Use of Poly(Ether Ether Ketone) Cages in Foot and Ankle Surgery

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KEYWORDS

• PEEK cage • PEEK foot fusion • Column-lengthening PEEK • Alternative bone graft

KEY POINTS

- The modulus elasticity of poly(ether ether ketone) (PEEK) is similar to bone.
- There are no donor site problems with PEEK.
- PEEK does not have the drawbacks associated with allografts.
- PEEK cages are radiolucent.
- Wedge-shaped cages are used for column lengthening.
- Box-shaped cages are used for height loss or in cavities.
- Bone fusion rates are high when PEEK cages are filled with autologous bone.
- PEEK is an effective alternative when structural bone graft is needed.

INTRODUCTION

Bone grafting is indicated for many surgical procedures on the foot and ankle, including arthrodesis, repair of complex fractures and malunions, and filling of defects within bones on the foot. When considering bone-grafting alternatives, the surgeon needs material that provides osteogenic cells (which differentiate into cells that are capable of producing bone),[1] osteoinductive factors (which produce elements that induce bone formation), and an osteoconductive matrix (which provides a scaffold that supports bone growth).[1]

Tricortical iliac crest bone graft is accepted to be the best option when structural defects or cavities need to be filled.[2,3] This graft can provide satisfactory clinical results and fusion rates. The complication rates of the donor site are around 20%,[4] some of the most common being pain, nerve damage, cosmetic problems, hemorrhage, hernia, fractures, and ureteral injury.[1] Arrington and colleagues[5]

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Foot Ankle Clin N Am 17 (2012) 449–457
http://dx.doi.org/10.1016/j.fcl.2012.07.001 foot.theclinics.com
1083-7515/12/$ – see front matter

identified 2 different groups: minor complications (which respond to aggressive nonoperative intervention such as aspiration and oral antibiotics), including superficial hematomas, superficial seromas, and superficial infections; and major complications (which need either a major change in treatment, prolonged hospitalization, or a return to the operating room), including donor-defect hernias, vascular injuries, nerve injuries, deep infections, deep hematomas, and iliac wing fractures.

Postoperative pain is the most common complication.[1] Fernyhough and colleagues[6] found a 29% incidence of chronic pain at the donor site in their retrospective study. Goulet and colleagues[7] noted in their review that pain was the most common complaint during the first 6 months (38%). This figure dropped to 18% 2 years after surgery. DeOrio and Farber[8] reviewed morbidity after harvest of anterior iliac crest bone graft for procedures involving the foot and ankle. Of their patients, 84% were limited in their activities because of pain at the bone graft site for less than 4 weeks; 7% had pain that resolved by 8 weeks; 4% had pain that resolved within 6 months; and 3% had limiting pain for more than 7 months. Pain can also be a result of a neurologic injury (lateral femoral cutaneous nerve or cluneal nerves). Meralgia paresthetica describes symptoms that are associated with injury of the lateral cutaneous nerve. DeOrio and Farber[8] reported postprocedure numbness in 29% of patients. This numbness resolved in 42%, improved in 29%, and remained unchanged in 29%. It is important that surgeons know the local anatomy of the site from which they take the graft, as this will aid in significantly decreasing the pain related to nerve injury.

Fractures of pelvic iliac wing after anterior iliac crest harvest have been described. Arrington and colleagues[5] described 2 cases in 414 patients. In both cases, harvesting of the anterior iliac crest bone graft was noted to be too close to the anterior superior iliac spine, causing the fracture of the anterior superior iliac spine from the iliac wing. Both patients were treated nonoperatively.

The most dramatic complication, though rare, is herniation of abdominal contents through the donor defect.

The application of allograft bone is another option in foot and ankle surgery. Allografts are advantageous because the quantity of allograft bone available to a given patient is essentially unlimited. The use of allograft bone would eliminate a second incision site (with no cosmetic problems), the operative risk associated with this procedure is low, and there is less pain and morbidity associated with the iliac crest donor site.[9] Allografts have several drawbacks. Such a graft is generally not as effective clinically as a comparable autograft,[10] and there is some risk of transmission of hepatitis B, hepatitis C, and human immunodeficiency virus (HIV).[9,10] Moreover, in Argentina the use of allografts increases the cost of surgery.

Considering this morbidity of the donor site and problems with allografts, the authors have decided to use poly(ether ether ketone) (PEEK) cages to replace iliac crest bone grafting in various procedures. PEEK polymers are obtained by step-growth polymerization by the dialkylation of bisphenolate salts. PEEK is a semicrystalline thermoplastic with excellent mechanical and chemical resistance properties that are retained up to high temperatures.

