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Clinical Study

Efficacy of anterior cervical fusion: Comparison of titanium cages, polyetheretherketone (PEEK) cages and autogenous bone grafts

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Abstract

This retrospective study was designed to analyze and compare the efficacy and outcomes of anterior cervical fusion using titanium cages, polyetheretherketone (PEEK) cages and autogenous tricortical bone grafts. Fifty-five patients who underwent segmental anterior discectomy with a follow-up period up to 12 months enrolled in this study. They were divided into three groups: titanium cage with biphasic calcium phosphate ceramic (Triosite; Zimmer, Berlin, Germany) in group A ($n = 27$); PEEK cage with Triosite in group B ($n = 9$); and autogenous tricortical iliac crest bone graft in group C ($n = 19$). The fusion rates after 6 months were 37.21% in group A , 93.3% in group B, and 84.85% in group C. The fusion rates after 1 year in groups A, B, and C were 46.51%, 100% and 100%, respectively. The PEEK cage is a viable alternative to autogenous tricortical bone grafts in anterior cervical fusion.

Keywords: Anterior cervical fusion; Cage; Titanium; PEEK; Tri-cortical autogeneous bone graft

1. Introduction

Since the pioneering days of the anterior cervical approach introduced by Cloward et al. in the early 1950s, anterior cervical discectomy and fusion (ACDF) has been the standard neurosurgical procedure for most discogenic and degenerative cervical spinal lesions.[1–4] Although traditional interbody fusion using iliac bone can maintain the patency of the neuroforamen and ensure solid fusion,[5] graft collapse, nonunion, dislodgement and donor site complications remain problematic.

Various materials have been used for interbody grafts in anterior cervical fusion.[6–9] To supplement the bone graft, a number of fusion devices have been developed over the past 4 decades for stand-alone use or in conjunction with anterior or posterior instrumentation. The objective of these spinal devices is to immobilize the unstable degenerated motion segment so that bony fusion can occur. Currently three types of spinal fusion devices are available: horizontal cylinders, vertical rings and open box cages.

In this retrospective study, we evaluated three different fusion materials: titanium cages, polyetheretherketone (PEEK) cages and autogenous tricortical iliac crest bone grafts. We also compared the fusion rates and the associated complications after follow-up periods of 6 to 12 months.

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2. Materials and methods

2.1. Patients

Fifty-five patients treated with multi-level segmental anterior cervical fusion between January 2002 and September 2004 were retrospectively reviewed. The pathogeneses included trauma, cervical spondylosis, ossification of the posterior longitudinal ligament (OPLL) and herniated intervertebral disc (HIVD) (Table 1). The level of the operation was determined mainly by the clinical presentation and related radiological findings (6-view cervical spinal plain films and MRIs). The levels of anterior segmental cervical fusion are shown in Table 2. Ancillary electrophysiological studies were performed in all cases.

2.2. Surgical procedures

A right-side anterior cervical approach using the Smith-Robinson microsurgical procedure with some extensive modifications was performed in all cases. All operations were performed by one of three senior surgeons in our institute, and surgeons operated on an equal number of patients. Segmental decompression was performed using a high-resolution microscope, a high-speed burr, and a specially designed 1 mm thin-blade punch. After complete discectomy, removal of osteophytes, and careful end plate preparation, the intervertebral space was opened with a retractor. The end plates were prepared for fusion by abrading them and removing the cortical cartilaginous layers without destroying the vertebral plates. The patients were treated in three different ways by surgeon preference: Group A (27 patients) underwent anterior discectomy with a non-threaded titanium cage (Advanced Spine Technology, Inc., Oakland, CA, USA) containing a biphasic calcium phosphate ceramic (Triosite, 40% b-tricalcium phosphate [b-TCP] and 60% hydroxyapatite; Zimmer, Berlin, Germany); Group B (9 patients) underwent anterior discectomy with PEEK cage (Solis; Stryker, Allendale, NJ, US) interbody fusion containing Triosite; and Group C (19 patients) underwent anterior discectomy with an autogenous tricortical bone graft which was taken from the anterior superior iliac crest. The Triosite blocks were cut into several segments and impacted into the cavity of the titanium or PEEK cage. We usually chose an appropriate size of cage (5, 6, or 7 mm height) for fusion. The cage had a large cranial contact surface with the vertebral end plate and a large bony distal contact area to promote fusion between the vertebral bodies. The cranial surface of the cage was convex to address the concavity of the cranial vertebral end plate. Trial implants in the distracted disc space during surgery were used to determine the appropriate implant size.

