Use of Poly Methyl Methacrylate as Prosthetic Replacement of Destroyed Foot Bones – Case Series

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Abstract:
Osteomyelitis and Charcot osteoarthropathy result in the destruction of foot bones. Amputation and excision of the involved bones results in altered biomechanics, new pressure points and callus ulcers. We replaced these destroyed bones in six patients (four patients had osteomyelitis and two patients had Charcot destruction) using poly methyl methacrylate (PMMA) as a prosthetic. This helped us avoid amputation and provide the patients with a cosmetically acceptable and functioning foot. Our follow up has shown that except for one patient who did not offload the affected limb in the immediate postoperative period and one who is being offloaded postoperatively, all are ambulant and have not developed new foot problems.

Key words: PMMA, Charcot foot, Osteomyelitis, Diabetic foot

Introduction

The prevalence of osteomyelitis in the diabetic foot has been found to vary between 18% to 68% in various studies. The treatment varies according to the extent of osteomyelitis and the degree of destruction of the involved bones. Limited and focal osteomyelitis seen on imaging with the probe to bone (PTB) test resulting negative is initially treated with empirical antibiotics. The choice of antibiotics should be guided by the sensitivity and frequency patterns of culture studies. In more extensive osteomyelitis or in cases where the osteomyelitic bone is easily approachable (PTB is positive), treatment with long term bone biopsy culture directed antibiotics is considered the gold standard. When small bones or segments of long bone are destroyed they can be resected and stabilized by external fixators. Arthrodesis of the foot and ankle may be the only alternative when the joints are destroyed. Amputation above the infected part may have to be considered when limb salvage is not possible.

A recent development in the treatment of osteomyelitis is the use of Polymethyl Methacrylate Antibiotic Laden Cement (PMMA-ALC) beads. This modality has been shown to be very effective in chronic and acute osteomyelitis where sustained higher bone and tissue concentrations can be achieved compared to systemic administration. This is because the systemically administered antibiotics fail to reach required concentrations due to coexisting Peripheral Occlusive Vascular Disease.

Armstrong has reported the prevalence of Charcot foot to be approximately 0.16% in general population and about 13% in the high risk diabetic patients presenting to a foot clinic. The acute Charcot foot is treated conservatively by off-loading the foot using a total contact cast (TCC). Administration of both intravenous (zolendronate) or oral (alendronate) bisphosphonates and (intranasal) calcitonin have been found to be useful in some studies. When the patient presents with a deformed or fractured Charcot foot, it may be reconstructed.
surgically using plates, screws and implants.\textsuperscript{13}

In unsalvageable cases where the foot is too deformed or bone destruction is extensive (bag of bones), the foot may have to be amputated.

\textbf{Patients / Materials and methods}

Preoperative bone cultures are sent from the osteomyelitic site so that heat stable culture specific antibiotics can be added to the poly methyl methacrylate (PMMA) cement before shaping it into the implant. A vascular work-up and revascularization is often necessary to ensure that blood supply and tissue oxygenation levels are adequate for the healing of surgical wounds.\textsuperscript{16} The patient’s foot is assessed with X-rays/multi dimensional computerized tomography (MDCT) scans to see whether the damaged bone can be replaced. Before surgery it must be ensured that the soft tissue infection is eliminated and the skin is intact. The cost, implications and follow-up of the surgery including the period of offloading and dangers of non-compliance are discussed with the patient. Spinal anesthesia or a regional block (popliteal or ankle) is usually preferred depending on the site involved.

\textbf{Poly Methyl Methacrylate (PMMA)}

PMMA is a powder that hardens with an exothermic reaction when a monomer reagent is added to it, forming a hard substance with a consistency similar to bone. Before setting and hardening completely it may be molded to the desired shape. This material is almost inert and has been used extensively in the field of orthopedics in hip and knee joint replacement surgeries.\textsuperscript{17}

\textbf{Poly Methyl Methacrylate Antibiotic Laden Cement (PMMA-ALC)}

Bone culture specific heat stable antibiotics are added to the bone cement\textsuperscript{18} in cases with osteomyelitis. Prophylactic antibiotics may be added when the prosthesis is made for replacing the non-infected, destroyed bones of a Charcot foot.

\textbf{Case 1}

A 51 year old diabetic male presented with a deformed and acutely inflamed midfoot Charcot arthropathy (\textit{Figure 1}).

