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EXPERIMENTAL USE OF POLYMETHYL METHACRYLATE TURNINGS FOR THE FILLING OF BONE DEFECTS

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In previous reports [1, 2] we have discussed the experimental use of fillings made of polymethyl methacrylate synthetic resin and nylon mesh for the repair of thoracic defects. The results induced us to extend the experiments also to other fields and next polymethyl acrylate turnings were used for the filling of bone cavities. The evidence obtained in animal experiments and in operations carried out in cooperation with Dr. K. Pap showed the polymerized methyl-methacrylate produced by the Plastics Research Institute to be suitable for surgical purposes. In agreement with other authors, we have found considerable appositional bone formation around the synthetic resin endoprostheses. Earlier, one of us (Bornemisza) observed that a connective tissue capsule is formed around collodiumized polymethyl methacrylate tubes which have been succesfully used for the repair of defects in the abdominal aorta [3]. Thus, the plastic in question undoubtedly exerts a contact proliferative effect. This is presumably the more marked, the larger the surface of the material. Heinze [4], who made a careful study of the use of plastics in surgery, found that synthetic resin can be used also in a septic environment, thus, for example, in cases of chronic osteomyelitis.

The filling of bone cavities due to different conditions (cysts, cavities formed in the course of chronic osteomyelitis, etc.) is often very difficult. Although several methods have been developed to solve the problem, it is always difficult to find the one most suited in a given case. The commonest method employed for filling non-infected cavities is the use of bone grafts. This is not a simple procedure. To obtain the autoplastic bone graft, the patient, already exposed to surgical stress, has to undergo a second operation, with all the inconvenience and risks it entails. As our experiments [5], too, testify homoiotransplants can be used at advantage but preservation, as well as the choice of the donor, often present difficulties. As regards heterotransplants, on the basis of the experimental and clinical results there is some reluctance to their use. In contrast with this, alloplastic resins, which are cheap, easy to purchase and resistant to infection, offer certain advantages. The physico-

chemical, mechanical and biological properties of polymethyl methacrylate have been discussed in detail in earlier reports [2, 6].

In the present experiments it has been attempted to enhance appositional bone formation by using polymethyl methacrylate as endoprosthesis in different operations (Fig. 1). The material has the advantage that, being a by-product, it is practically without cost and, being neutral to tissues and most chemicals, it can be mixed with antibiotics and chemotherapeutics, a property most advantageous in infected areas. Turnings seem to be superior to globules, because the latter have to be formed and shaped and lose the active agents in their crevices more easily, than the turnings.

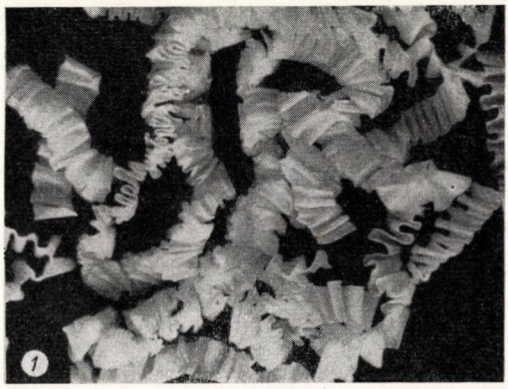


Fig. 1. Magnified appearance of the methacrylate turnings used

To fill large cavities, turnings can be used simultaneously with plastic or even bone grafts to provide sufficient mechanical strength. Thus a wide variety of combinations is possible.

When making the turnings to be used for such purposes, all kinds of contamination must be avoided carefully and the work should be carried out with interruptions so as to prevent depolymerisation due to heat, the monomeric form of the material being toxic.

In earlier experiments with thoracic fillings made of plastic turnings in nylon sac, histological evidence was obtained showing that connective tissue trabecules with ample vascular supply had developed, interweaving the turnings. There was no sign of inflammation or tumorous growth, either at gross or at microscopic examination. The final outcome was that the fillings, which initially had been merely alloplastic, had become "auto-alloplastic" as far as the organism's own tissues were represented in it in a proportion nearly equal to that of the alloplastic material.

