



## RESEARCH

# Primary cancellous bone formation around micro-chambered beads<sup>☆</sup>



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### KEYWORDS

Bone substitute;  
Cancellous bone;  
Bone defect;  
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Open wedge osteotomy

### Abstract

**Objectives:** The question has been raised whether benign bone defects in patients can be treated with bone forming osteoconductive ceramics achieving primarily a cancellous bone scaffold, which is under load from the beginning.

**Materials and methods:** Ten reconstructions were performed in 9 patients (6 women and 3 male), with a mean age of 49 (25–65) years, suffering a high variety of epi- and metaphyseal defects, four tibial fractures, two calcaneal fractures, one pathological phalangeal fracture, one chondroma of the distal femur and two open-wedge osteotomies were filled with micro-chambered ceramic beads of 4 and 6 mm in diameter. The mean follow-up was 22 (7–8) months. X-rays and CT-scans formed the basis for the evaluation of the reconstruction of the cancellous bone scaffolds.

**Results:** All cancellous structures were rebuilt, if completely filled with bone-forming elements. If the filling was incomplete, no physiological cancellous bone scaffold resulted. The  $\beta$ -TCP micro-chambered beads were completely reabsorbed or sandwich-like incorporated at the time of evaluation. The HA micro-chambered beads revealed a contrast enhancement and were integrated in the osseous construction of the bone scaffold.

**Conclusion:** Primary cancellous bone formation can be achieved with osteoconductive ceramic micro-chambered beads and can be combined with any osteosynthesis for stable fixation.

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**PALABRAS CLAVE**

Sustitutivo óseo;  
 Hueso esponjoso;  
 Defecto óseo;  
 Fractura;  
 Osteotomía de  
 apertura

**Formación de hueso esponjoso con esferas microcompartimentales****Resumen**

**Objetivo:** Analizar el resultado del tratamiento y la evolución de los defectos en el hueso trabecular en pacientes tratados con cerámicas osteoconductoras.

**Material y métodos:** Se estudiaron 10 reconstrucciones efectuadas en 9 pacientes (6 mujeres y 3 hombres) con defectos epifisarios y metafisarios, con una edad media de 49 (rango: 25-65) años en diferentes etiologías, 4 fracturas de tibia, 2 fracturas del calcáneo, una fractura patológica de metatarsiano, un condroma de fémur distal y 2 osteotomías de apertura. Los defectos se rellenaron con esferas de cerámica de  $\beta$ -fosfato tricálcico ( $\beta$ -TCP) e hidroxiapatita, de 4 y 6 mm de diámetro. El tiempo medio de seguimiento fue de 22 (7-48) meses. La evaluación de la reparación se realizó con radiografías y TC.

**Resultados:** En todos los casos observamos la reconstrucción trabecular. Cuando el relleno era completo se observó la formación de hueso; por el contrario, si era incompleto no se apreció la formación de hueso trabecular. Las esferas fueron completamente reabsorbidas o integradas en el momento de la evaluación. Por su parte, las esferas de hidroxiapatita mostraron un mayor contraste en las imágenes, aunque se integraron en el esqueleto óseo.

**Conclusión:** La formación primaria de hueso esponjoso se puede lograr con cerámicas osteoconductoras que se pueden combinar con cualquier tipo de osteosíntesis.

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**Introduction**

Occasionally, in epiphyseal and metaphyseal fractures, particularly in osteoporotic bones, tumors, cysts, after an infection, in loosened implants and in open wedge osteotomies, large cancellous bone defects are created which are difficult to fill. There are very few studies on cancellous bone repair,<sup>1,2</sup> and it has even been reported that trabecular bone defects cannot be repaired.<sup>2</sup> After studying biopsies taken from patients treated with compression arthrodesis, Charnley and Baker<sup>1</sup> indicated that cancellous bone healing offers low osteogenic activity. Based on this observation, Radin and Rose<sup>3</sup> explained the pathogenesis of osteoarthritis noting that the calcified cartilage plate distributed the stresses of the underlying elastic cancellous bone, so that any defects in the trabecular bone altered the distribution of impacts on the joint surface. However, most studies have focused on proving joint incongruity, insufficient reduction, instability or metabolic changes in the joint cartilage caused by the inflammation itself or by cellular necrosis, following joint trauma.<sup>4</sup>

After their reduction, epiphyseal fractures leave large cancellous bone defects which are responsible for deformities and secondary displacement or epiphyseal subsidence.<sup>5</sup> Therefore, the use of allografts,<sup>6</sup> iliac crest autografts<sup>7</sup> and bone substitutes<sup>8-11</sup> is recommended for the treatment of tibial plateau fractures. The question is whether these methods are able to reproduce the original structure. In some cases, such as metaphyseal fractures in elderly patients with defects or with brittle bones or in tumoral pathological fractures, they have been treated with internal fixation (osteosynthesis) and bone cement (polymethylmethacrylate [PMMA]).<sup>12</sup> PMMA has also been recommended for the treatment of collapses of proximal tibial metaphyseal fractures in elderly patients, in order to enable early load.<sup>13</sup> Moreover, benign bone tumors, paratumoral lesions and those with a low grade of malignancy (giant cell tumors) are often treated by curettage and the defect

is filled with PMMA.<sup>14</sup> On the other hand, bone cysts and open osteotomies have often been filled with granulated bone substitutes<sup>15</sup> which do not reproduce the trabecular structure.<sup>16-18</sup>

The aim of our study was to determine if defects caused in benign skeletal lesions can be treated with osteoconductive ceramics, and whether these treatments regenerate cancellous bone so that it can withstand loads.

**Materials and methods**

Bone defects in the epiphysis and metaphysis of long bones were filled in 9 patients (Table 1). These defects were filled with micro-chambered beads made of  $\beta$ -tricalcium phosphate ( $\beta$ -TCP) or hydroxyapatite (HA) or a mixture of both. The beads had a diameter of 4 and 6 mm (Ceraball®, Karl Storz Endoskope LLC & Co. KG, Tuttlingen, Germany) (Fig. 1). The study was approved by the Ethics Committee of the University, and all patients signed informed consent documents. Osteosynthesis plates (Synthes Inc., Freiburg, Germany) were used in all cases of fracture.

We treated 3 fractures with collapsed lateral condyles of the proximal end of the tibia, 2 distal tibial fractures, 2 comminuted calcaneal fractures, 1 chondroma of the distal femur, 1 enchondroma with pathological fracture of the fifth metacarpal bone and 2 open wedge osteotomies (Table 1).

After fracture reduction or curettage of benign tumors, the spaces were filled with beads and fixed with the appropriate osteosynthesis to stabilize the bone, without destroying the ceramic material. The spheres were placed using a trocar, which was also used to lift the tibial plateau. In the remaining cases, placement was carried out directly into the fracture or within the wedge produced by the osteotomy itself.

Our study included 6 females and 3 males, with a mean age of 45 years (range: 25–65 years), with a mean follow-up period of 22 months (range: 7–48 months) and a minimum

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