REACTION OF BONE TO METHACRYLATE : INTERFACE REMODELLING

by M. PORTIGLIATTI BARBOS*, B. BACCHINI**, C. BALBO* and C. VIGLINO*

Histologic findings of the bone-cement junction are presented for 10 implants in rabbits and 12 human specimens. Nondecalcified sections were made, employing embedding techniques that conserve the cement. Different time periods from operation were considered. The histological approach considers mainly the distribution of the osseous elements, with a description of the sites of new and old bone, of resorptive lacunae and of fibrous tissue. Fluorescent sequential labelling of bone tissue allowed a dynamic evaluation of the viability of bone after insertion of the cement. Histologic features may be summarized as follows :

— In the initial phase after PMMA implantation a zone of necrosis is present around the cement.

— In a second phase there is very active bone formation and remodelling in the tissue adjacent to the cement, with fibrous tissue formation.

— Long-term adaptive bone remodelling leads to extensive resorption of cortical bone and new bone formation producing a shell around the cement with new trabeculae radiating towards the cortex.

Keywords : bone ; histology ; polymethylmethacrylate.

Mots-clés : histologie ; os ; méthylméthacrylate.

RÉSUMÉ

M. PORTIGLIATTI BARBOS, B. BACCHINI, C. BALBO et C. VIGLINO. Réaction de l'os au méthacrylate de méthyle. Remodelage de l'interface.

Les auteurs présentent une étude histologique de l'interface os-ciment de 10 implants placés chez le lapin et de 12 implants placés chez l'homme. Nous avons examiné des coupes non décalcifiées, en utilisant une technique originale d'inclusion qui préserve le ciment. L'analyse s'attache à préciser au cours du temps la distribution des éléments osseux en particulier dans l'os néoformé, les lacunes de résorption, et le tissu fibreux. Le marquage fluorescent séquentiel du tissu osseux a permis l'évaluation dynamique de la vitalité de l'os après cimentage. Les résultats histologiques peuvent être résumés : 1) pendant la phase initiale après implantation du P.M.M.A. on observe une zone de nécrose tout autour du ciment. 2) plus tard dans le tissu jouxtant le ciment, on assiste à une néoformation d'os et à un remaniement très actif avec formation du tissu fibreux. 3) après un certain temps le remaniement osseux mène à une résorption étendue de l'os cortical avec formation d'une sorte de coquille tout autour du ciment et de trabécules radiaux en connexion avec la corticale.

SAMENVATTING

M. PORTIGLIATTI BARBOS, B. BACCHINI, C. BALBO en C. VIGLINO. Reaktie van het bot op methylmethacrylaat : remodellering van de interface.

De auteurs beschrijven de histologische bevindingen thv de bot-cement junctie bij 10 implantaten in konijnen en bij 12 humane specimens. Niet gedecalcifieerde fragmenten, met een originele inclusie techniek, waarbij het cement bewaard wordt, werden onderzocht. De fragmenten werden gepreleveerd na variërende postoperatieve perioden. De verdeling van de ossale elementen, in het bizonder in een neoformatie-bot, de resorptie-lacunes en de verdeling van fibreus weefsel, werden tijdens de evolutie be-

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paald. Sekwentiële fluorescente markering van het botweefsel gaf een dynamische evaluatie van de vitaliteit van het bot, na insertie van cement. De histologische kenmerken kunnen als volgt samengevat worden :
— tijdens een eerste fase, na implantatie van PMMA, is er een necrose-zone rond het cement
— in een tweede fase is er aktieve botopbouw en remodellering in de om het cement liggende weefsels, met fibreus weefsel
— op lange termijn leidt de adapterende botremodellering naar een uitgebreide resorptie van het corticale bot en naar productie van nieuw ossaal weefsel, als een schelp rond het cement, met nieuwe trabeculae, verlopend naar de cortex.

INTRODUCTION

A number of investigators (3, 4, 5, 7, 8, 10, 12, 16, 17) have reported on the reaction of bone to acrylic cement. Several authors studied the histologic changes of bone in contact with polymethylmethacrylate in human and animal implants (2, 6, 9, 11, 14, 15). The study of the bone turnover and the fluorochrome labelling suggests that decreased bone formation occurs in implanted bone immediately surrounding the cement implant. Over several years changes evolve at the bone-cement interface.