Table 1
Pathogenesis in 55 patients with multilevel anterior segmental cervical fusion

Etiology	Number of patients		
	Group A ($n = 27$)	Group B ($n = 9$)	Group C ($n = 19$)
Traumatic	1	2	6
Cervical spondylosis	10	0	10
OPLL	1	0	0
HIVD	15	7	3

OPLL = ossification of the posterior longitudinal ligament, HIVD = herniated intervertebral disc.

Table 2
Levels of anterior segmental cervical fusion

Fusion levels	Number of patients		
	Group A ($n = 27$)	Group B ($n = 9$)	Group C ($n = 19$)
One level	14	3	10
Two levels	10	6	4
Three levels	3	0	5
Total	43	15	33

Titanium cages were introduced to our institute more than 4 years before the time of writing. However, the PEEK cage was introduced to our institute only 1 year ago. There were 11 men and 16 women (age range, 37–77 years; mean age, 55.2) in Group A, six men and three women (age range, 42–66 years; mean age, 54.2) in Group B, and 14 men and five women (age range, 15–83 years; mean age, 47.6) in Group C. All patients wore a soft collar for approximately 3 months.

2.3. Fusion and complication analysis

All participants were followed-up via X-ray of the cervical spine and observation of clinical symptoms 6 and 12 months postoperatively. Standard, flexion-extension and bilateral oblique X-rays were obtained. Fusion was deemed to have occurred if trabecular bone appeared across the interfaces. Nonunion was deemed to have occurred if there was lucency between the implants and vertebral endplate surfaces. A donor site was deemed to be painful if the patient experienced pain lasting more than 2 weeks and was analgesic-dependent.

3. Results

3.1. Fusion

The fusion rates in the first 6 months were 37.21% in Group A, 93.3% in Group B, and 84.85% in Group C. The fusion rates at 12 months were 46.51% in Group A, and 100% in Group B, and 100% in Group C (Fig. 1; Table 3). The fusion rates in Group B and C were better than those in Group A (Fisher's exact test, $p < 0.05$). There was no significant difference in fusion rates between Groups B and C (Fisher's exact test, $p > 0.05$).

3.2. Complications

The overall complication rates in Groups A, B, and C were 40.7% (11/27), 11.1% (1/9), and 52.6% (10/19),

respectively. In Group A, the major problem was non-union, which had occurred in seven patients at the 1-year follow-up (25.9%, 7/27) (Table 4). One patient experienced subsidence of a titanium cage containing Triosite (Fig. 2). In Group A, the new symptoms that developed post-operatively included limb numbness (3.7%, 1/27), neuropathic limb pain (3.7%, 1/27), limb weakness (3.7%, 1/27), and fusion level subluxation observed on X-ray (3.7%, 1/27). In Group B, one patient suffered from cervical wound pain for more than 2 weeks (11.1%, 1/9). In Group C, limb numbness and wound pain developed in one case (5.3%, 1/19). There were eight patients with donor site complications (42.1%, 8/19), which included one donor site hematoma (5.3%, 1/19) and seven painful donor sites (36.8%, 7/19) in Group C.

