were 8.67 and 4.41, respectively. The mean improvement of VAS score was 4.26±1.54. The amount of postoperative VAS score improvement in two groups was not significantly different (p=0.436) (Table 3, 4).

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### Table 2. Characteristics of 33 patients with pyogenic vertebral osteomyelitis

| Case No. | Sex/Age | Level of infection | Type of graft | Culture findings | Previous spinal op/procedure | Comorbidity or history |
|----------|---------|--------------------|---------------|-----------------|-------------------------------|------------------------|
| 1        | M/68    | L2-3               | Cadaveric allograft | S. epidermidis   | PLIF                          | HTN                    |
| 2        | M/55    | L3-4               | Cadaveric allograft | (-)             | Discectomy                    | Hepatitis, DM          |
| 3        | F/56    | L4-5, L5-S         | Cadaveric allograft | S. epidermidis   | (-)                           |                        |
| 4        | M/22    | T12-L1             | Cadaveric allograft | S. aureus        | Discectomy                    | (-)                    |
| 5        | F/45    | L4-5               | Cadaveric allograft | S. epidermidis   | (-)                           | HTN                    |
| 6        | F/74    | L5-S               | Cadaveric allograft | (-)             | MLD                           | Tbc.                   |
| 7        | F/65    | L3-4, L4-5         | Cadaveric allograft | S. aureus        | NRB                           | DM                     |
| 8        | F/72    | L4-5               | Cadaveric allograft | A. baumannii     | Discography                   | DM, HTN                |
| 9        | M/59    | L3-4               | Cadaveric allograft | S. aureus        | (-)                           | HTN                    |
| 10       | M/34    | L2-3               | Cadaveric allograft | (-)             | (-)                           | (-)                    |
| 11       | F/41    | L4-5, L5-S         | Cadaveric allograft | S. epidermidis   | (-)                           | Discectomy (-)         |
| 12       | M/66    | L3-4               | Cadaveric allograft | (-)             | Nucleoplasty                  | DM                     |
| 13       | F/53    | L5-S               | Cadaveric allograft | S. aureus        | (-)                           | (-)                    |
| 14       | M/47    | L3-4, L4-5         | Cadaveric allograft | Corynebacterium  | PLIF & TPSF                   | HTN                    |
| 15       | M/69    | L3-4               | Cadaveric allograft | S. epidermidis   | NRB                           | DM, HTN                |
| 16       | M/51    | L1-2               | Titanium          | S. epidermidis   | (-)                           | (-)                    |
| 17       | M/67    | L3-4               | Titanium          | S. aureus        | (-)                           | (-)                    |
| 18       | F/68    | L3-4               | Titanium          | S. epidermidis   | (-)                           | (-)                    |
| 19       | M/75    | L4-5               | Titanium          | S. epidermidis   | NRB                           | DM, HTN                |
| 20       | F/35    | L2-3               | Titanium          | S. aureus        | (-)                           | (-)                    |
| 21       | F/46    | L5S1               | Titanium          | S. epidermidis   | Discectomy (-)                | (-)                    |
| 22       | M/42    | L3-4, L4-5         | Titanium          | (-)              | Discectomy                    | HTN                    |
| 23       | F/58    | L2-3               | Titanium          | A. baumannii     | PLIF                          | (-)                    |
| 24       | F/64    | L4-5               | Titanium          | (-)              | NRB                           | DM                     |
| 25       | F/57    | L4-5               | Titanium          | S. aureus        | (-)                           | (-)                    |
| 26       | F/68    | L4-5               | Titanium          | A. baumannii     | PLIF                          | (-)                    |
| 27       | F/63    | L5S1               | Titanium          | S. aureus        | NRB                           | Tbc.                   |
| 28       | M/78    | L1-2               | Titanium          | S. epidermidis   | NRB                           | DM, HTN                |
| 29       | F/31    | T12-L1             | Titanium          | (-)              | Discectomy (-)                | (-)                    |
| 30       | M/29    | L3-4               | Titanium          | S. aureus        | Discectomy (-)                | (-)                    |
| 31       | F/24    | L4-5               | Titanium          | Corynebacterium  | Discectomy (-)                | (-)                    |
| 32       | M/52    | L5S1               | Titanium          | (-)              | (-)                           | (-)                    |
| 33       | M/47    | L2-3               | Titanium          | S. epidermidis   | PLIF                          | (-)                    |

