Acta orthop. scand. *53,* 513–519, 1982

# VIABILITY AND OSTEOGENICITY OF BONE GRAFT COATED WITH METHYLMETHACRYLATE CEMENT

MOSHE ROFFMAN*, MICHAEL SILBERMANN** & DAVID G. MENDES*

Department of Orthopedic Surgery, The Research Center of Implant Surgery, Rothschild University Hospital* and the Division of Morphological Sciences**, Faculty of Medicine, Technion – Israel Institute of Technology, Haifa, Israel

The idea of utilizing bone grafts during hip arthroplasty has been discussed in the literature and clinical successes have been indicated. These communications, however, did not relate to long-term results. Thus, to date, we still lack sufficient understanding as to the fate of bone grafts when they are coated with methylmethacrylate. In order to elucidate the above issue further an experimental study has recently been initiated in an attempt to provide answers to the following questions: a) do bone grafts remain viable when they are held in place with methylmethacrylate bone cement? and b) do such grafts retain their osteogenic potential? In the present study osteotomies were made in the femora of dogs and cortico-cancellous strips of autogenous bone were placed around the osteotomy site. The grafts were then surrounded by polymethylmethacrylate bone cement. Mechanical examinations and morphological studies, performed 3, 6 and 10 months following surgery, revealed the elaboration of fibro-osseous union. Our present findings tend to indicate that bone grafts, even if they are covered with methylmethacrylate bone cement, still retain their viability as well as their osteogenic potential.

*Key words:* bone cement; bone grafts; bone viability; osteogenesis

Accepted 8.xii.81

During recent years various reports have described the use of bone grafts in conjunction with the use of bone cements (Salvati et al. 1975, McCollum et al. 1980, Heywood 1980). However, despite the fact that clinical experience indicated fairly good results, relatively little is as yet known about the fate of bone grafts when they are placed in close proximity to bone cement such as methylmethacrylate cement. In order to clarify further the nature of the changes taking place in the implanted tissue an experimental model has been established in order to answer two crucial questions: a) do bone grafts tolerate the exothermic polymerization or toxicity of methylmethacrylate cement, and hence retain their viability? and b) do such grafts retain their osteogenic potential?

## MATERIALS AND METHODS

Nine mongrel dogs weighing between 16–18 kg underwent surgery under general anesthesia using intravenous Nembutal (30 mg/kg). All animals received 1.0 gram of Penbritin (I.M.) 2 hours prior to surgery and 1 week thereafter (the same dose per day). Initially, the femurs were osteotomized at about their midshaft and thereafter a sheet of silastic was placed in between the two fragments in order to prevent the elaboration of bony union. The operated femurs were then stabilized through the insertion of an intramedullary rod. During the same operation autogenous bone grafts were obtained from the iliac bone. The bone grafts which measured about 7 cm in length, 4 cm in width and 3–4 cm in thickness were placed (5–6 of them) around the osteotomy site on the femur, thereby ensheathing the operative region from all its sides. Subsequently, the bone grafts were covered with polymethylmethacrylate (CMW) bone cement and in this way were isolated from

0001-6470/82/040513-07 $02.50/0

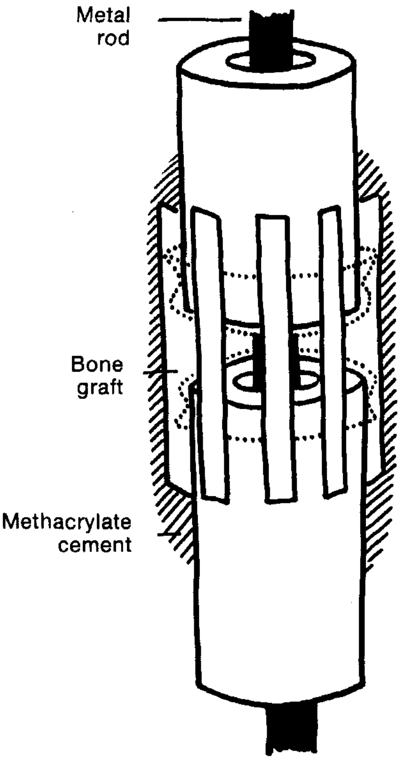

*Figure 1. A graphic representation of our experimental model: the femur has been osteotomized and the free ends of both fragments coated with a silastic sheet to prevent osseous union. Chips of cortico-cancellous bone were placed all around the osteotomy site and the entire region ensheathed by methylmethacrylate bone cement. A metal rod was inserted to provide further stabilization to the operated region.*

the surrounding soft tissues (Figure 1). The contralateral femur, which underwent the same procedure except for the placement of bone grafts, served as control.

