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Mechanical effects of intramedullary acrylic cement on fracture healing in rats

In one group of rats, the medullary cavity was reamed and bone cement was injected. In a control group, only reaming was performed. A closed fracture was then produced in the middle of the femur. At 40,60 and 90 days following operation the torsional moment, the elastic stiffness, the volume and the density of the callus tissue were evaluated.
No differences were found between the two groups. It is concluded that acrylic bone cement in the medullary cavity does not impair the healing of non-immobilized fractures in young rats.

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Methylmethacrylate (MMA) bone cement has been used as an adjunct in the fixation of pathological and osteoporotic fractures (Parrish & Murray 1970, Harrington et al. 1973, Harrington 1975, Benum 1977). However, bone cement may harm fracture union by the release of heat and cytotoxic monomer.

The object of this experiment was to study the mechanical effects of bone cement on the healing of non-immobilized fractures.

Material and methods

A total of 52 male/Wistar/Af/Mol SPF rats was used. At the start of the experiment they were about 12 weeks old with a median weight of 295 g.

Following intraperitoneal anaesthesia (Mebumal® 5%), the left hip region was shaved and cleaned with 0.5% clorhexidine. Operations were performed under aseptic conditions. An incision was made over the greater trochanter. The gluteal muscles were loosened by an osteotomy of the greater trochanter, and the external rotators were cut. Entry of the medullary cavity was performed using an awl. The medullary cavity was then reamed successively to a dimension of 1.6 mm using steel burrs mounted on an electric drill. A canule of 1.2 mm diameter was inserted into the cavity to the end, and isotonic saline was injected to wash out bone marrow remnants.

The rats were divided into two weight-matched groups. In the control group the operation was concluded at this point by closing the wound. In the cemented group reaming of the medullary cavity was followed by implantation of bone cement into the medullary cavity. A canule of 1.4 mm diameter was inserted into the end of the cavity. Two grams polymer powder and 1 ml monomer fluid of Surgical Simplex® cement was prepared and injected into the medullary cavity by the use of a syringe. When the cement was seen to emerge from the insertion hole, the canule was slowly retracted, thus filling the entire medullary cavity from distal to proximal. The operation was then concluded by closing the wound.

After the operation a closed transverse fracture of the midshaft of the femur was performed in all animals by the use of a special forceps, as described by Ekeland et al. (1982). The fractured limbs were not immobilized.

At 40, 60 and 90 days following operation 8–9 animals from each group were killed with ether and weighed. Both femora were dissected free and kept in isotonic saline. Within 2 h the fractured and intact femora were tested in torsion as described by Engesæter et al. (1978). A standard hydraulic testing machine (type 7-1/1, AB Lorentzen & Wettres Maskinaffär, Stockholm) was run at a constant rate (0.04 rad/s). The load values were transferred by a trans-ducer to a chart recorder which displayed the load-deformation curve. The strength was calculated as the torsional moment necessary to produce fracture. The torsional rigidity was determined from the slope of the linear elastic part of the load-deformation curve.

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weight was recorded after heating (60°C). The density of the callus tissue was calculated as the dry weight divided by the volume.

The median with 0.25- and 0.75 fractiles was used to express average and dispersion of data. The Wilcoxon two-tailed test was used to evaluate the statistical differences between the two groups. Differences were considered significant when $P \leqq 0.05$.

Results

The body weight of the animals increased by about 40 per cent in both groups during the experimental period.

The torsional moment of the intact femora increased by about 37 per cent from Day 40 to Day 90 following operation. The torsional moment of the healing fractures increased from 0.191 (0.148–0.274) Nm to 0.423 (0.331–0.472) Nm from Day 40 to Day 90 in the control group. The corresponding figures for the cemented femora were 0.196 (0.174–0.246) Nm and 0.412 (0.336–0.447) Nm, respectively. The differences in torsional moment between the two groups were not significant during the experimental period. At 90 days after the fracture, the torsional moment of the healing fractures did not differ from that of the contralateral intact femora, and 10 of 17 fractures occurred outside the callus.

The torsional rigidity of the healing fractures increased during the experimental period without differences between the two groups. In the control group there was an increase from 0.013 (0.010–0.019) Nm/deg at Day 40 to 0.036 (0.029–0.047) Nm/deg at Day 90 following operation, and in the cemented group the rigidity increased from 0.012 (0.010–0.014) Nm/deg to 0.037 (0.030–0.038) Nm/deg.

The volume of the callus tissue decreased while the density of the callus increased from Day 40 to Day 90 after operation, again without differences between the two groups. The volume of the callus tissue was reduced from 0.633 (0.539–0.660) ml to 0.456 (0.376–0.506) ml in the control group and from 0.612 (0.567–0.662) ml to 0.448 (0.340–0.551) ml in the cemented group. The density of the callus increased from 0.809 (0.771–0.831) mg/ml to 1.134 (1.018–1.204) mg/ml in the control group and from 0.769 (0.744–0.854) mg/ml to 1.110 (1.107–1.168) mg/ml in the cemented group.

Discussion

Recovery of mechanical strength is the main requirement in fracture healing. In this experiment, introduction of acrylic bone cement into the medullary cavity did not impair the healing of non-immobilized fractures in young rats.

Torsional moment expresses the strength of healing fractures, but the strength alone is not a sufficient measure to evaluate the process of bone repair (Ekeland et al. 1982). In the early phase of healing of unstable fractures the callus mass consists of fibrous and cartilagenous tissue, and the volume produced is rather large (Rokkanen & Slätis 1964, Slätis & Rokkanen 1965). With increasing mineral deposition the callus tissue becomes more mature, and the stability of the fracture proceeds to consolidation. Consequently, it should be appropriate to investigate the rigidity, the volume and the density to evaluate the quality of the callus tissue. There were no significant differences in these parameters between the two groups during the experimental period.

Polymerization of MMA causes tissue injuries due to release of heat and of cytotoxic monomer (Henricksen et al. 1953, Lindwer & Van der Hoff 1957, Wiltse et al. 1957, Hullinger 1962, Schlag et al. 1973, Linder 1977). According to Feith (1975) implantation of bone cement into the medullary cavity provokes necrosis on the endosteal side of the cortex and periosteal reaction. This might interfere with the process of bone repair. Previous histological studies are conflicting regarding this question: Szyszkowitz & Cockin (1974) found that intramedullary bone cement did not prevent the healing of osteotomies, whereas Hubbard (1980) found a slower rate of union associated with intramedullary cement.

The healing of unstable fractures is the result of callus production. External callus develops primarily from the periosteal side of the bone (Mindell et al. 1971). Intramedullary bone cement does not seem to have devitalizing effects on this side of the cortex. On the contrary, intramedullary procedures which result in endosteal necrosis seem to be followed by periosteal reaction (Danckwardt–Lillieström 1969, Danckwardt–Lillieström et al. 1970, Feith 1975). These factors may explain why the process of fracture healing was not impaired or delayed in this study.

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