DM: diabetes mellitus, HTN: hypertension, MLD: microscopic lumbar discectomy, PLIF: posterior lumbar interbody fusion, NRB: nerve root block, Tbc: Tuberculosis

### Table 3. Clinical characteristics in 33 patients with pyogenic osteomyelitis

|               | Mean VAS score | Lower extremity motor grade (MMT) | Bladder dysfunction |
|---------------|----------------|-----------------------------------|--------------------|
| Cadaveric allograft group |                |                                   |                    |
| Preoperative  | 9.04           | Grade 0 : 3 (20.0%) Grade 1 : 1 (6.7%) Grade 2 : 3 (20.0%) Grade 3 : 3 (20.0%) Grade 4 : 3 (20.0%) Grade 5 : 2 (13.3%) | 1/15 (6.67%) |
| Postoperative | 4.70           | Grade 0 : 1 (6.7%) Grade 1 : 1 (6.7%) Grade 2 : 2 (13.3%) Grade 3 : 2 (13.3%) Grade 4 : 5 (33.3%) Grade 5 : 4 (26.7%) | 1/15 (6.67%) |
| Titanium cage group |             |                                   |                    |
| Preoperative  | 8.67           | Grade 0 : 1 (5.5%) Grade 1 : 3 (16.7%) Grade 2 : 3 (16.7%) Grade 3 : 4 (22.2%) Grade 4 : 3 (16.7%) Grade 5 : 4 (22.2%) | 2/18 (11.1%) |
| Postoperative | 4.41           | Grade 0 : 1 (5.5%) Grade 1 : 2 (11.1%) Grade 2 : 2 (11.1%) Grade 3 : 3 (16.7%) Grade 4 : 5 (27.8%) Grade 5 : 5 (27.8%) | 2/18 (11.1%) |

VAS: visual analogue pain score
simply classified the patients’ condition based on the presence or absence of a paraspinal abscess. Thirteen (86.6%) out of 15 patients in the cadaveric allograft group and 14 (78%) out of 18 patients in the titanium cage group were noted to have paraspinal abscess on preoperative MR images (Table 5). There was no statistical difference in the formation of paraspinal abscess between the two groups ($p=0.525$).

Imaging-documented fusion (osseous union) was achieved in 29 out of 33 patients. In the cadaveric allograft group, 93.3% of patients (14 of 15) showed the osseous union (Fig. 4), while in the titanium cage group, 83.3% of patients (15 of 18) was done (Fig. 5). There was no statistical difference in the fusion rate between the two groups ($p=0.397$). Subsidence was noted in 12 of the patients. In our study, 36.3% of patients (12 out of 33) showed unsettling amounts of subsidence postoperatively, 46.6% of patients (7 out of 15) in the cadaveric allograft group and 27.7% of patients (5 out of 18) in the titanium cage group, respectively. There was no statistical difference in the subsidence rate between the two groups ($p=0.276$). The degree of kyphosis of involved segments was measured preoperatively by using the Cobb method. These values were 7.2±13.1° in the cadaveric allograft group and 9.3±11.6° in the titanium cage group, which were not significantly different ($p=0.424$). However, the amount of postoperative improvement in segmental kyphosis at the last follow-up was 4.96±0.22° in the cadaveric allograft group and 5.20±0.32° in the titanium cage group, which were significantly different between two groups ($p=0.022$) (Table 6).

**DISCUSSION**

Spinal infections encompass a spectrum of distinct disease entities such as septic discitis, vertebral osteomyelitis, and epidural abscess, caused by various organisms. In recent years, a rise in the incidence of pyogenic osteomyelitis has been reported, as a consequence of an increasing number of individuals with predisposing factors as followings; advanced age, diabetes mellitus, chronic renal or liver disease, intravenous drug use, HIV infection, long-term steroid use, malignancy, chemotherapeu-
therapy, severe trauma, and previous surgery. *Staphylococcus aureus* is the most common etiologic agent\(^5,6,19,28\). Diagnosis of pyogenic osteomyelitis is suggested by the presence of unremitting back or neck pain, which is relieved by neither rest nor analgesics, sometimes in combination with fever and neurological deficit. Diagnosis is supported by laboratory data and appropriate imaging changes such as plain radiography, CT-scan, and MRI, but can be confirmed only by isolation of the causative organism or histological evidence from blood culture or tissue biopsy\(^8\).