The animals were ambulated soon after surgery and were checked periodically for the degree of movement of both the hip and knee joints and for the overall use of the operated legs. Roentgenograms were taken during the second and fourth week after surgery and monthly thereafter. Two dogs were killed after 3 months, three dogs after 6 months and two dogs after 10 months. (Two additional dogs were excluded from this study due to the development of wound infections.) The femurs were dissected out, stripped of all soft tissues, the intramedullary rods removed and the bones were then examined for stability of the osteotomized site. A portion of the bone cement was removed in order to unveil some of the bone grafts and check grossly their location and mode of attachment. Later on, the remains of the bone cement were removed, the femur was sliced in the horizontal plane above and below the osteotomy site, decalcified, and cut into smaller pieces each containing cortical bone of the host and the graft. The pieces were embedded in Paraplast, sectioned serially (6 µm in thickness) and stained with hematoxylin and eosin.

## RESULTS

During the first 2 weeks postoperatively the dogs ambulated with an uneven weight distribution, but later on used their operated legs without difficulty. The range of motion, which was initially rather limited, improved after the third week. Roentgenographical examinations indicated that by 3 months there was an appreciable periosteal reaction around the implanted bone cement (Figure 2). By 6 and 10 months after surgery signs of bony union were noted between the grafts and their host in spite of the existence of a radiolucent line at the osteotomy site (Figure 3). Control

*Figure 2. Radiograph of test femur 3 months following surgery and the implantation of bone grafts and bone cement. Note the pronounced periosteal reactivity (arrow) around the implanted cement.*

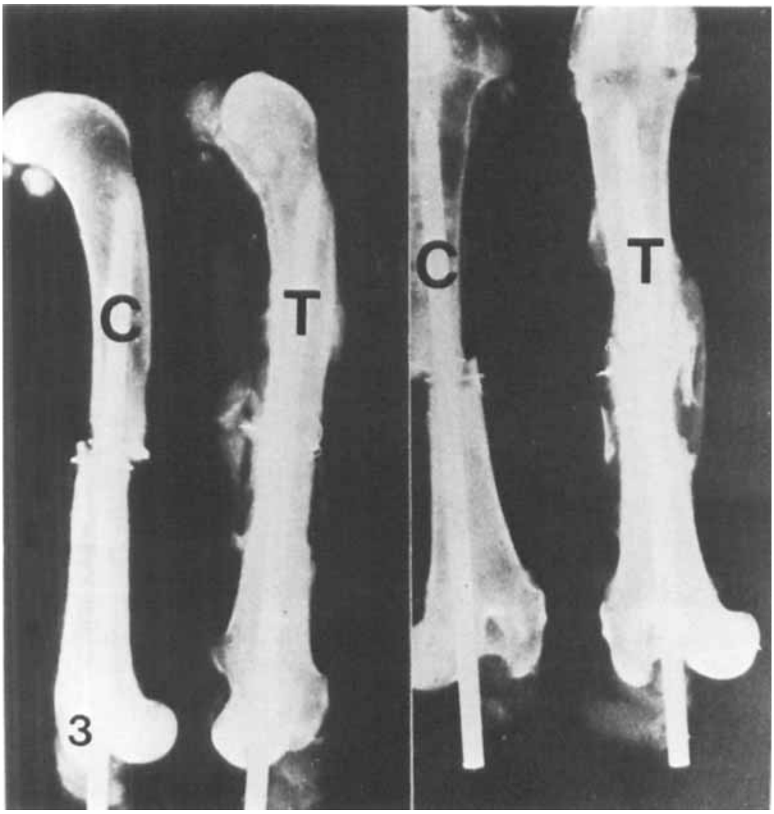

*Figure 3. Radiographs of two different test femurs and their controls 10 months following surgery, revealing obvious differences between those areas that were supplemented with bone grafts and those lacking them. T – test femur; C – control.*