The Young modulus of PEEK is 3.6 GPa and its tensile strength 90 to 100 MPa. PEEK has a glass transition temperature at around 143°C (289°F) and melts around 343°C (662°F). It is highly resistant to thermal degradation as well as attack by both organic and aqueous environments. It is attacked by halogens and strong Bronsted and Lewis acids, as well as some halogenated compounds and aromatic hydrocarbons at high temperatures (**Fig. 1**).[11]

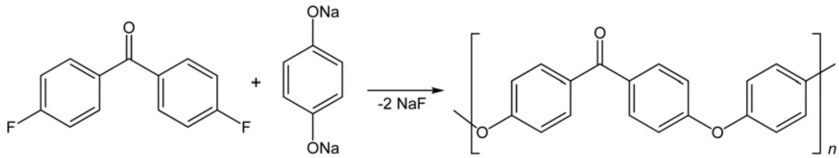

Fig. 1. Qualitative formula of PEEK.

MATERIAL AND METHODS

During 2009 and 2010, 32 cages were used in different procedures in 22 patients (14 females and 8 males) (**Table 1**):

- 3 subtalar joint fusions
- 4 subtalar joint fusions with lateral column lengthening in posterior tibial tendon dysfunction (PTTD)
- 11 lateral column lengthening in PTTD
- 1 calcaneocuboid joint fusion
- 3 first metatarsophalangeal (MTP) joint fusions after failed Keller procedure

All patients were treated at the foot and ankle service in the Instituto Dupuytren. The authors were unable to obtain cages for foot surgery in Argentina; therefore, together with a local company (Equimedica SRL, Buenos Aires), they designed cages for foot and ankle surgery. Two different types of cage were made: box-shaped cages of 20 × 20 mm and 15 × 15 mm, and wedge-shaped cages of 20 × 20 mm and 15 × 15 mm. For both groups, different sizes were made: 7, 9, 11, and 13 (**Fig. 2**).

The entire structure is radiolucent, and both designs have been used. Wedge shapes are indicated for lateral column lengthening and subtalar fusion; and the box shape is used when cavities or height loss is the main concern. PEEK cages were always filled with cancellous bone resected from the fusion site or the calcaneal lateral wall, when medial slide osteotomy and lateral column lengthening was performed.

The wedge-shaped PEEK cage was the most commonly used (28 cases), 15 for lateral column lengthening (8 fixed with titanium staples and 7 with 4.0-mm cannulated screws) and 13 for subtalar joint fusions (all fixed with 2 6.5-mm cannulated screws) (**Figs. 3–6**).[12]

A box shape was used only for failed Keller procedures that needed MTP fusions (3 cases) and length restoration in calcaneocuboid joint fusion (1 case) (**Fig. 7**).

RESULTS

All 22 patients were evaluated with plain radiography and computed tomography (CT) as well as clinically during the follow-up. Radiographically the fusion status was rated as fused, delayed union, or pseudoarthrosis.[13,14]

When there was absence of a solid fusion mass but no evidence of halo around the implant and absence of pain with articular motion, this was classed as delayed union.

Pseudoarthrosis was suspected if there was persistent localized pain, worsened with activity, relieved with rest, and/or hardware failure, and radiographic evidence of pseudoarthrosis (lack of bridging callus, areas of lucency, or lack of a solid fusion mass).[15]

Bone fusion was obtained in 21 patients (14 weeks average); one patient (#21) had a delayed union (20 weeks).

One patient (#15) had a 4-mm cage dorsal migration based on radiographs and CT, but no second procedure was needed because she had no complaints.