The causes of pyogenic osteomyelitis development are various. In our study, the major cause was previous spinal operation in those who were immune-compromised or who had comorbidities such as diabetes mellitus or old age. A total of 16 of our 33 patients underwent lumbar discectomy or posterior lumbar interbody fusion before the infection developed and 8 out of 33 patients had diabetes mellitus.

In the natural course of lumbar pyogenic osteomyelitis, granulation tissue invades the disc from the subchondral tissue and absorbs disc tissue to suppress the infection\(^12\). This process would finally result in fusion. Pseudoarthrosis or kyphotic deformity would develop in cases without a fusion. Although it has been stated that fibrous or osseous union occurs by between 6 and 24 months after conservative treatment for discitis, Fredrickson et al.\(^18\) reported an incidence of osseous union in only 35% of patients. The objectives of surgery are to debride the necrotic material, decompress the neural structures, stabilize the unstable segments through bone graft or implant and increase the chances of faster wound healing by restoring spinal alignment\(^9,10\).

Many studies have described the surgical management in pyogenic osteomyelitis. Autologous bone grafting after VB resection in the presence of active infection was first reported by Wiltberger in 1952 and has since been demonstrated to be safe and effective regardless of the causative organism\(^24,32\). Grafting with

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**Fig. 4.** A 47-year-old male patient complaining of severe back pain with elevated ESR and CRP. The patient had circumferential fusion history on L3-4, L4-5 level. A: Preoperative L-spine AP view. B: Preoperative L-spine lateral view. C: Preoperative lumbar magnetic resonance (MR) sagittal T1-weight (T1W) images, which shows a high signal intensity of epidural space, lower L4 and upper L5 vertebral body. D: Sagittal T2-weighted (T2W) MR image shows a high signal intensity of L4-5 intervertebral space, which was confirmed as abscess formation in operative field. Interbody cage at L4-5 was removed and a cadaveric allograft bone was inserted into the intervertebral space. E: Postoperative L-spine AP X-ray view followed up at 24 months after surgery. F: Postoperative L-spine lateral view, which shows a successful osseous fusion between L4 and L5 vertebral body.

**Fig. 5.** A 53-year-old male patient complaining of low back pain and intermittent high fever. The patient had history of nerve root block L2-3, L3-4 level about 6 month ago. A: Preoperative L-spine AP view. B: Preoperative L-spine lateral view, which shows erosions of the cortical end plates on both sides of a narrowed L2-3 intervertebral disc. C: Preoperative lumbar magnetic resonance (MR) sagittal postcontrast T1-weighted (T1W) images, which shows a homogeneous signal intensity and contrast enhancement within the epidural space at L2 and L3 vertebral body. Infected vertebral body and disc was resected and titanium cage filled with autologous cancellous iliac bone was inserted into the intervertebral space. D: Postoperative L-spine AP X-ray view followed up at 24 months after surgery. E: Postoperative L-spine lateral view, which shows a successful osseous fusion between L2 and L3 vertebral body.
Table 6. Postoperative imaging outcomes

|                                | Cadaveric allograft group | Titanium cage group | p-value |
|--------------------------------|---------------------------|---------------------|---------|
| Fusion rate (%)                | 93.3 (14/15)              | 83.3 (15/18)        | 0.397   |
| Subsidence rate (%)            | 46.6 (7/15)               | 27.7 (5/18)         | 0.276   |
| Mean change in degree of kyphosis (°) | 4.96±0.22               | 5.20±0.32          | 0.022   |

other material also has been introduced. However, some authors have argued against grafting with foreign material, because it may decrease antibiotic effectiveness and increase bacterial adherence and glycocalyx formation.23,24,26 Oga et al.26 evaluated the adherence properties of Staphylococcus epidermidis to stainless steel and found that the bacteria heavily colonized the rods. However, titanium may be less prone to bacterial colonization than other materials such as polymethylmethacrylate and stainless steel.27 Recently, several authors have reported the use of titanium cages in the treatment of pyogenic osteomyelitis.11,15,18,20 According to one report, the use of titanium cages may provide better column support, given that their structural integrity is not affected by degradative enzymes in an infected environment.15

While many studies described for autologous bone graft in pyogenic osteomyelitis, only a few studies described for interbody fusion with cadaveric allograft in pyogenic spinal infection. Allen et al.21 have reported that rhBMP-2 use, in combination with antibiotics and circumferential instrumented fusion, provides a safe and successful surgical treatment of medically nonresponsive pyogenic osteomyelitis, with solid fusions obtained, good clinical results, and no adverse side effects from the BMP.