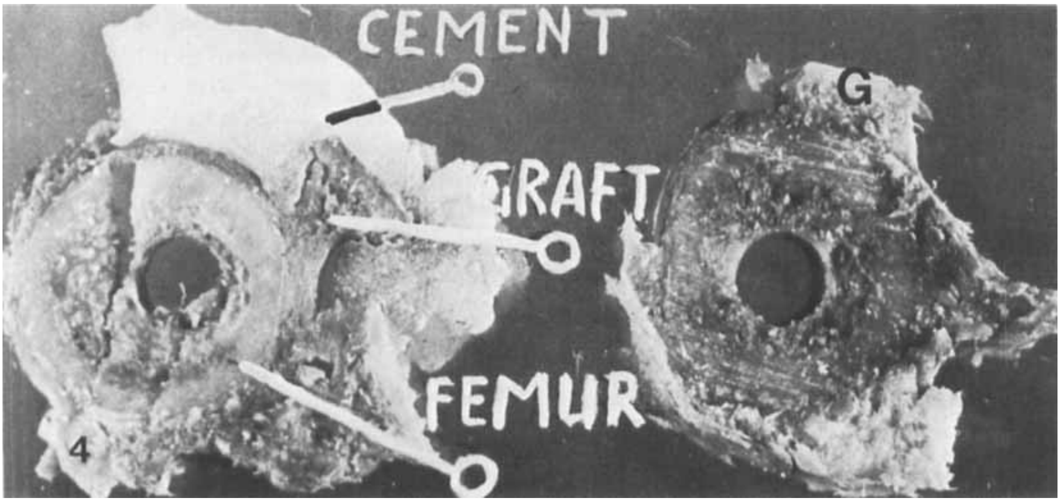

*Figure 4. Photograph of slices of test femurs 10 months following surgery. Note the union of the graft with the host's cortical bone. The specimen on the right side shows the graft (G) after the removal of the cement.*

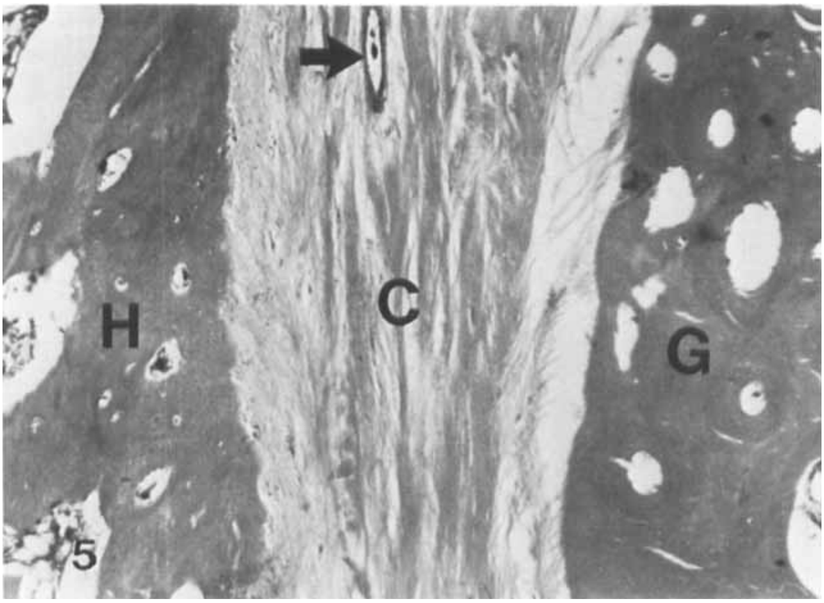

*Figure 5. A section through the interface between the graft (G) and its host (H) as seen 3 months following the osteotomy and implantation procedure. Most of this space is occupied by a dense collagenous material (C). Some capillaries can also be seen in between the collagen fibers (arrow). H&E ×192.*

specimens revealed, consistently, clear signs of non-union.