Table 1
Patients, hardware, and procedure

Patient #	Hardware	Procedure
1	20 × 20 × 9 mm cage + 22 × 22 mm Ti staple	Calcaneocuboid joint fusion
2	15 × 15 × 11 mm cage + dorsal plate	First MTP joint fusion
3	20 × 20 × 9 mm cage + 6.5 mm CS + 22 × 22 mm Ti staple	Lateral column lengthening in PTTD
4	Two 20 × 20 × 9 mm cages + 2 6.5 × 90 mm CS	Subtalar joint fusion
5	15 × 15 × 11 mm cage + dorsal plate	First MTP joint fusion
6	15 × 15 × 7 mm cage + 2 6.5 mm CS + 4.0 × 30 mm CS	Lateral column lengthening in PTTD
7	Two 20 × 20 × 11 mm cages + 20 × 20 × 7 mm cage + 6.5 mm CS + 25 × 22 mm Ti staple	Subtalar joint fusion with lateral column lengthening in PTTD
8	15 × 15 × 7 mm cage + 10 mm step plate + 4.0 × 30 mm CS	Lateral column lengthening in PTTD
9	20 × 20 × 9 mm cage + 10 mm step plate + 22 × 22 mm Ti staple	Lateral column lengthening in PTTD
10	15 × 15 × 7 mm cage + dorsal plate	First MTP joint fusion
11	20 × 20 × 11 mm cage + 10 mm step plate + 22 × 22 mm Ti staple	Lateral column lengthening in PTTD
12	Two 20 × 20 × 9 mm cages + 15 × 15 × 9 mm cage + 2 6.5 × 85 mm CS + 22 × 22 mm Ti staple	Subtalar joint fusion with lateral column lengthening in PTTD
13	20 × 20 × 11 mm cage + 6.5 × 85 mm CS + 22 × 22 mm Ti staple	Lateral column lengthening in PTTD
14	Two 20 × 20 × 13 mm cages + 2 6.5 × 85 mm CS	Subtalar joint fusion
15	20 × 20 × 11 mm cage + 10 mm step plate + 16 × 15 mm Ti staple	Lateral column lengthening in PTTD
16	20 × 20 × 7 mm cage + 10 mm step plate + 16 × 15 mm Ti staple	Lateral column lengthening in PTTD
17	Two 20 × 20 × 11 mm cages + 15 × 15 × 7 mm cage + 6.5 × 85 mm CS + 4.0 × 30 mm CS	Subtalar joint fusion with lateral column lengthening
18	Two 20 × 20 × 13 mm cages + 15 × 15 × 9 mm cage + 6.5 × 85 mm CS + 4.0 × 34 mm CS	Subtalar joint fusion with lateral column lengthening
19	20 × 20 × 9 mm cage + 10 mm step plate + 4.0 × 28 mm CS	Lateral column lengthening in PTTD
20	20 × 20 × 11 mm cage + 6.5 × 90 mm CS + 4.0 × 30 mm CS	Lateral column lengthening in PTTD
21	15 × 15 × 11 mm cage + 6.5 × 85 mm CS	Subtalar joint fusion
22	20 × 20 × 11 mm cage + 10 mm step plate + 4.0 × 30 mm CS	Lateral column lengthening in PTTD

Abbreviations: CS, cannulated screw; MTP, metatarsophalangeal; PTTD, posterior tibial tendon dysfunction.

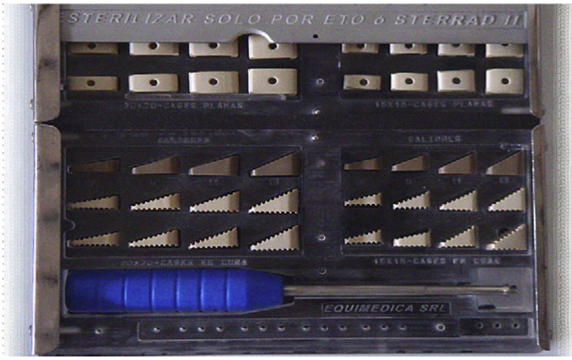

Fig. 2. The two different types of PEEK cage design: box-shaped and wedge-shaped.

A fifth metatarsal stress fracture happened at 6 months postoperatively followed by a fourth metatarsal stress fracture at 9 months in the same patient (#9), probably because of lateral overlengthening, which healed with conservative treatment.

No local complications were reported at the donor site.

DISCUSSION

There are more than 200 publications on the use of the PEEK implant on PubMed, the majority being related to spine surgery. No reports were found on the use of PEEK in foot and ankle surgery.

Fig. 3. Lateral column lengthening.

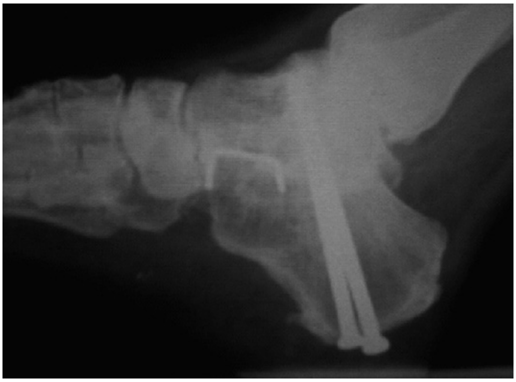

Fig. 4. Subtalar fusion.

