Displaced intra-articular calcaneal fractures treated with open reduction internal fixation (ORIF) combined with an injectable and bone remodeling bone substitute (CERAMENT™|BONE VOID FILLER): A preliminary report.

Author: Papadia D.
Department of Orthopaedic and Traumatology Surgery, Santa Chiara hospital Trento, Italy

Abstract
Displaced intra-articular calcaneal fractures Sanders 3 and 4 leaving a large bone void after reposition, continue to pose a therapeutic challenge. The purpose of this study was to determine the effects of open reduction and internal fixation (ORIF) combined with the injectable bone substitute CERAMENT™|BONE VOID FILLER in patients with a bone gap > 2 cm after reduction. Twelve consecutive cases were included and followed for one year. Two cases underwent minor revisions due to superficial infections. A bone biopsy in one patient, taken after 5 months, showed bone formation at multiple sites in the implanted material. In all patients, full bone healing was demonstrated on X-ray after one year, with no deterioration of the Böhler angle. From this preliminary report, it is concluded that filling large bone defects with CERAMENT™|BONE VOID FILLER (BONESUPPORT AB, Sweden) can result in full bone remodeling and a preserved Böhler angle after one year.

Introduction
Intra-articular fractures of the calcaneus are severe injuries, often with devastating, life-altering consequences. Many patients remain incapacitated for 3 to 5 years after injury and often never return to full function. The majority of fractures involve young working males, and the economic impact of these fractures is substantial. The treatment of calcaneal fractures remains a debated topic with non-conclusive study results, especially in displaced intra-articular calcaneal fractures Sanders 3 and 4 with significant voids after reduction and a risk of secondary collapse and reduced Böhler angle.

Although bone grafts have been used for decades, conventional bone grafting appears to not accelerate healing or reduce the time to weight-bearing, while causing significant morbidity from the harvest site. Thus, it has been claimed that with proper surgical technique, bone grafting can be avoided.

However, more recently the introduction of synthetic biologic materials has opened new prospects for treatment. Thus, the use of calcium phosphate cements have been reported to allow early weight-bearing in calcaneal fractures. For example, in a study on Norian SRS, biopsies showed nearly complete bone apposition, areas of vascular penetration, and reversal lines illustrating progressive cycles of resorption and new bone formation. Curing calcium phosphate cements do, however, have the drawback of slow bone remodeling, with a risk of late material fracture or hematogenous osteomyelitis facilitated by the presence of a foreign body.

We have experienced a number of cases with significant bone defects after treatment with ORIF LCP without filling the void, that have demonstrated loss of calcaneal height of the posterior facet and reduction of Böhler’s angle following full weight bearing. We thus decided to use an injectable composite ceramic bone void filler that has typically transformed into bone within a year (CERAMENT™|BONE VOID FILLER) in a series of patients with displaced intra-articular calcaneal fractures (DIACFs) Sanders 3 and 4, and a significant bone defect after reposition.

Material and Methods
During two years, patients older than 20 years with displaced intra-articular calcaneal fractures (DIACFs) and a significant bone defect over 2 cm after open reduction and internal fixation (ORIF), were included in the study. Exclusion criteria were a history of anaphylactic reaction to iodine-based radiopaque contrast agents, known bleeding disorders, hyperthyroidism or thyroid adenoma.

After appropriate antibiotic prophylaxis, a pneumatic thigh tourniquet was applied and inflated to 350 mm Hg. All surgeries were performed by the same surgeon with lateral approach and a full-thickness flap, followed by Kwire repositioning of articular bone fragments under fluoroscopy, and fixation with LCP plate and cancellous screws. After full fixation, a flowable and curing bone substitute (CERAMENT™|BONE VOID FILLER) was applied under fluoroscopy. CERAMENT™|BONE VOID FILLER consists of highly
Fig 1.
a) Displaced intra-articular fracture. b) Postoperative radiogram demonstrating the radiopacity of CERAMENT™|BONE VOID FILLER, and c) Bone healing after 11 months with full weight bearing at 6 months postoperatively.