Depite these great improvements in our knowledge about the changes at the bone-cement interface, three questions are still open :

1. Can an experimental model in animals be representative of the human situation ?
2. How can we obtain sections for histomorphological study of the bone-cement interface ?
3. What is the natural history of the bone-cement interface ?

The aim of this study is to define with an original histomorphological approach, a baseline histological reaction of bone to acrylic cement at different time periods from the time of implant.

MATERIALS AND METHODS

Histology of the bone-polymethylmethacrylate (PMMA) junction was studied employing an original embedding technique that conserves the cement (1). We have used a modified Araldite with substitution of propylene oxide (which dissolves the cement) by ethyl ether. In this way we could obtain thin sections of bone-cement specimens without histomorphological alterations. These were then studied with polarized and fluorescent light and histologic staining methods.

The study was performed on 10 adult rabbits, and the observations were compared with the results of a study of 12 human specimens (13).

In all rabbits a hole was drilled under general anesthesia, either proximally or distally, in the lateral diaphyseal cortex of one femur into the marrow cavity (fig. 1). The hole was then filled with PMMA (CMW3 R) using conventional techniques.

Walking was allowed immediately after surgery. Tetracycline (Reverin®) was administered subcutaneously in doses of 20 mg/kg of body weight

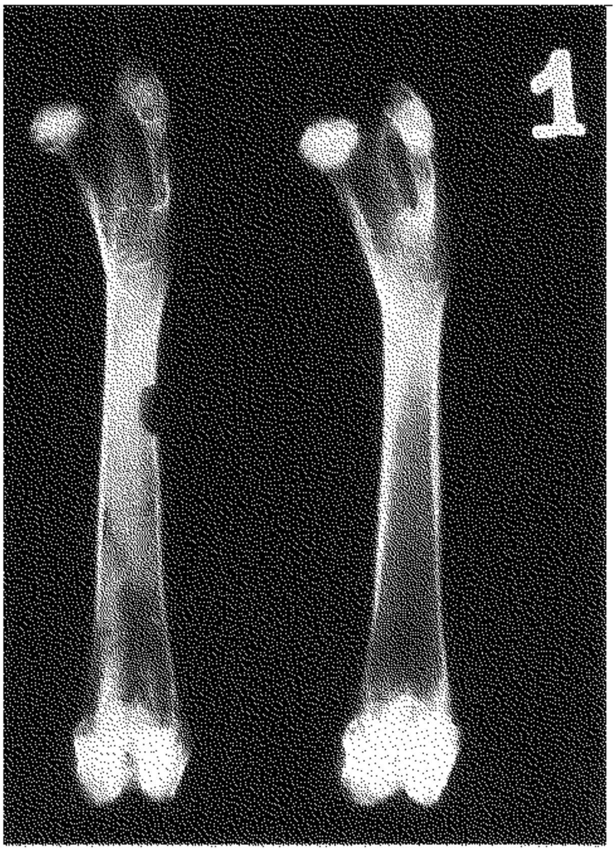

Fig. 1. — Femur of a rabbit before and after PMMA implantation.

on two successive days at least 3 days before killing the animals.

Both femurs were prepared free of soft tissue, and fixed, dehydrated and embedded nondecalcified as previously described. All specimens were sectioned in a transverse plane using a Leitz mocrotome with a rotating saw to obtain 50-micron thick sections. The sections were mounted and examined under incident light with a Leitz Orthoplan fluorescent microscope. In addition 70-micron thick sections were microradiographed. Some specimens were decalcified, embedded in paraffin and cut to obtain 5-to-10-micron thick sections for staining.

The property of tetracycline of forming a deposit of newly formed bone and of producing yellow fluorescence under ultraviolet light was utilized in the examination of normal and treated femurs in order to evaluate the viability of bone after insertion of the cement and the bone-PMMA interface changes.

The histological approach with different staining methods has been mainly that of description of the distribution of the osseous elements, including the sites of new and old bone, of resorptive lacunae and of fibrous tissue.

As each pair of rabbits was killed at 4 days, 10 days, 20 days, 35 days, and 6 months after operation, the role of the time factor could be evaluated.

RESULTS

4 days after PMMA implantation in the rabbit

The early histopathological change in the bone adjoining acrylic cement is the presence of a zone of dead bone and marrow tissue surrounding the implant without any sign of tetracycline labelling. This probably results from heat produced during polymerization, from toxic effects of nonpolymerized monomer, or from a combination of these factors.