However, there have been few reports about efficacy and safety of cadaveric allografts or titanium cages in pyogenic osteomyelitis. In our studies, surgical procedures including debride-ment of infected tissue, discectomy, and insertion of cadaveric allografts were performed in 15 cases and the titanium cages in 18 cases. We compared the safety and efficacy of cadaveric allografts with that of titanium cages in pyogenic osteomyelitis. The use of titanium cages has several benefits over cadaveric allografts. The cage provides immediate stability and can tolerate compression forces well. The significant interface strength between the cage and endplates prevents extrusion or displacement.5,24,26 Titanium cages provide good vertebral column support combined with posterior pedicle screw fixation. These cages have a wide contact area, and therefore abnormal load distribution between the cage and vertebral endplate can be minimized. The size and height of the cages could be chosen to restore disc space height and to obtain ideal sagittal alignment.

However, findings in our studies were inconsistent with these reports. Seven of 15 patients (46.6%) in the cadaveric allograft group showed greater than 5 mm of sinking of graft material or with greater than 5 mm of disc space collapse compared with immediately postoperative radiographs, while 5 out of 18 patients (27.7%) in the titanium cage group were proven as subsidence. Although the subsidence rate was higher in the cadaveric allograft group, there were no statistical significances in subsidence rate between the two groups (p=0.276). The fusion rate was higher in the cadaveric allograft group than the titanium cage group. In a follow up lumbar spine X-ray at 24 months after surgery, 14 out of 15 patients (93.3%) showed osseous fusion in the cadaveric allograft group and 15 out of 18 patients (83.3%) was shown in the titanium cage group. However, there were no statistical significances in the fusion rates between the two groups (p=0.397). These findings showed that there were no statistical significances in the subsidence rate and fusion rates between the two groups mean that the cadaveric allograft alone, not combined with titanium cage was effective as the titanium cage in pyogenic osteomyelitis.

The patients in this study using titanium cages and cadaveric allograft materials exhibited excellent fusion rate without recurrence of infection or hardware failure. The improvement in sagittal alignment was greater in the titanium cage group than the cadaveric allograft group, which was significantly different (p=0.022). These findings were consistent with report from Hee et al.,13 which showed that sagittal alignment was improved 5 times greater in the titanium cage group than autologous bone graft group. Hee et al.13 compared the clinical and imaging outcomes for fusion of infected spines between patients who underwent titanium cage placement and autologous bone placement. To our knowledge, however, there are no reports on comparison of cadaveric allograft and titanium cages in the literature. In our series, there were no statistical differences in either clinical or imaging outcomes between the groups, except for the improvement of segmental kyphosis. In other words, our studies described that cadaveric allograft use alone has a good effect in controlling infections in infected spines comparable with titanium cages.

The most common causative organism in our study was Staphylococcus epidermidis in 11 patients, which is inconsistent with findings in other studies. Throughout the literature, Staphylococcus aureus has been identified as the most common organism; it was the second-most common organism (9 patients) in our study. The high frequency of Staphylococcus epidermidis as a causative organism may be due to the high proportion of postoperative infection in our series. In one study of surgical site infections following spinal fusions between 1994 and 1998, 36% of the infections were due to aerobic gram-negative bacilli, 27% were due to Staphylococcus epidermidis, and 23% were due to Staphylococcus aureus.27 We estimated the severity of infection caused by each organism by using Pee et al.27 grading system.