Following the removal of the intramedullary rod in test femurs, at 6 and 10 months, the osteotomized regions exhibited stability whereas in control femurs the above regions fell apart. Furthermore, after the removal of the cement "coat" it became evident that the grafts were indeed adhered to the femur, a feature that was more clearly demonstrated in the horizontally sectioned specimens (Figure 4).

Morphological examinations revealed that by 3 months the implanted grafts were attached to the cortical bone of the femur via a relatively thick layer of connective tissue containing collagen fibers, small capillaries and fibroblasts. Most of the fibers ran in a parallel direction to the horizontal axis of the shaft (Figure 5). At this stage, the cortical surface of the host, as well as the graft, appeared quiescent as no osteoblastic activity was noted in either bone. Noticeable structural changes became apparent 6 months following the grafting procedure: the "interosseous space" was occupied by a dense collagenous material, many fibroblasts and a well developed vasculature (Figure 6). With time, the gap between the host and the graft decreased with both tissues exhibiting clear signs of bone remodeling: osteoblasis and osteoclasis. Continuous rows of osteoblasts could be identified along the free surface of the graft, as well as that of the host (Figure 7), concomitant with an active resorption process via giant multinuclear cells located within Howship lacunae. This trend of an active constructive response proceeded so that by the tenth month post-surgery many of our test femurs demonstrated newly formed loci of ossification (Figure 8). These loci of new bone formation were for the most part isolated from one another and often also from both the graft and the host. At the same time, the gap between the host and the graft almost diminished with only a minute strip of connective tissue separating the two. Thus, 10 months were necessary for the development of the initial signs of "osseous bridging" in this model system.

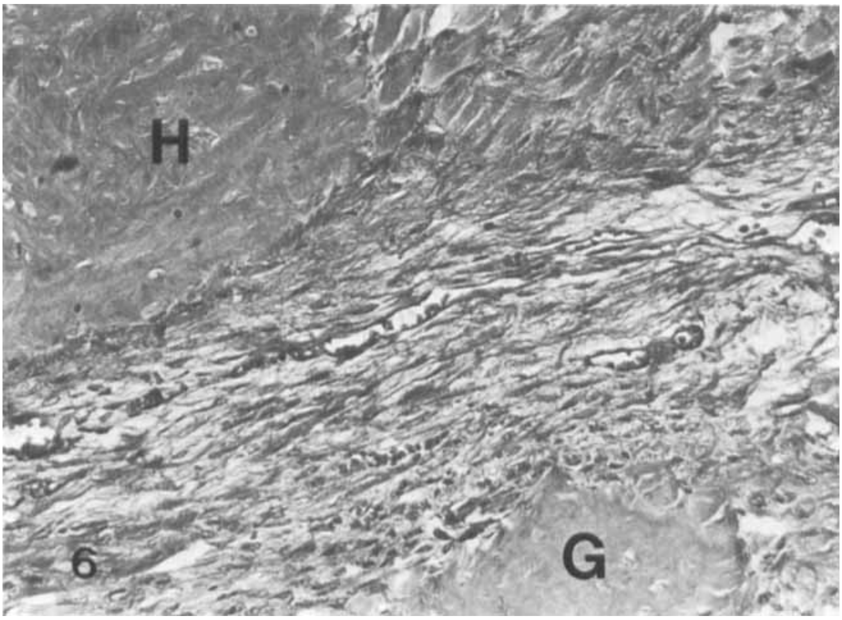

*Figure 6. A similar section to that shown in Figure 5 but obtained 6 months after the surgical procedure. The gap between the graft (G) and the host (H) reveals connective tissue that is markedly richer in blood vessels and fibroblast-like cells. H&E ×192.*