On the contrary, a thin zone of tetracycline labelling is evident in periosteal bone and in a few growing osteones of the central and the external portions of the cortex (fig. 2).

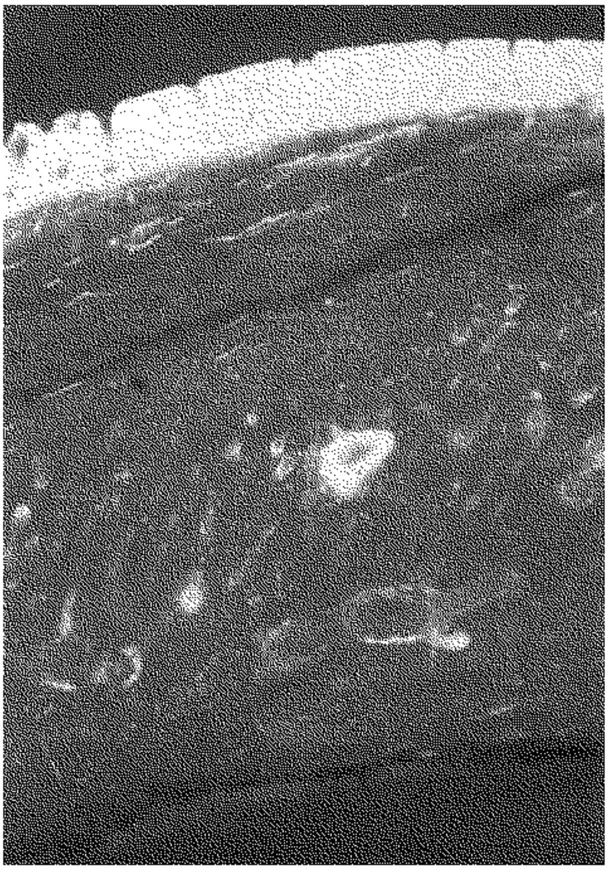

Fig. 2. — 4 days after PMMA implantation in the rabbit. A zone of dead bone surrounds the cement. Labelling is present only in periosteal bone.

10 days after PMMA implantation in the rabbit

The cement is in contact with only dead osseous tissue. On the contrary, the spongy bone of the metaphysis (where PMMA has not penetrated) shows extensive endosteal and periosteal osteogenesis (more than the control femur).

20 days after PMMA implantation in the rabbit

Bone remodelling processes are very active. An increasing number of lacunae is present especially in the inner cortex of the treated femur.

Few specimens show lamellar tetracycline labelling. Osteogenesis is more evident in the external portion of cortical bone (osteones and periosteal bone are labelled from tetracycline administration) (fig. 3). On the contrary at the interface between bone and PMMA only small and irregular labelling is present (fig. 4) with a thin membranous layer often separating the cement from the other tissues.

Fig. 3

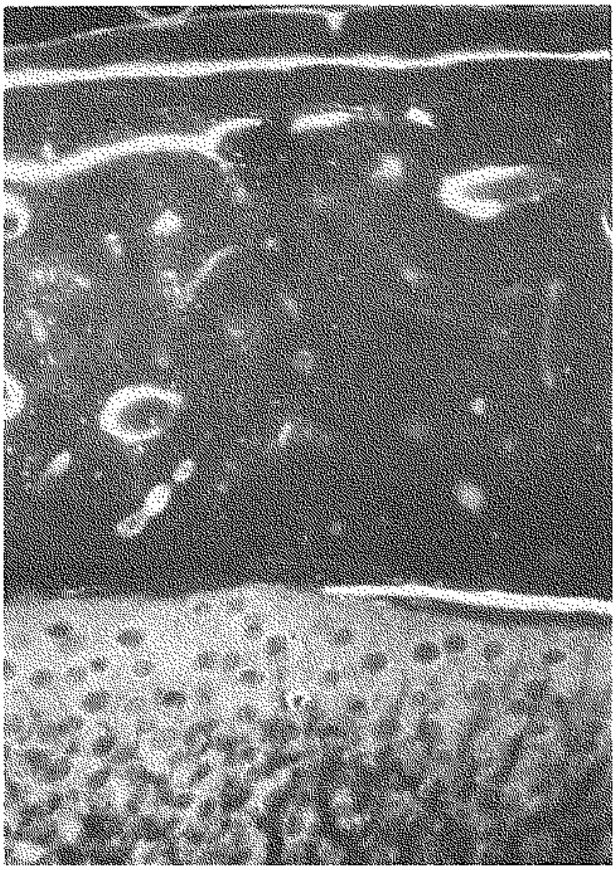

Fig. 4

Fig. 3-4. — 20 days after PMMA implantation in the rabbit. Osteogenssis is more evident in the external portion of cortical bone. At the interface between bone and PMMA only small and irregular labelling is present (fig. 4).

