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Review Article

Polyetheretherketone (PEEK) cages in cervical applications: a systematic review

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Abstract

BACKGROUND CONTEXT: Polyetheretherketone (PEEK) cages have been widely used during the past decade in patients with degenerative disorders of the cervical spine. Their radiolucency and low elastic modulus make them attractive attributes for spinal fusion compared with titanium and bone graft. Still, limitations are seen such as pseudoarthrosis, subsidence, and migration of the cages. Limited evidence on the clinical outcome of PEEK cages is found in the literature other than noncomparative cohort studies with only a few randomized controlled trials.

PURPOSE: To assess the clinical and radiographic outcome of PEEK cages in the treatment of degenerative disc disorders and/or spondylolisthesis in the cervical spine.

STUDY DESIGN: Systematic review of all randomized controlled trials and prospective and retrospective nonrandomized comparative studies with a minimum follow-up of 6 months and all noncomparative cohort studies with a long-term follow-up of more than 5 years.

OUTCOME MEASURES: The primary outcome variable was clinical performance. Secondary outcome variables consisted of radiographic scores.

METHODS: The MEDLINE, EMBASE, and Cochrane Library databases were searched according to the Preferred Reporting Items of Systematic reviews and Meta-Analyses statement and Meta-analysis Of Observational Studies in Epidemiology guidelines. No conflict of interest reported. No funding received.

RESULTS: A total of 223 studies were identified, of which 10 studies were included. These comprised two randomized controlled trials, five prospective comparative trials, and three retrospective comparative trials.

CONCLUSIONS: Minimal evidence for better clinical and radiographic outcome is found for PEEK cages compared with bone grafts in the cervical spine. No differences were found between PEEK, titanium, and carbon fiber cages. Future studies are needed to improve methodology to minimize bias. Publication of lumbar interbody fusion studies needs to be promoted because differences in clinical and/or radiographic scores are more likely to be demonstrated in this part of the spine.

Keywords: PEEK; Interbody fusion; Degenerative disc disorders; Clinical outcomes; Radiological outcomes; Systematic review

FDA device/drug status: Not applicable.

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Introduction

Chronic back pain is a major health problem and results in high socioeconomic costs and loss of quality of life [1,2]. Degenerative disc disorders are seen as an important source of pain [3,4]. degenerative disc disorders can initiate secondary changes leading to stenosis, spondylolisthesis, and/or facet joint osteoarthritis. This may also lead to abnormal movement in the affected motion segment, which causes pain [3,5,6]. Surgical stabilization of the degenerative segment by a bony fusion is a method to eliminate the pain. Some of the modern surgical techniques involve removal of the degenerated disc and placement of a graft in the intervertebral space to achieve interbody fusion through an anterior approach in the cervical spine or an anterior or posterior approach in the lumbar spine.

To promote interbody fusion of the affected segments, autologous bone grafts were originally used. However, donor site morbidity, together with high failure rates resulting from collapse, subsidence, retropulsion, or resorption of the graft with subsequent pseudoarthrosis or prolonged healing time were frequently seen [7–10]. Therefore, interbody fusion cages were developed as an alternative for bone grafts [10]. These are designed to contain a bone graft, allowing bony fusion through the cage between the adjacent vertebrae. Cages allow for direct axial load-bearing and restoration of height of the intervertebral and foraminal space.

In 1988 Bagby introduced a stainless steel implant, which he used as a cage to promote spinal fusion and restore the disc height [11]. This Bagby and Kuslich cage showed good fusion rates [12]. In the subsequent years, titanium alloy cages were commercialized. Although high fusion rates and good clinical improvement scores were reported [13–15], these cages still had some disadvantages. For instance, subsidence is still seen in high percentages, varying from 16% to 60% [16–19]. Furthermore, titanium is radiopaque, which makes it difficult to visualize bone formation on radiograms after implantation.

To improve visualization of bone formation, radiolucent cages have been developed. Examples of these are resorbable poly(L-lactide-co-D, L-lactide) (PLDLLA) [20] and carbon fiber cages [21]. However, subsidence and pseudoarthrosis are still seen with these types of cages. One-third of patients with PLDLLA cages actually showed a 10% worsening of visual analog scale (VAS) and Oswestry Disability Index (ODI) scores. Also, signs of osteolyses were seen in the PLDLLA treatment group [20].

Polyetheretherketone (PEEK) cages became available during the late 1990s. They reduce stress shielding because of their lower elastic modulus compared with titanium [22,23]. Radiopaque markers are used to visualize PEEK cages. They cause less artifacts on computed tomography (CT) and magnetic resonance scans as compared with titanium and allow visualization of bony fusion.

Historical background

PEEK materials were commercialized in the 1980s and belong to the family of polyaryletherketone polymers [24]. PEEK has the ability to withstand high temperatures (up to 300°C) and is resistant to chemicals and radiation. PEEK is compatible with reinforcing agents and strength exceeding many metals [25,26]. Originally used in industrial applications, PEEK was explored as a biomaterial in prosthetic implants during the 1980s [27,28]. Not until the late 1990s was PEEK offered commercially as a biomaterial for spinal cages [22]. The first composites consisted of carbon-fiber–reinforced polyetherketoketherketonketon (PEKEKK) and showed positive biomechanical results in a cadaveric cervical and lumbar study [29]. In that study, the PEKEKK implant was compared with allograft human bone blocks of the proximal femur. Compression tests showed the PEKEKK implant had a similar compressive strength as the highest quality of bone implant, and the pullout resistance of the PEKEKK implant exceeded those of the allograft. In addition, an animal study was performed in which Spanish goats received either a PEKEKK cage with autologous iliac crest graft (CFRP cage) or allograft bone blocks [30]. At 6 and 12 months, higher histological and radiographic fusion rates were seen for CFRP cages compared with allograft. Furthermore, the cage was clinically evaluated in a US Food and Drug Administration–approved prospective multicenter study in 221 patients [31]. All patients underwent a lumbar interbody fusion with the carbon-fiber–reinforced PEKEKK cage filled with autologous graft, followed by posterior fixation with pedicle screws and plates. At 24 months, 98.6% of patients who had a 2-year radiographic evaluation (178 patients) achieved fusion. In 13.5% of patients, there were minor device-related complications, the majority of which were broken pedicle screws. There were 10.4% major non–device-related complications, with eight deep wound infections requiring reoperation. Further surgery was performed in 46.1% (102 patients) because of elective removal of screws and plates (35.2%); these addressed new disc levels or repaired dural tears. Five of 221 patients (2.2%) needed revision of the pedicle screws or cages. The lumbar carbon–reinforced PEKEKK cage came to be known as the Brantigan cage [22]. Carbon-fiber–reinforced PEKEKK cages were abandoned however by their industrial supplier for reasons that are not well-documented in literature and thus have ceased to exist [22]. This laid the foundation to the current use of PEEK cages.

PEEK cages have been widely used during the past decade [22,32–34]. Their radiolucency and low elastic modulus make them attractive for spinal fusion [35]. Still, drawbacks are seen, such as subsidence and migration of the cages [36–38]. PEEK has a hydrophobic surface, which allows neither protein absorption nor promotion of cell adhesion [39]. An animal study has reported that PEEK cages are encapsulated by a thin fibrous tissue layer [40];