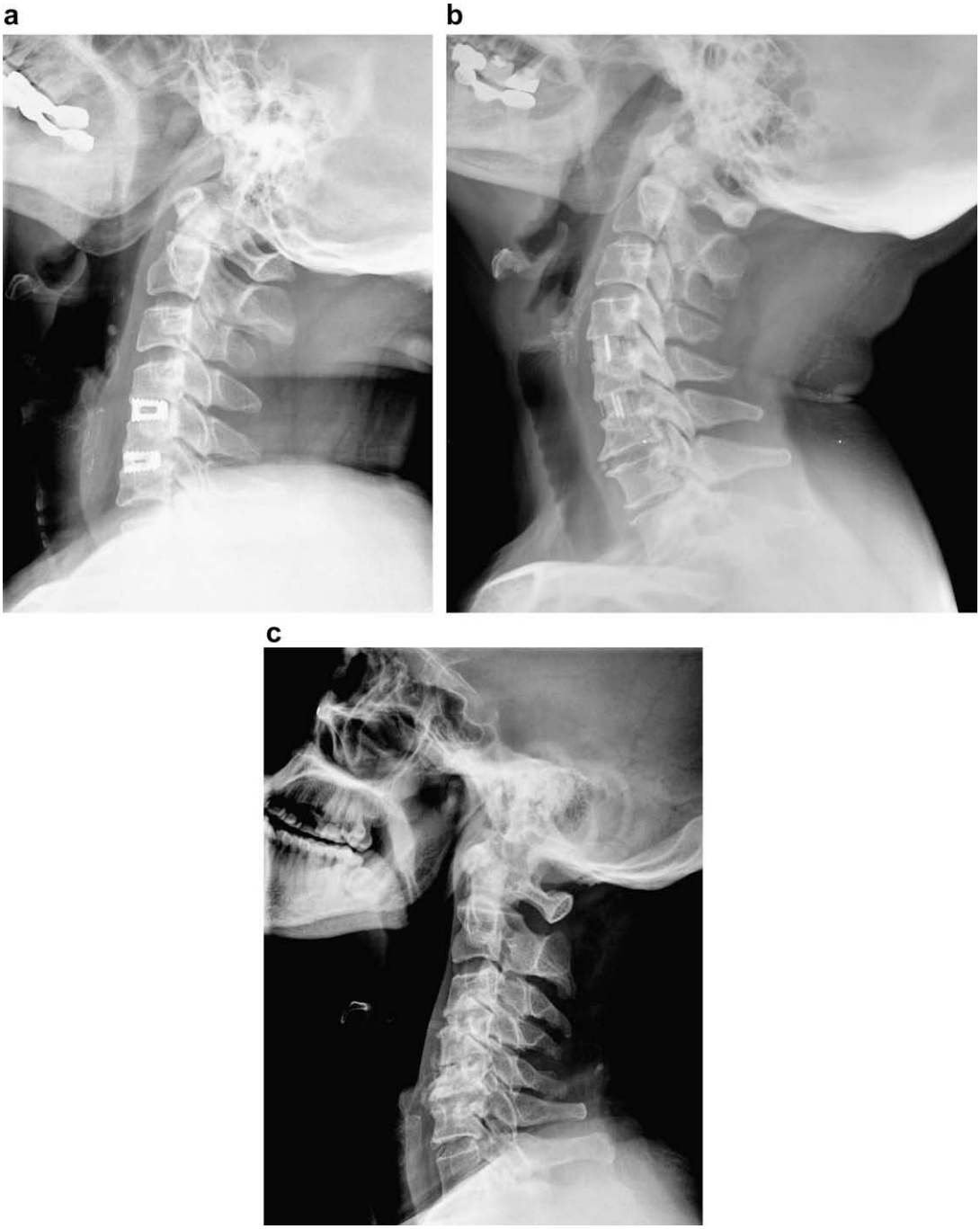

Fig. 1. Representive imaging (a) A 47-year-old male patient who underwent anterior cervical discectomy and fusion (ACDF) with a titanium cages had interbody fusion at C4–5 and 5–6 evident on a 1-year follow-up X-ray. (b) A 53-year-old female patient who underwent ACDF with a polyetheretherketone (PEEK) cages had interbody fusion at C4–5 and 5–6 evident on a 3-month follow-up X-ray. (c) A 61-year-old male patient who underwent ACDF with autogenous tricortical bone grafting had interbody fusion at C3–4, 4–5 and 5–6 evident on a 6-month follow-up X-ray.