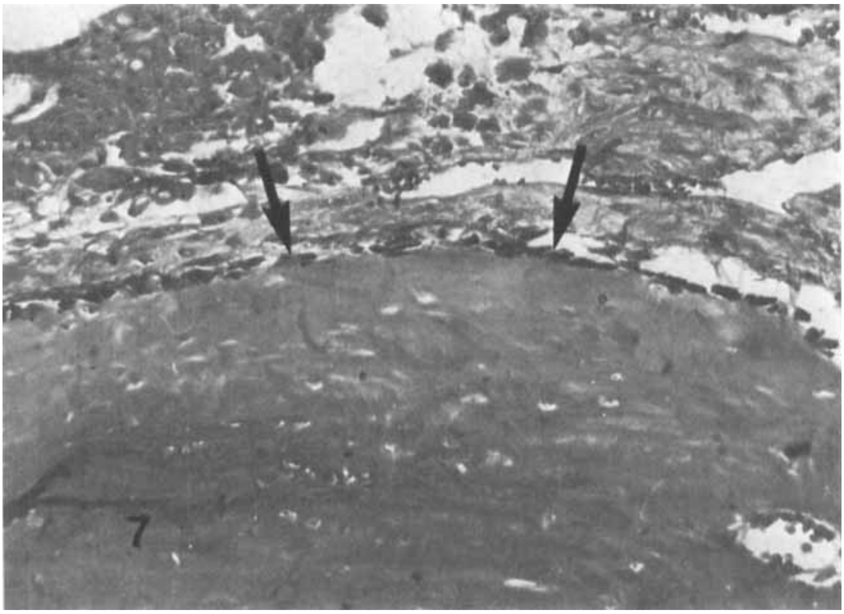

*Figure 7. A section through an implanted bone graft that had been coated with methylmethacrylate cement for 10 months. Note the continuous row of osteoblasts (arrows) along the free surface of the graft. H&E ×240.*

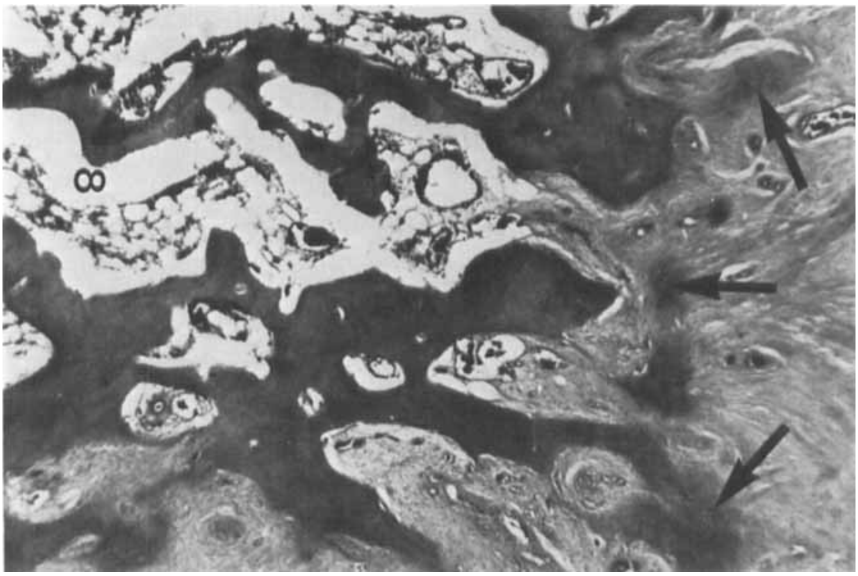

*Figure 8. A section through an implanted bone graft and its adjacent tissue. The newly formed loci of ossification (arrows) can be clearly seen within the collagenous tissues surrounding the graft. H&E ×192.*

## DISCUSSION

The use of bone grafts underneath methylmethacrylate bone cement has already been described in the literature; however, we still lack sufficient information and understanding with regard to the *in vivo* effects of the methylmethacrylate cement upon bony tissue. Charnley et al. (1968) and Homsy et al. (1972) described cases of bone necrosis apparently due to the high temperatures generated during the polymerization process in the curing cement. Reckling & Dillon (1977) and Meyer et al. (1973), on the other hand, expressed the belief that the temperature within the mass of the cement gradually cools off as the cement-bone interface is reached. Henricksen et al. (1953), Wiltse et al. (1957), Willert et al. (1974), Lindwer & Van der Hooff (1975) and Linder (1977) all suggested that the leakage and diffusion of the toxic monomer and possibly other components could be responsible for the necrotic changes observed underneath the cement. It is, however, accepted that despite the above-mentioned damaging effects of the cement, the bone is capable of overcoming such changes and eventually re-establishes new and healthy fibrocartilage or bone (Feith 1975). Thus, whatever the potential devitalizing effects of the cement may be, it is not as yet fully clear what is the fate of bone grafts that are placed in close contact with such a bone cement. Would such grafts be able to withstand the deleterious effects of the polymerizing cement? And would the compromised blood supply be sufficient to enable the induction of new bone? These were some of the questions that we attempted to clarify further in the present study.