There are limitations to this study; first of all, we adopted the Pee et al.27 system to correlate findings on preoperative images
(MR images, CT scans, and plain radiographs) for the severity of pyogenic osteomyelitis. We retrospectively classified the severity of infection in all patients according to this system. The differentiation between each grade was somewhat obscure and subjective. For this reason, this study may not be a true case-control study. According to our grading system, there was no statistical difference in disease severity between the two groups ($p=0.335$). We also tried to estimate the severity of infection based on the formation of paraspinal abscess, but most patients in both groups had signs of paraspinal abscess on preoperative MR images and there was no statistical difference between the two groups ($p=0.525$). Secondly, the fusion rate was assessed on the absence of radiolucent lines covering more than 50% of either implant, translation of 3 mm or less and a range of motion of less than 5 degrees, absence of halo, and formation of the contiguous bony bridge between the upper and the lower vertebral bodies$^{417}$. Unlike to degenerative spinal diseases, bone bridge formation between two vertebral bodies takes longer in pyogenic osteomyelitis. We could not meet all 4 conditions as successful fusion criteria.

**CONCLUSION**

Posterior interbody fusion with titanium cages followed by posterior pedicle screw fixation can be an effective surgical option in the treatment of pyogenic osteomyelitis. However, not only the titanium cages, but also the cadaveric allografts alone exhibited no differences in terms of improvement in pain, functional disability, fusion rate and subsidence rate. However, the correction of segmental kyphosis was significantly more effective in the titanium cage groups than the cadaveric allograft groups.

Although the cadaveric allograft use in pyogenic osteomyelitis has several limitations, especially in respect to improvement of segmental kyphosis, it may be a useful adjunct in restoring and maintaining sagittal plane alignment without infection recurrence in pyogenic osteomyelitis.