The X-ray showed features suggestive of midfoot Charcot (\textit{Figure 2}). This was substantiated with technetium 99 regional scintigraphy (Tc99) studies (\textit{Figure 3}).
Surgical Procedure

1) Amrita Sling Technique

Lateral and medial incisions, 3 to 5 centimeters long, slightly dorsally placed, are made at the midfoot level. The nerves and vessels are retracted out of the way. The incisions are then deepened to the bone level. After necessary excision of bony prominences, a blunt tipped artery forceps is passed close to the tarsal bone. This can be done from medial to lateral or in the opposite direction. Taking extreme care not to damage the plantar vessels, a space of about a five-centimeter width is created. A polypropylene mesh, of 10 x 7 centimeters in dimension, is folded so as to get a double layer of a 5-centimeter width. This is then passed along the passage created in the midfoot area. Next, with a K-wire and driver, a hole is drilled just above the medial and lateral malleolar prominences, not involving the ankle joint. With the help of a thin malleable probe, a number 2 Fiberwire suture is passed through this hole.

The patient was treated initially with intravenous zolendronate and offloading with a bivalve walking total contact cast for a period of three months. Once the acute phase had resolved he was taken up for reconstructive surgery. The preoperative computerized tomography scan (Figure 4) showed destruction and displacement of the cuneiform bones of the right foot. It was decided to replace them with a poly methyl methacrylate prosthetic and reinforce the medial and lateral arches with the Amrita sling technique.  

Figure 2. X-ray of the same foot showing Charcot changes

Figure 3. Tc99 scan showing increased uptake in the midfoot region

Figure 4. MDCT scan showing destroyed cuneiforms of the right foot
Using a long, thin Kelly’s forceps, a deep subcutaneous tract is made on either side of the foot and ankle, from the midfoot plantar incision sites up proximally to the Fiberwire on either side of the ankle. Care is taken not to injure the posterior tibial and peroneal arteries. The suture is pulled down subcutaneously to the site of the polypropylene mesh. The two ends of the suture are then tied on to the ends of the mesh, using a round tipped needle. While doing this, proper tension is maintained on the mesh, so that it snugly fits under and around the sides of the midfoot tarsal bones. An assistant holds the foot in the desired neutral position of the foot and ankle, while the suture is being tied on to the mesh. A suction drain is placed just under the mesh. The incision sites are closed in layers with appropriate sutures. The wounds are dressed and a graduated compression bandage is applied. A fiberglass posterior splint is applied with the foot and ankle in the neutral position.

One modification that has been recently incorporated is the elimination of the polypropylene mesh because of the slightly increased risk of infection. The Fiberwires are now passed underneath the arches and are tied together to support them like a hammock.

2. PMMA prosthetic replacement

The damaged bone or part of the bone is then resected (Figure 5). The size of the replacement is assessed by measuring the dimensions of the resected bone or the void left after its removal (Figure 6, 7, 8). The PMMA and antibiotic powders are mixed with the reagent and molded into the required dimensions over a titanium screw or K-wire within the setting time (Figure 9, 10). A K-wire is passed through the adjacent bones under fluoroscopic control (Figure 11, 12). The K-wire is removed after reaming the bones and the prosthetic screwed in place (Figure 13, 14, 15, 16).

The correction of deformity is evident from pre and postoperative (Figure 17, 18). The postoperative X-rays show the near perfect alignment of the prosthesis (Figure 19, 20).
Figure 7. Assessing the void left after excision of the bones

Figure 8. Measuring the dimensions of the space to be filled

Figure 9. PMMA powder being mixed

Figure 10. Molding the PMMA cement into the required dimensions

Figure 11. K-wire being passed through adjacent bones under fluoroscopy.

Figure 12. K-wire passed through the navicular bone
Figure 13. The navicular bone being reamed over the K-wire

Figure 14. The prosthesis being screwed into place

Figure 15. The prosthesis in place

Figure 16. The C-arm shows the prosthesis in place

Figure 17. Preoperative foot with medial bump

Figure 18. Postoperative foot
Six cases treated by PMMA-ALC prosthesis replacement

Our first patient had Calcaneal Osteomyelitis (Figure 21).

We replaced the calcaneus with a PMMA-ALC prosthesis (Figure 22,23).