Fig. 5. Tarsal arthrodesis.

Fig. 6. Two years after surgery.

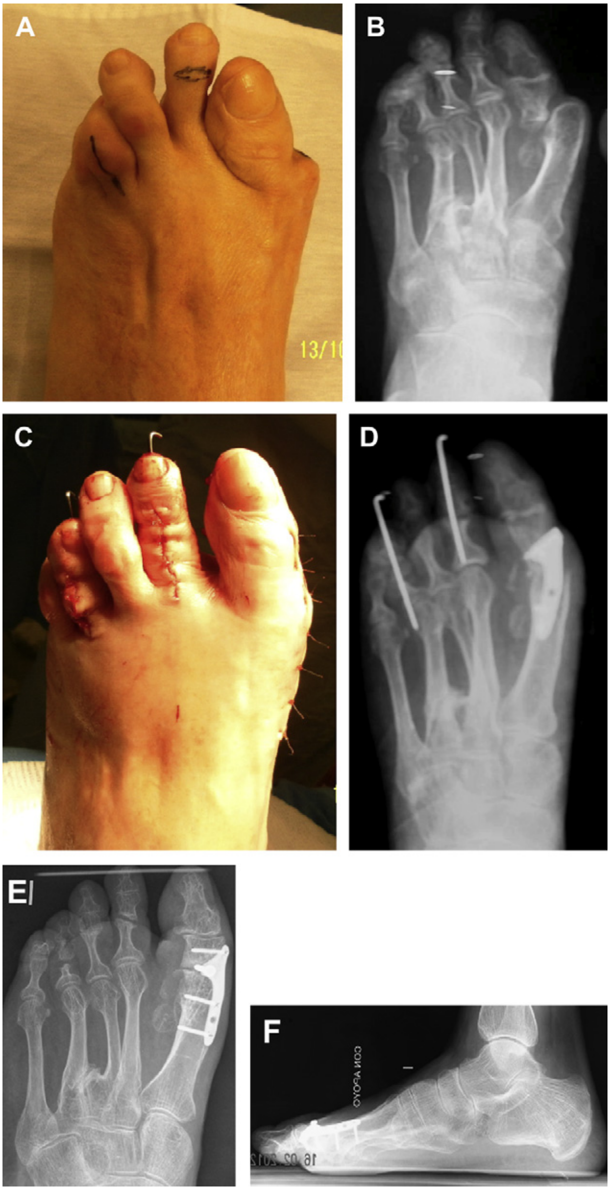

Fig. 7. (*A*) Preoperative photo. (*B*) Preoperative radiograph. (*C*) Postoperative photo. (*D*) Postoperative radiograph. (*E*, *F*) Postoperative (1 year) radiographs of an akin osteotomy.

The PEEK cage demonstrated absence of cytotoxicity and mutagenicity in an in vitro study.[16] The modulus of elasticity of PEEK is similar to bone. Lee and colleagues[17] showed that patients treated with posterior lumbar interbody fusion (PLIF) using harvested local bone inserted into a PEEK cage had a high rate of fusion: The 6-month fusion rate of the segment was 86.7%, which increased to 90.0% at 12 months (Three-dimensional CT scans were performed to check this). In the authors' study, bone fusion was obtained in 95% of the patients within 14 weeks. Perhaps this difference between series is related to differences in biomechanics.

Implantation of empty PEEK cages after anterior cervical discectomy shows an unexpectedly low rate of fusion according to radiologic criteria (bony fusion was present at 71.7%).[18] In 2008 Liao and colleagues[19] obtained 74% bone fusion after filling the cages with cancellous allograft bone. Allograft bone is not often available in Argentina because it is very expensive. It has some risk of bacterial contamination and viral transmission, albeit very small.[20,21]

Empty cages or cages with cancellous allograft bone were not used by the authors, the rates of fusion being judged to be low.

The use of bone morphogenetic protein for filling the cage has been associated with a greater amount of resorption and migration of the implant.[22]

SUMMARY

- PEEK cages are an effective alternative when structural bone graft is needed for different fusions around the foot and ankle.
- Bone fusion rates are high when PEEK cages are filled with autologous bone.
- No difference in consolidation time in patients was noticed between the cages fixed with staples and those fixed with cannulated screws.
- Nerve damage, residual pain at the donor site, and cosmetic problems are avoided with the use of PEEK cages.
- There is no risk of transmission of hepatitis B, hepatitis C, and HIV when using PEEK cages.

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