The experimental model, which utilized cortico-cancellous bone grafts, showed a gradual formation of fibro-osseous union between the femur and the graft in the presence of a relatively large mass of methylmethacrylate cement. It might be possible that the slight motion at the osteotomy site, allowed by the intramedullary rod, promoted the development of fibrous tissue rather than a more solid bony union. However, the mere fact that one could identify *de novo* formation of loci of ossification provides substantial experimental evidence that bone grafts do retain their osteogenic capacity even in the presence of a noxious factor such as methylmethacrylate cement.

## ACKNOWLEDGMENTS

This study was supported in part by the Hy and Ann Natovitch Orthopaedic and Rehabilitation Research Fund, and by CMW Laboratories Ltd., Bone Cement Division, Blackpool, England. The authors wish to express their gratitude to Mrs. T. Barad for her technical assistance.

## REFERENCES

Charnley, J., Follaci, F. M. & Hammond, B. T. (1968) Long term reaction of the bone to self-curing acrylic cement. *J. Bone Joint Surg.* **50**-B, 822–829.

Feith, R. (1975) Side effects of acrylic cement implanted into bone. *Acta Orthop. Scand.,* Suppl. 16.

Henricksen, E., Jansen, K. & Krough-Poulsen, W. (1953) Experimental investigation of tissue reaction to acrylic plastics. *Acta Orthop. Scand.* **22**, 141–146.

Heywood, A. W. B. (1980) Arthroplasty with a solid bone graft for protrusio acetabuli. *J. Bone Joint Surg.* **62**-B, 332–336.

Homsy, C. A., Tullos, H. S., Anderson, K. S., Differante, N. M. & King, J. W. (1972) Some physiological aspects of prosthesis stabilization with acrylic polymer. *Clin. Orthop.* **83**, 317–328.

Linder, L. (1977) Reaction of bone to the acute chemical trauma of bone cement. *J. Bone Joint Surg.* **59**-A, 82–87.

Lindwer, J. & Van Der Hoof, A. (1975) The influence of acrylic cement in the femur of the dog. *Acta Orthop. Scand.* **46**, 657–671.

McCollum, D. E., Nunley, J. A. & Harrelson, J. M. (1980) Bone grafting in total hip replacement for acetabular protrusion. *J. Bone Joint Surg.* **62**-A, 1065–1073.

Meyer, P. R. Jr., Lautenschlagen, E. E. P. & Moore, B. K. (1973) On the setting properties of acrylic bone cement. *J. Bone Joint Surg.* **55**-A, 149–156.

Reckling, F. W. & Dillon, W. L. (1977) The bone-cement interface temperature during total joint replacement. *J. Bone Joint Surg.* **59**-A, 80–82.

Salvati, E. A., Bullough, P. & Wilson, P. D. Jr. (1975) Intrapelvic protrusion of the acetabular component following total hip arthroplasty. *Clin. Orthop.* **111**, 212–227.

Willert, H. G., Ludwig, J. & Semlitsch, M. (1974) Reaction of bone to methacrylate after hip arthroplasty. *J. Bone Joint Surg.* **56**-A, 1368–1382.

Wiltse, L. L., Hall, R. M. & Stenchjem, J. C. (1957) Experimental studies regarding the possible use of self-curing acrylic in orthopaedic surgery. *J. Bone Joint Surg.* **39**-A, 961–972.

Correspondence to: Prof. Michael Silbermann, Technion School of Medicine,
Division of Morphological Sciences, 12 Haaliya Street, Bat-Galim, Haifa 31096, Israel.