35 days after PMMA implantation in the rabbit

Histology shows increasing osteogenesis at the bone-cement interface (fig. 5) ; otherwise there are no noticeable changes.

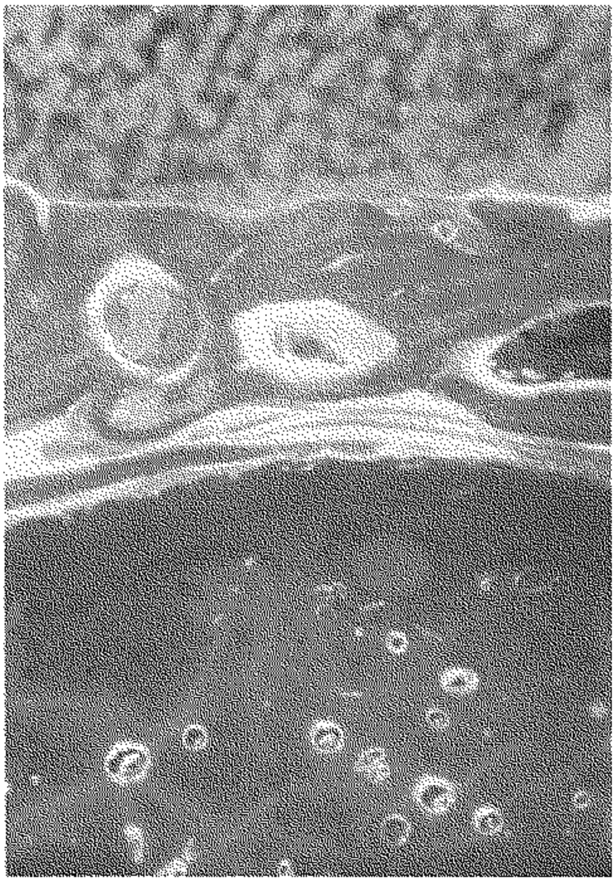

Fig. 5. — 35 days after PMMA implantation in the rabbit. Increasing osteogenesis at the bone-PMMA interface.

6 months after PMMA implantation in the rabbit

In the tissue adjacent to the cement there is very active bone formation and remodelling, fibrous tissue formation and multinucleated giant cells, frequently forming a syncytium having few visible cell boundaries.

Adaptive bone remodelling leads to extensive resorption of cortical bone and the new bone tends to form a shell around the cement (fig. 6) with new trabeculae radiating towards the cortex.

Fig. 6. — 6 months after PMMA implantation in the rabbit. Adaptive bone remodelling leads to extensive resorption of cortical bone and new bone tends to form a shell around the cement.

Fig. 7-8. — Human specimens. A layer of collagenized fibrous tissue separates the cement from other tissues (fig. 7). The trabeculae closer to the cement are parallel to the PMMA surface and are united to the cortex by a few radially oriented trabeculae. The remainder of the cancellous bone is often porous (fig. 8).