In our experiments concerned with the filling of bone cavities we have investigated whether there sould develop bony trabecules in the interspaces between

the turnings, that would not only fill the interspaces but would at the same time form structures sufficiently resistant to be exposed to mechanical stress.

As preliminary experiments, both tibiae were fractured in 7 dogs. On the left side a small amount of methacrylate turnings was placed between the fracture ends, whereas on the right side, which served as the control, nothing was interposed between the fractured ends of the tibia. The fractured limbs were immobilized by means of plaster casts until recovery was complete. The

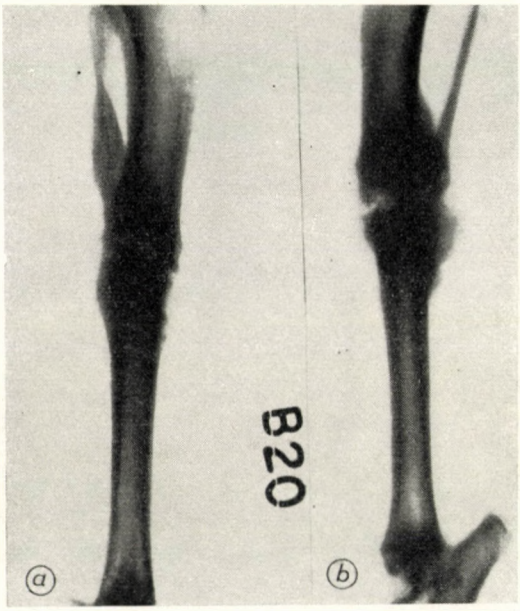


Fig. 2. Fracture of the tibia. Dog. Radiographic appearance 3 weeks after operation. *a)* Side treated with methacrylate turnings. *b)* Control side

first comparative radiographs were made two weeks after operation, repeating the examination when so required. Except for two cases in which the fracture ends had been dislocated and thus the results could not be evaluated, callus formation was found to be enhanced on the side with the synthetic resin interpositum (Fig. 2). Although the two tibiae could not be fractured in exactly the same way and there could have been differences in healing, the results were considered as a standard, the more so as histological examination showed callus formation to be normal also on the side where methacrylate had been interposed between the fracture ends.

Next, experiments were made on 20 dogs. Under Evipan anaesthesia, in the proximal epiphysis of both tibiae we created cavities as big as possible without causing the cortical layer to break, taking care that the cavities be

equal in size. Into the right tibial cavity a small volume of penicillin solution was injected and the periosteum and soft tissues were united. The cavity in the left tibia was filled with methacrylate turnings mixed with penicillin powder, closing the periosteum and soft tissues as in the case of the right tibia. No casts were applied. The results were evaluated by observing the experimental animals, by making radiographs and histological studies.

In general, the animals tolerated the operation well and stood on their limbs in 2 or 3 days. None of them developed secondary fracture or suppuration.

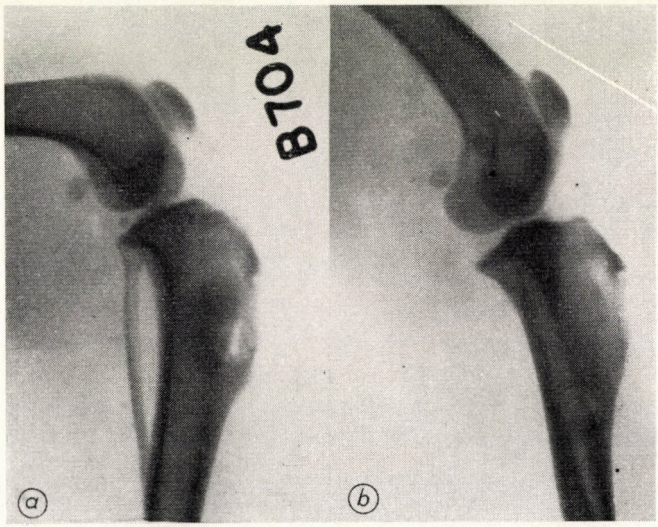


Fig. 3. Radiographic appearance of cavities created in the proximal tibial epiphysis 2 months after operation. *a)* Condensation around the cavity containing methacrylate turnings. *b)* No such change is visible on the control side