The patient is now ambulant on molded footwear. Our second patient had osteomyelitis of the proximal phalanx of the great toe. We did a phalangeal replacement (Figure 24). The patient is now ambulant with anterior Ortho-Wedge shoes. Our third patient had osteomyelitis of the fourth metatarsal head (Figure 25). This was resected and replaced with prosthesis (Figure 26). The patient is mobile on standard footwear. The fourth patient had osteomyelitis of the great toe distal phalanx (Figure 27), which was resected and replaced (Figure 28). However, the patient did not offload postoperatively. The K-wire and prosthesis were displaced and was subsequently removed. Patient number five (previously illustrated) had destroyed cuneiform bones due to Charcot arthropathy (Figure 29). They were resected and replaced (Figure 30).
Figure 25. X-ray showing destroyed 4th metatarsal head

Figure 26. Reconstructed Metatarsal Head using PMMA prosthesis

Figure 27. Left great toe distal phalangeal osteomyelitis

Figure 28. PMMA prosthesis replacing the distal phalanx

Figure 29. X-Ray shows destroyed and displaced cuneiform bones

Figure 30. PMMA prosthesis used to replace the cuneiforms
He is now ambulant on molded footwear. Our final patient developed Charcot destruction of the right talus and calcaneus following neuropathy secondary to spinal trauma. With the help of maxillofacial surgeons we were able to make a talocalcaneal implant of PMMA, which was used to replace both the bones using the Amrita sling technique. Postoperatively this patient has been discharged with instructions for offloading.

A total of six patients have undergone prosthetic replacement of the destroyed bones. Four patients had osteomyelitis and two had Charcot as the pathology. Our first patient had calcaneal osteomyelitis. We replaced the calcaneus with a PMMA prosthesis. On follow up for two years the patient is ambulant on molded footwear and has not reported any foot problems. Our second patient had osteomyelitis of the proximal phalanx of the great toe. We did a phalangeal replacement. He has been on follow up for a year. The patient is ambulant with anterior Ortho Wedge shoes. Our third patient had osteomyelitis of the fourth metatarsal head that was resected and replaced with an appropriately sized prosthesis.

The patient has been walking using prescribed diabetic footwear and has had no foot problems in the past twelve months of follow up. Our fifth patient had destroyed cuneiform bones of the right foot due to Charcot arthropathy. They were resected and replaced with the prosthesis. He is now ambulant on molded footwear and is reporting no associated problems. The sixth patient in the series who had an osteolytic talus and calcaneus due to Charcot arthropathy underwent replacement of both bones with PMMA. The patient has been discharged with instructions to offload the right foot and review after several weeks.

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Follow up</th>
<th>Present state</th>
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<tbody>
<tr>
<td>Calcaneal osteomyelitis</td>
<td>2</td>
<td>Ambulant</td>
</tr>
<tr>
<td>Right great toe proximal phalanx</td>
<td>1 year</td>
<td>Ambulant</td>
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<tr>
<td>Right 4th metatarsal head osteomyelitis</td>
<td>10 months</td>
<td>Ambulant</td>
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<tr>
<td>Charcot destruction of right cuneiform</td>
<td>5 months</td>
<td>Ambulant</td>
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<tr>
<td>Left great toe distal phalanx</td>
<td>6 months</td>
<td>Ambulant but prosthesis had to be removed after it was exposed following walking barefoot within 2 weeks of surgery</td>
</tr>
<tr>
<td>Charcot destruction of right foot talus and calcaneus</td>
<td>2 weeks</td>
<td>Patient is offloaded</td>
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Our fourth patient in the series who had osteomyelitis of the left great toe distal phalanx underwent prosthetic replacement of the same. She, however, failed to comply with our instructions for off-loading the foot postoperatively and walked barefoot on the sixteenth postoperative day resulting in wound dehiscence, displacement and expulsion of the prosthesis. She is ambulant at present but has a partial great toe.

Hence four (three osteomyelitis and one Charcot) of our operated patients are ambulant on molded or modified footwear and have a functionally and cosmetically acceptable foot. One patient who has recently undergone surgery is awaiting removal of sutures and is being offloaded. One patient with osteomyelitis did not follow the postop instructions and walked on sixteenth day post surgery resulting in displacement and exposure of the prosthesis, which had to be removed.

Discussion

The diabetic foot is very prone to both osteomyelitis and Charcot neuroarthropathy. The destruction or excision of the foot bones result in both deformed feet with altered biomechanics and the appearance of new pressure points in regions of the foot unaccustomed to bear such forces. This results in formation of calluses and ulcers. The infection, non-healing, and progression of these ulcers very often lead to loss of the limb. Amputations of the toes and limb not only place limitations on the physical activity of the patient, but also are not cosmetically appealing.