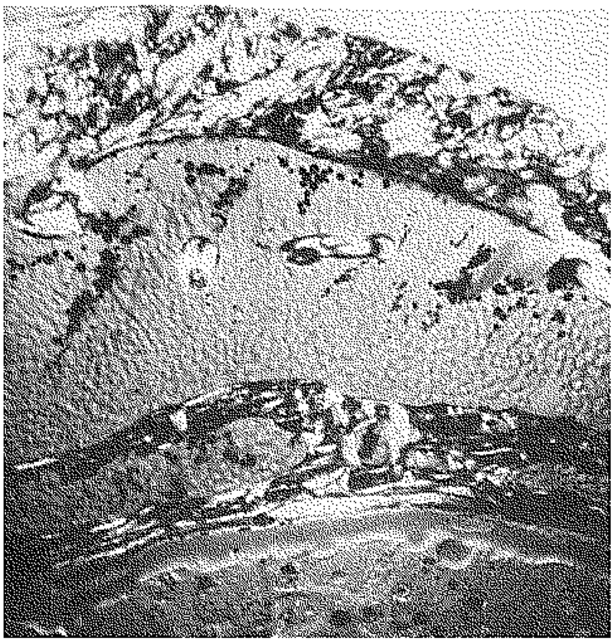

Fig. 6

Fig. 7

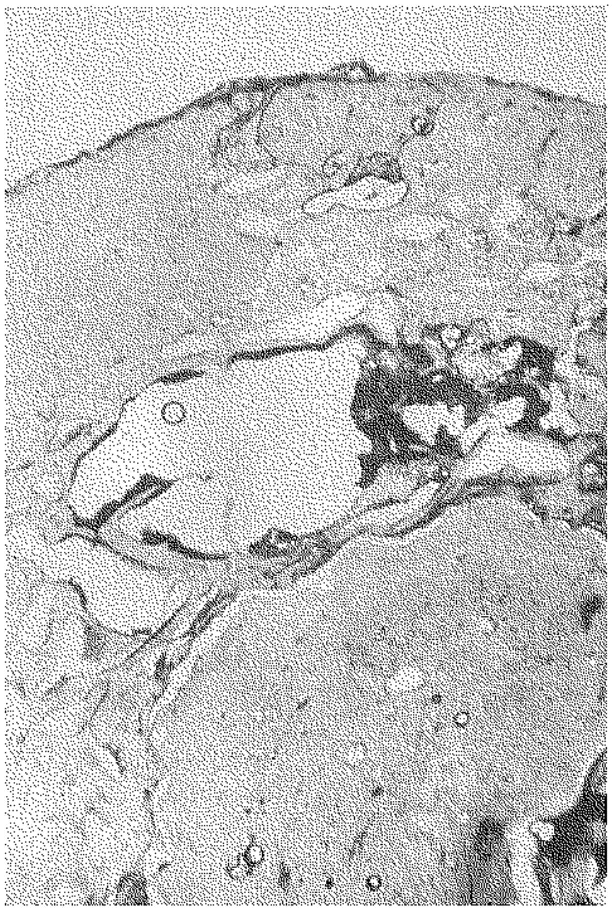

Fig. 8

Human specimen results

The bone-cement junction up to an average of 7.4 years after implantation was studied in patients in whom the prosthesis became loose and removal was indicated (13). The sequential fluorescent labelling of bone tissue has allowed a precise evaluation of the vitality of bone.
Histologic features may be summarized as follows : 1) At the bone-PMMA interface, the cement is separated from the living tissue by a membranous acellular layer which may be thin and delicate ; more commonly, there is an additional layer of collagenized fibrous tissue separating the cement from other tissues (fig. 7). 2) Reduced bone formation can be recognized in areas close to the cement. At greater distances from the cement surface the bone has a normal morphology and the newly formed bone is clearly shown by fluorescent labelling. 3) The trabeculae closer to the cement are oriented parallel to the cement surface. The remainder of the cancellous bone is often porous. The cortex is united with the trabeculae around the implant by a few radially oriented trabeculae (fig. 8).

Conclusion

In the initial phase after PMMA implantation in rabbits we observed a zone of necrosis around the cement which is in general agreement with the literature. During the resorptive phase that follows the dead bone is removed and then replaced by new living bone ; this process is very active at 6 months after PMMA implantation. The resorptive phase in man is likely to follow similar stages, but we did not observe such regular and extensive osteogenesis at the bone-PMMA interface, probably because of the loosening of the implants. Moreover, in all patients the cement was separated from the adjacent bone by a layer of fibrous tissue that would appear to be capable of allowing some degree of movement between PMMA and bone. In conclusion, we found that the natural history of the bone-cement interface is based on three major phases :

— In the initial phase after PMMA implantation a zone of necrosis is present around the cement.
— In a second phase there is very active bone formation and remodelling in the tissue adjacent to the cement, with fibrous tissue formation. In our human specimens, loosening of the implant was probably responsible for persistent bone necrosis around the cement and for an additional layer of collagenized fibrous tissue at the interface.
— Long-term adaptive bone remodelling leads both in humans and animals to extensive resorption of cortical bone and to new bone formation producing a shell around the cement with new trabeculae radiating towards the cortex.

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