Subsequently, radiographs were made at intervals, the first one 1 month after operation. For histological study the animals were sacrified 1 to 14 months after operation. As early as in 2 months, the margins of the cavity filled with acrylate turnings appeared much denser than those of the contralateral, control one (Fig. 3). Later on the site of the cavity filled with acrylate turnings gave a much more intense shadow than did the control cavity, the intensity of the shadow increasing gradually. This was interpreted as indicating that at first condensation developed at the margins of the cavity, to extend later into its interior, as a sign of intensive ossification on the side containing the acrylate turnings, which give no X-ray shadow.

For histological study the decalcinated bones were treated with acetone to dissolve the acrylate, to allow making sections. It was found that in the first 3 months around the filling neither inflammation, nor any other patho-

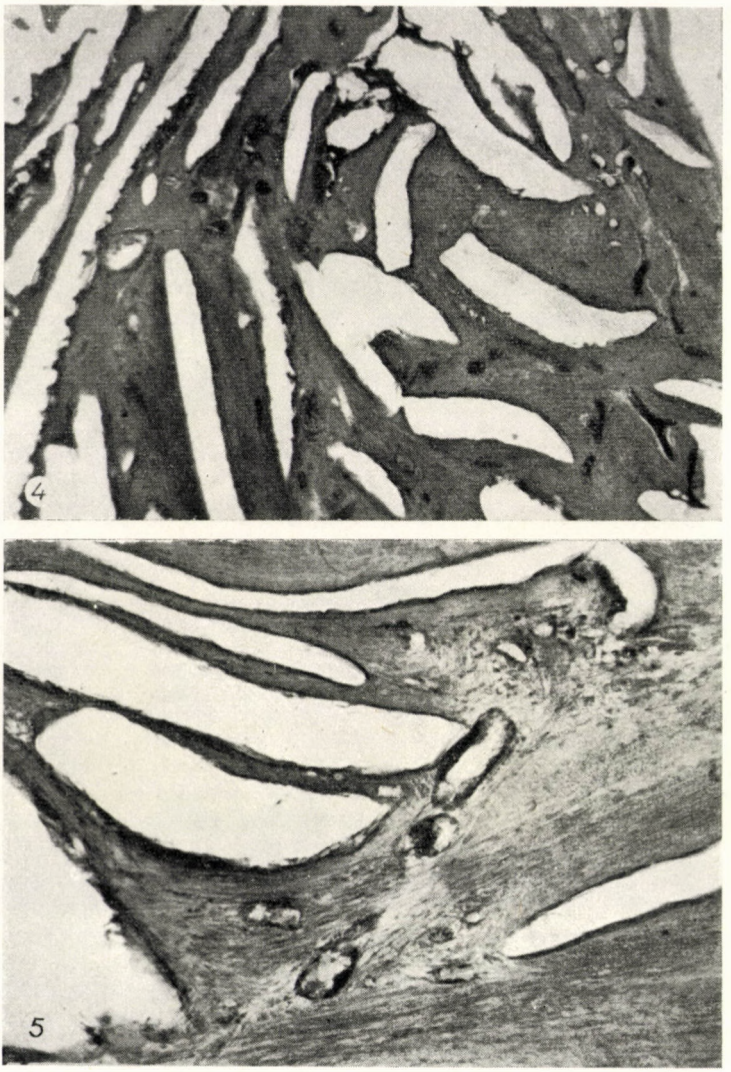
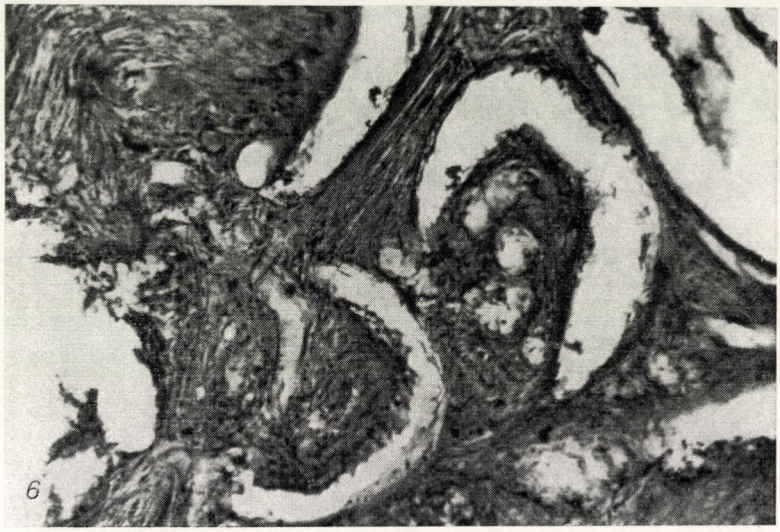