**References**

1. Atkins S, Lord J, Bernauer E, Fowler WM Jr, Lieberman JS, Berck P : Relationship of manual muscle testing to objective strength measurements. *Muscle Nerve* 12 : 173-177, 1989
2. Allen RT, Lee YP, Stimson E, Garfin SR : Bone morphogenetic protein-2 (BMP-2) in the treatment of pyogenic vertebral osteomyelitis. *Spine* (Phila Pa 1976) 32 : 2996-3006, 2007
3. Barth E, Myrlik QM, Wagner W, Gristina AG : In vitro and in vivo comparative colonization of Staphylococcus aureus and Staphylococcus epidermidis on orthopedic implant materials. *Biomaterials* 10 : 325-328, 1989
4. Burkus JK, Dorschak JD, Sanders DL : Radiographic assessment of interbody fusion using recombinant human bone morphogenetic protein type 2. *Spine* (Phila Pa 1976) 28 : 372-377, 2003
5. Butler JS, Shelly MJ, Timlin M, Powderly WG, O’Byrne JM : Nontuberculous pyogenic spinal infection in adults : a 12-yearexperience from a tertiary referral center. *Spine* (Phila Pa 1976) 31 : 2695-2700, 2006
6. Carragee EJ : Pyogenic vertebral osteomyelitis. *J Bone Joint Surg Am* 79 : 874-880, 1997
7. Chang CC, Merritt K : Infection at the site of implanted materials with and without preadhered bacteria. *J Orthop Res* 12 : 526-531, 1994
8. Cottle L, Riordan T : Infectious spondylodiscitis. *J Infect* 56 : 401-412, 2008
9. Eismont FJ, Bolighman HH, Soni PL, Goldberg VM, Freehafer AA : Pyogenic and fungal vertebral osteomyelitis with paralysis. *J Bone Joint Surg Am* 65 : 19-29, 1983
10. Emery SE, Chan DP, Woodward HR : Treatment of hematogenous pyogenic vertebral osteomyelitis with anterior debridement and primary bone grafting. *Spine* (Phila Pa 1976) 14 : 284-291, 1989
11. Fayazi AH, Ludwig SC, Dabbah M, Bryan Butler R, Gelb DE : Preliminary results of staged anterior debridement and reconstruction using titanium mesh cages in the treatment of thoracolumbar vertebral osteomyelitis. *Spine* 4 : 388-395, 2004
12. Fraser RD, Ossi OL, Vernon-Roberts B : Laticogenic discitis : the role of intravenous antibiotics in prevention and treatment. An experimental study. *Spine* (Phila Pa 1976) 14 : 1025-1032, 1989
13. Grant JP, Ozand TR, Dvorak MF : Mapping the structuralproperties of the lumbosacral vertebral endplates. *Spine* (Phila Pa 1976) 26 : 889-896, 2001
14. Gristina AG, Hobgood CD, Webb LX, Myrlik QN : Adhesive colonization of biomaterials and antibiotic resistance. *Biomaterials* 8 : 423-426, 1987
15. Hee HT, Majd ME, Holt RT, Pienkowski D : Better treatment of vertebral osteomyelitis using posterior stabilization and titanium mesh cages. *J Spinal Disord Tech* 15 : 149-156; discussion 156, 2002
16. Jensen AG, Espersen F, Skinhej P, Rosdahl VT, Frimodt-Moller N : Increasing frequency of vertebral osteomyelitis following Staphylococcus aureus bacteraemia in Denmark 1980-1990. *J Infect* 34 : 113-118, 1997
17. Kim JW, Park HC, Yoon SH, Oh SH, Roh SW, Rim DC, et al. : A multicenter clinical study of posterior lumbar interbody fusion with the expandable stand-alone cage (Tyche(R) Cage) for degenerative lumbar spinal disorders. *J Korean Neurosurg Soc* 42 : 251-257, 2007
18. Korovessis P, Petsinis G, Koureas G, Iliaopoulos P, Zacharatos S : Anterior or surgery with insertion of titanium mesh cage and posterior instrumented fusion performed sequentially on the same day under one anesthesia for septic spondylitis of thoracolumbar spine : is the use of titanium mesh cages safe? *Spine* (Phila Pa 1976) 31 : 1014-1019, 2006
19. Kowalski TJ, Berbari EE, Huddleston PM, Steelberg JM, Osmon DR : Do follow-up imaging examinations provide useful prognostic information in patients with spine infections? *Clin Infect Dis* 43 : 172-179, 2006
20. Kuklo TR, Potter BK, Bell RS, Moquin RR, Rosner MK : Single-stage treatment of pyogenic spinal infection with titaniummesh cages. *J Spinal Disord Tech* 19 : 376-382, 2006
21. Løkke AC, Demers AM, Rodrigues R, Arlet V, Tanguay K, Moore DL : Discitis following removal of intervertebral disc. *J Spinal Disord T ech* 19 : 618-622, 1982
22. Lindholm TS, Pylkkänen P : Discitis following removal of intervertebral disc. *J Spinal Disord T ech* 15 : 149-156; discussion 156, 2002
23. Lindholm TS, Pylkkänen P : Discitis following removal of intervertebral disc. *Spine* (Phila Pa 1976) 26 : 372-382, 2006
24. McGuire RA, Eismont FJ : The fate of autogenous bone graft in surgically treated pyogenic vertebral osteomyelitis. *J Spinal Disord* 7 : 206-215, 1994
25. McHenry MC, Easley KA, Locker GA : Vertebral osteomyelitis : long-term outcome of 253 patients from 7 Cleveland area hospitals. *Clin Infect Dis* 34 : 1342-1350, 2002
26. Oga M, Sugita Y, Hobgood CD, Gristina AG, Myrlik QN : Surgical biomaterials and differential colonization by Staphylococcus epidermi- dis. *Biomaterials* 9 : 285-289, 1988
27. Pee YH, Park JD, Choi YG, Lee SH : Anterior debridement and fusion...
followed by posterior pedicle screw fixation in pyogenic spondylodiscitis: autologous iliac bone strut versus cage. J Neurosurg Spine 8: 405-412, 2008

28. Perronne C, Saba J, Behloul Z, Salmon-Céron D, Leport C, Vildé JL, et al.: Pyogenic and tuberculous spondylodiscitis (vertebral osteomyelitis) in 80 adult patients. Clin Infect Dis 19: 746-750, 1994

29. Safran O, Rand N, Kaplan I, Sagiv S, Floman Y: Sequential or simultaneous, same-day anterior decompression and posterior stabilization in the management of vertebral osteomyelitis of the lumbar spine. Spine (Phila Pa 1976) 23: 1885-1890, 1998

30. Sapico FL, Montgomerie JZ: Pyogenic vertebral osteomyelitis: report of nine cases and review of the literature. Rev Infect Dis 1: 754-776, 1979

31. Tsiodras S, Falagas ME: Clinical assessment and medical treatment of spine infections. Clin Orthop Relat Res 444: 38-50, 2006

32. Waldvogel FA, Papageorgiou PS: Osteomyelitis: the past decade. N Engl J Med 303: 360-370, 1980