The treatment of osteomyelitis requires that sufficiently high concentrations of antibiotic be present in the involved bone and surrounding tissue. However, due to coexisting peripheral occlusive vascular disease the antibiotics seldom reach the required concentrations\(^\text{20}\). Also, the systemic doses of antibiotics may be too high for the patient whose liver and renal functions may have already been compromised.

Our treatment modality attempts to replace the destroyed bone and correct the deformity, thus restoring the normal biomechanics of the foot almost completely and preventing the appearance of new ulcers and further deformities. Furthermore, as substantiated by other studies, we too by using antibiotic laden PMMA prostheses may be able to achieve higher local concentration of antibiotics well below the toxic level of systemic administration.\(^\text{19}\)

Patient selection is very important before surgery. Only patients who will comply with the postoperative instructions should be given this option of prosthetic replacement. It is necessary that the patient have sufficient vascularity in the lower limbs based on ABI and TcpO2 values to permit adequate healing of the surgical wounds. Only patients who can be revascularized by angioplasty or vascular bypass to improve their vascularity can be offered this modality of treatment.

Patients have to undergo a multi-dimensional computerized tomography scan with three-dimensional reconstruction of the foot if bones other than the phalanges are involved. Only after analyzing the image can a decision is made whether the displaced and damaged bone can be replaced, and what surgery is to be done.

In case of osteomyelitic destruction of the bone, a bone biopsy is sent for cultures and antibiotics to be added to the PMMA are determined based on the reports. In case of destruction of bones due to Charcot arthropathy, we prophylactically add antibiotics. This is to prevent secondary infection when the foot is vulnerable in the immediate postoperative period. The antibiotics should be heat stable as the setting of the PMMA is an exothermic reaction.

Once the patient is deemed fit for surgery, under regional anesthesia incisions are made to avoid vascular damage and the destroyed bones
In conclusion, this technique of prosthetic replacement and arthroplasty is an effort to salvage the diabetic foot by replacing the damaged bones rather than simply removing them. With good patient compliance the results have been very encouraging. Being cosmetically more acceptable and having the potential to provide the patients with a biomechanically stable and functional foot is a major advantage of the procedure.

are removed. PMMA powder and the antibiotics are added to the monomer reagent. They are mixed well and molded into the required shape on the back table. The excised bones may be used as grafts to fill the gaps. Under fluoroscopy the prosthesis is screwed into place. If the mid foot bones are replaced, an Amrita sling is applied to support the arches and prevent further collapse. The soft tissue is closed with Vicryl sutures and nylon over a closed vacuum drain. A posterior slab splint is used to immobilize the foot.

The patient is continued on intravenous antibiotics until the drain is removed. Oral antibiotics are continued from date of discharge until skin suture removal. The foot is offloaded for at least three months allowing the fibrosis and soft tissue healing to consolidate and support the prosthesis preventing its displacement. Once the X-rays reveal no abnormality and wounds have healed completely the patient is provided with molded footwear with strict instructions for wear whenever walking or standing indoors or outdoors. If phalangeal replacement has been done first the patient may be initially mobilized on anterior Ortho Wedge shoes followed by diabetic footwear. Patients are asked to return for review once every three months.

There are major advantages of the procedure as a future digital or foot amputation may be averted. The replacement rather than only excision of the bone may prevent further derangement of the pedal architecture and biomechanics.

Reconstruction techniques using the Ilizarov method has disadvantages like pin tract infections. The use of the Amrita sling technique to support the arches eliminates the need for any external fixation and risk of pin tract infection. Internal fixation using plates and screws look good immediately postoperatively, but once the patients starts walking and the bone density further falls there may be loosening and displacement of the plates resulting in collapse of the foot arches. In this technique with time, unlike other implants, the prosthesis is held more firmly in position by soft tissue fibrosis. The use of implants without antibiotic impregnation put the already immune-compromised foot at risk for further infection. Our procedure, on the other hand, decreases the risk of infection due to higher local antibiotic concentrations. Also, this procedure is more cosmetically acceptable to the patient.

There are a few risks and limitations of the procedure. If the vascularity has been compromised during the surgery the foot may develop gangrene. Also, the prosthesis evokes an inflammatory reaction, which causes soft tissue swelling. The foot, being a closed compartment, is at risk of further vascular compromise. The prosthesis never integrates with the bone and is held in place by the screws and soft tissues around it. Since the bone density is low, there is always a chance of the screws becoming loose and the prosthesis being displaced if the soft tissues are not able to hold it in place. Though there have been no recurrences of the ulcers, it has not been proven by in-shoe pedopodogram that the biomechanics are unaltered. Furthermore, our follow up has been for short periods and cases are few.
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