Table 3
Fusion rates of segmental anterior cervical discectomy and fusion expressed as level fused per levels at which discectomy was performed

	Group A[a]	Group B[b]	Group C[c]	Fisher's exact test p-value a*b	Fisher's exact test p-value b*c	Fisher's exact test p-value a*c
6 months	37.21% (16/43)	93.3% (14/15)	84.85% (28/33)	0.00014	0.65	<0.01
12 months	46.51% (20/43)	100% (15/15)	100% (33/33)	0.0004	1	<0.01

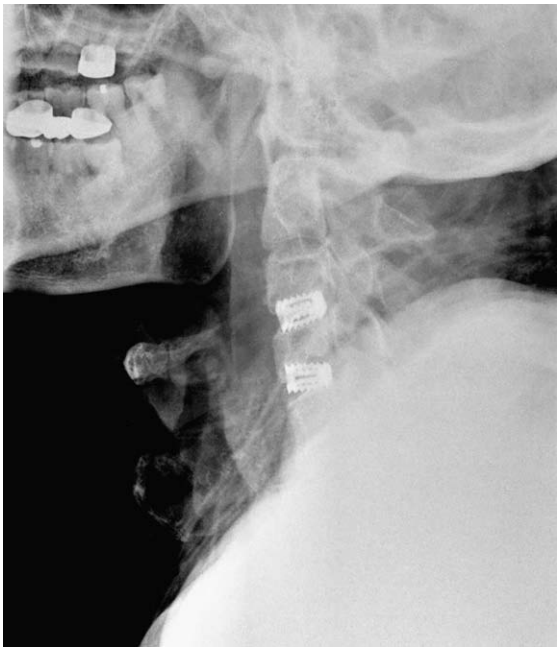

Fig. 2. A 76-year-old male patient with cervical spondylosis in C4–5 experienced subsidence of a titanium cage containing Triosite 6 months postoperatively.

4. Discussion

In this retrospective study, the fusion rates at 6 and 12 month follow-ups among patients who underwent ACDF with PEEK cages and autogenous bone grafts were significantly better than those using titanium cage fusion (Fisher's exact test, $p < 0.05$). Although Moreland and Schmieder reported titanium cage fusion rates of 95% and 98%, respectively, we could not duplicate their results.[10,11] Rather, our result echoed the results of a study by Cho et al.,[12] who found that the fusion rate was better, and that fusion occurred sooner in patients who underwent anterior cervical discectomy (ACD) with PEEK fusion. The PEEK cage has a hard frame appropriate to the high levels of cervical loading, is more rigid than an iliac bone graft, and proves rigid in compression and rotation tests.[12,13] PEEK cages have two titanium spikes on the upper and lower frames, which dig into the vertebral bodies to aid cage fixation. The PEEK cages also have retention teeth on the surfaces of the upper and lower frames to reduce cage dislodgement and to offer a fixation mechanism, similar to the function of a plate and screw. These features might contribute to fixation and promote early fusion.

Anterior cervical discectomy is a standard neurosurgical treatment for myelopathy and radiculopathy.[14–16] Smith and Robinson's original discectomy method preserved the end plate and posterior longitudinal ligament (PLL). In recent years, several surgeons have modified this surgical technique to achieve more extensive decompression and to enhance the rate of fusion.[1–3] In our series, we applied a specially designed 1-mm disc punch, a high-speed drill and a microscope to remove the disc, PLL and uncinate osteophyte. The posterior border of the vertebral body was tunneled for adequate cord decompression, and a foraminotomy was performed for nerve root decompression. In respect of multilevel cervical spinal lesions, there are options for decompression, including segmental ACDs, corpectomy, laminectomy and laminoplasty. The major concerns with all these various options are adequate decompression, immediate stability and final bony fusion.