Fig. 4. Cavities remaining after dissolution of methacrylate turnings ; connective tissue filling the interspaces. Four months after operation

Fig. 5. Ample vascularisation in connective tissue (4 months)

logical changes had developed and that the interspaces between the turnings were gradually filled by connective tissue septa. The turnings and the connective tissue interweaving them formed a "concrete like" structure, which on weight bearing, i. e. under the influence of function, became more and more capable of fulfilling its statical role. In the compact and the spongious layers the cavity system remaining after the acrylate had been dissolved was clearly



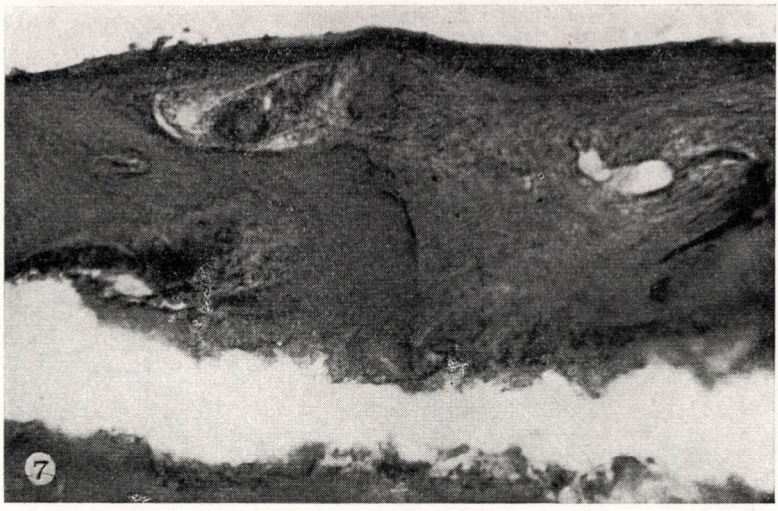


Fig. 6. Condensation of tissue in the connective tissue septa next to the acrylate filling (4 months)

Fig. 7. After 11 months the thinner connective tissue trabecules have ossified

visible. These kinds of cavity were clearly distinguishable from the original ones of the spongiosa, partly on grounds of the presence of red marrow in the spongiosa interspaces, and partly by the irregular, tortuous, peaked shape of these cavities. In Fig. 4 this cavity system and the connective tissue filling its spaces can be seen as it appeared 4 months after operation. During the first few months fibroblasts abounded in the young connective tissue, which contained also other types of connective tissue cells, as well as lympho-

cytes and plasma cells. As it can be seen in Fig. 5., the connective tissue was amply vascularized. At the connective tissue-bone junction there is a sharp line ; the ossification line. In the control specimen of the same age the cavity is filled with loose connective tissue.