Fig 2.
Preoperative (a,b) and immediate postoperative radiograms (c,d), with good visibility of the bone void filled with CERAMENT™|BONE VOID FILLER containing the radiocontrast agent iohexol. After 45 days (e,f), iohexol is washed out and early bone formation is seen. In the images taken 5 months after surgery and with the plate removed, radiological bone healing is demonstrated (g, h).

osteoc conducive hydroxyapatite particles embedded in an injectable calcium sulphate (CaS) paste, which is prepared 3 minutes before application by mixing with the water-soluble radiocontrast agent iohexol and water in a closed system. Once implanted, CERAMENT™|BONE VOID FILLER has a wet compressive strength of 5 MPa, which is comparable to that of healthy trabecular cancellous bone. Due to the microporosity of the CaS, an immediate flow of tissue fluids with nutrients and growth factors are allowed to penetrate the implant. Full transformation and remodeling into mature bone in 6-12 months has been shown in case studies.19-22

Clinical follow up was performed according to clinical practice and included radiographic and clinical examination at 1 year. A CT scan was taken preoperatively to examine the fracture, for surgery planning and for fracture classification according to Sanders.

**Results**
In total 12 patients with DIACF (8 male), age 48 ± 17 (mean ± SD), were included over a two year period. Three of the patients presented with bilateral fractures. All fractures were treated with ORIF and the average volume of CERAMENT™|BONE VOID FILLER used was 10 cc (Fig 1). Fracture reduction and correction of the Böhler angle was successful in all cases. Two patients developed superficial infections that were treated with debridement and antibiotics.

In a 54 year old female allowed full weight bearing after 3 months, it was decided to remove the plate after 5 months due to local discomfort (Fig 2), and a bone biopsy was taken from the implant region.

*Animal Studies and case studies are not necessarily indicative of clinical results.
Histology from the biopsy demonstrated residual CERAMENT™|BONE VOID FILLER with bone formation at multiple sites, no giant cells, and a tight junction without interposition of fibrous tissue between CERAMENT™|BONE VOID FILLER and newly formed bone (Fig 3).

Fig 3.
Bone biopsy (a) taken 5 months after implantation with CERAMENT™|BONE VOID FILLER. Newly formed bone intersperses with CERAMENT™|BONE VOID FILLER at multiple sites. Note the direct contact between ingrowing bone and CERAMENT™|BONE VOID FILLER without fibrous tissue or foreign body cells (b).

All patients presented with preserved Böhler angle and full bone healing after 12 months, and no re-operations were needed.

Discussion
The question, whether or not to utilize bone grafts to fill voids in connection with ORIF in calcaneus fractures, goes beyond the scope of this preliminary report. Irrespective of using autogenous or allogenic bone grafts, there exist disadvantages that cannot be overlooked, for instance donor site pain and morbidity, blood loss, infection, slow rate of incorporation and secondary fractures. For these reasons there has been an emergence of bone graft substitutes in the area of trauma and orthopedic surgery. In this study we wanted to investigate the use of a biphasic and highly biocompatible bone substitute with attractive handling properties. CERAMENT™|BONE VOID FILLER bioceramic bone substitute, which consists of hydroxyapatite embedded in a synthetic calcium sulphate carrier and mixed with the radiocontrast agent iohexol to form an injectable and hardening paste, possesses a combination of distinctive advantages that warrant its use. A passive precipitation of hydroxyapatite on the surface of the implant20 allows the bone void filler to be replaced by ingrowing bone that typically remodels to form trabeculae.24, 25

It can be preliminary concluded that radiological and clinical healing was obtained in all cases of our study. It is also worth noting that no postoperative compression occurred during the follow-up period of 12 months. It is preferable with a compressive strength and stiffness similar to that of the cancellous bone being substituted, and a bone regeneration rate with subsequent remodeling, that takes place over the shortest possible time. In our preliminary results, CERAMENT™|BONE VOID FILLER fulfills these requirements. The product delivers hydroxyapatite particles embedded in an injectable and curable calcium sulphate paste combined with the water-soluble radiocontrast agent iohexol. This composite has the porosity and interconnectivity to allow for efficient osteoconduction. Interestingly, histology from a bone biopsy taken after 5 months showed multiple sites of bone regeneration with the new bone interspersing with CERAMENT™|BONE VOID FILLER.

In conclusion, CERAMENT™|BONE VOID FILLER is a material with attractive handling properties and has shown remodeling to bone in 6-12 months,19-22 which makes it an attractive alternative to autologous bone or allografts. Although an animal study22 and case studies on osteoporotic patients,19-22 have demonstrated bone remodeling after treatment with CERAMENT™|BONE VOID FILLER, the concept has to be further proven in studies comparing the outcome with that obtained after autologous bone transplant.

*Animal Studies and case studies are not necessarily indicative of clinical results.
References


CERAMENT™ BONE VOID FILLER is a trademark of BONESUPPORT AB.

All trademarks herein are the property of Biomet, Inc. or its subsidiaries unless otherwise indicated.