Various materials have been used as interbody grafts in anterior cervical fusion because there are problems with iliac bone grafting, such as graft collapse, nonunion, dislodgement and donor site complications.[6–9,17] Cage fusion technology originated in 1979 from Bagby's work and the work of veterinary surgeons seeking to treat spondylitic

Table 4
Complications experienced by 55 patients with anterior segmental cervical fusion

Complications	Group A ($n = 27$)	Group B ($n = 9$)	Group C ($n = 19$)	Total
Subsidence	25.9% (7/27)	0	0	12.7% (7/55)
Limb numbness	3.7% (1/27)	0	5.3% (1/19)	3.6% (2/55)
Limb pain	3.7% (1/27)	0	0	1.8% (1/55)
Limb weakness	3.7% (1/27)	0	0	1.8% (1/55)
Subluxation	3.7% (1/27)	0	0	1.8% (1/55)
Cervical wound pain	0	11.1% (1/9)	5.3% (1/19)	3.6% (2/55)
Donor site hematoma	0	0	5.3% (1/19)	1.8% (1/55)
Painful donor site	0	0	36.8% (7/19)	12.7% (7/55)
Total	40.7% (11/27)	11.1% (1/9)	52.6% (10/19)	40% (22/55)

cervical myelopathy in horses.[18] Because of an unacceptably high level of graft harvesting morbidity when using Cloward's procedure, they developed the first interbody fusion cage, the Bagby Bone Basket, a fenestrated hollow cylindrical device made of stainless steel, allowing bone ingrowth. In 1988, Bagby described the principle of distraction compression, the basic principle of stand-alone intervertebral cage fusion.[19] The approach was first used in humans in around 1990, first in the lumbar area by Ray (using the threaded fusion cage, TFC),[20] by Bagby and Kuslich (using a threaded cylindrical titanium interbody fusion cage, BAK)[21] and by Brantigam (using a rectangular impacted carbon interbody fusion cage, I/FC).[22] Rectangular block cages are made of a biocompatible titanium alloy in which holes and grooves are cut in the interbody cage, and both upper and lower zigzagged surfaces match the vertebral bodies, safely resisting expulsion or retropulsion of the cage and allowing fibrous union and osseous growth.[23,24] Interbody cages provide initial segmental stability by tensioning the ligmentous apparatus, which anchors a cage's top and bottom areas to the adjacent endplates. Titanium cage-assisted ACDF provides long-term stabilization, increasing lordosis, segmental height and foraminal height.[25] PEEK is a semicrystalline polyaromatic linear polymer that provides a good combination of strength, stiffness, toughness and environmental resistance.[26–29] The elastic modulus of the PEEK cage is close to that of bone, which helps to decrease stress shielding and increase bony fusion. The PEEK cage has a deleterious influence on cell attachment and growth and exhibits a stimulatory effect on the protein content of osteoblasts.

Although autogenous bone grafting may produce an optimal fusion rate, the associated morbidity may also be high, as reported in the literature.[6–9,17,30] In our series, we used Triosite as a fusion medium in the PEEK and titanium cages, and we found an excellent fusion rate for PEEK cages without donor site morbidity. Triosite has two components: 40% b-TCP and 60% hydroxyapatite. The biointegration of Triosite is caused by partial dissolution of the ceramic crystals (b-TCP) by multinucleated cells.[31–33] Triosite does not contain osteoblasts and osteocytes. It provides the only osteoconductive role in cervical fusion, and under biodegradation and ingratiation processes the bony ingrowths were found to take 6–8 months to develop in an animal study.[24] Although it may take more time for fusion to occur, a cage containing Triosite may reduce donor site complications. In this series, the donor site complication rate was 42.1% (8/19), which resembles values reported in the literature (Chen et al. 36.7%; Cho et al. 54.3%).[12,17]

In our series, the titanium cage fusion group had a subsidence rate of 25.9%, which is comparable to that of the titanium cage reported by Moreland et al.[10] However, Schmieder and Jonbergen reported significantly lower subsidence rates of 2% and 9%, respectively.[11,34] Subsidence behavior of interbody fusion cages may be influenced by various factors, including three-dimensional segmental stability and the mechanics at the cage–end plate interface, and they are compromised by cage design, cage size, the contact area at the implant–bone interface, end plate geometry, and the bone quality of the vertebral end plates.[35]

5. Conclusion

Anterior cervical fusion using PEEK cages containing Triosite yielded similar fusion rates to anterior cervical fusion using autogenous tricortical bone grafts, with fewer donor site complications. ACDF using PEEK cages is a viable alternative to autogenous tricortical bone grafting. The low fusion and high complication rates associated with titanium cages may mean that these should no longer be used in clinical practice.

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