As a result of the contact proliferative effect of the plastic, in the animals sacrificed after 8 months ossification was considerably more marked on the side containing the acrylate than it was on the control side. Marginally, at the junction between acrylate and bone, ossification was much more marked than the other side. The ossification of the connective tissue trabecules started at the bony margins bordering the cavity, and spread gradually into the cavity itself. Fig. 6. shows the appearance of this process after 4 months. On the control side the rate of ossification always remained less marked than on the side containing the acrylate turnings. In the animals killed after 11 months or later the connective tissue trabecules have been replaced by bony trabecules (Fig. 7). The process was complete at 12 months ; at that time there is a netwerk of bony trabecules filling the cavity as a whole, whereas no such structures are visible in the control cavity, in which there is ossification spreading from the periphery, but the centre is filled with connective tissue only.

On the basis of the above results, we recommend for filling small cavities methacrylate turnings alone, and for large ones, with a thin cortical layer liable to fracture, methacyrlate turnings in combination with other methods. It seems that in this field plastics certainly offer some advantages.

Summary

Experimentally created bone cavities were filled with polymethyl methacrylate turnings obtained practically without cost as a by-product of shaping of blocks. The interspaces between the turnings were observed to be filled in time by connective tissue septa, which later under went ossification. Thus, the cavity in which the acrylate turnings had been placed became filled with a network of bony trabecules ; this phenomenon was not observable in the control cavity not containing turnings.

Polymethyl methacrylate turnings can be applied in combination with antibiotics also in septic areas. They can be combined with the application of grafts, made either of plastic or of bone.

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ЭКСПЕРИМЕНТАЛЬНОЕ ПРИМЕНЕНИЕ СТРУЖЕК ПОЛИМЕТИЛМЕТАКРИЛАТА ДЛЯ ЗАПОЛНЕНИЯ КОСТНЫХ ПОЛОСТЕЙ

ДЬ. БОРНЕМИСА и Г. БАКО

Авторы излагают метод для заполнения искусственно вызванных костных полостей стружками, полученными от полимеризированного метилметакрилата в качестве отбросного продукта. Они сделали то наблюдение, что в щелях, между упомянутыми стружками образовались соединительнотканные прослойки, которые со временем окостенели. Таким образом полость на пролиферативное действие контакта с искусственной смолой заполнялась костной тканью со стороны периферии скорее, чем на противоположной стороне. Но параллельно с этим в системе соединительной ткани, заполняющей всю полость, произошел также процесс окостенения. Таким образом заполнение костной тканью полостей, заполненных стружками искусственной смолы, произошло скорее чем на контрольной стороне. Полученная в качестве отбросного продукта стружка искусственной смолы не требует почти никаких затрат и в комбинации с антибиотиками ее можно применять также и при септических процессах. Применение стружек можно сочетать с одновременным применением костяных шин, либо шин из искусственной смолы.

EXPERIMENTELLE ANWENDUNG VON POLYMETHYLMETHACRYLAT-SPÄNEN ZUR AUSFÜLLUNG VON KNOCHENHÖHLEN

GY. BORNEMISZA und G. BAKÓ

Es wird ein Verfahren zur Füllung experimentell hervorgerufener Knochenhöhlen mit aus polymerisiertem Methylmethacrylat als Abfallprodukt erhaltenen Spänen beschrieben. Es wurde beobachtet, dass in den Spalten zwischen den erwähnten Spänen sich Bindegewebeschichten bilden, die sich mit der Zeit verknöchern. Auf diese Weise wurde die Höhle nicht nur schneller als die Gegenseite von der Peripherie aus mit Knochengewebe ausgefüllt, sondern parallel damit ging in dem die ganze Höhle ausfüllenden Bindegewebenetzsystem auch ein Verknöcherungsprozess vor sich. Auf diese Weise erfolgte die Ausfüllung mit Knochengewebe der mit Kunstharzspänen gefüllten Höhlen viel schneller als auf der Kontrollseite. Die als Abfallprodukt erhaltenen Kunstharzspäne kosten nichts und können mit Antibiotica kombiniert auch in septischen Gebieten Anwendung finden. Die Verwendung von Spänen kann mit dem gleichzeitigen Gebrauch von Knochen- oder Kunstharzleisten verbunden werden.

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