Effect of Degradable Implants Placed Across the Growing Epiphyses : An Experimental Study in Rabbit Distal Femur

S.M. KUMTA, MS.
P.C. LEUNG, MS.
R. SPINNER
Department of Orthopaedics & Traumatology, Prince of Wales Hospital, Shatin, N.T. Hong Kong

Abstract : The effect of placing biodegradable rods across the growing epiphyses has been studied in skeletally immature rabbits. Two biodegradable rods were placed across the distal femoral epiphyses through each femoral condyle in 8 week rabbits. The rabbits were serially sacrificed at intervals of 2,3,4,6,8 and 12 weeks, and the femora were harvested for gross examination and histologic studies. Femoral shortening was measured and growth disturbances if any were noted. Histologic observations revealed local disturbance of the growth plate at the site of implant penetration. However the rest of the growth plate retained its normal characteristics and femoral growth remained undisturbed. A biological reaction to the PGA implant was observed. This reaction stimulated the formation of reactive new bone around the degrading implant. A non specific inflammatory response to polyglycollic acid debris was seen in the synovium of the knee joint in some rabbits.

INTRODUCTION

Considerable clinical interest has been generated with the reported use of degradable implants in fracture fixation[1]. Transepiphyseal fracture fixation has recently been reported in supracondylar fractures of the humerus in children[2]. The absorbable nature of the implant has obvious advantages, however there is insufficient data available on the clinical effects on epiphyseal growth, since none of these patients have been followed to skeletal maturity. Growth disturbances were observed after placement of a 3.2 mm diameter polyglycollic acid rod across the distal femoral epiphyses[3]. Similar disturbance in growth was observed after a large drill hole of equal diameter was made across the growth plate.Trauma to the epiphyses rather than the biological effect of the degradable implant has been cited as the possible cause of growth disturbance within 6 weeks of implantation. We want to study the intraosseous degradation of a commercially available degradable implant known as Biofix* and to note its effects on bone growth.

MATERIALS AND METHODS

Thirty six rabbits, 8 weeks old and weighing 2000-2500 gm. were used for this study. Rabbit femoral growth has been studied and the rate is found to be maximum between 8 to 16 weeks of age after which it reaches a plateau at 20 weeks. The rabbit achieves skeletal maturity at 26-28 weeks[4]. The rabbits were give Pentobarbitone anesthesia and the left knee was prepared for surgery with aseptic precautions. The distal femur was exposed through a parapatellar incision and the patella was dislocated laterally. Two polyglycollic acid rods,(Biofix*) of 1.5 mm diameter and 2.5 mm length were introduced across the distal femoral epiphyses via the knee joint(Fig.1). The joint capsule was closed with non absorbable material(5/0 Prolene) and the wound was closed after application of topical antibiotics. The opposite femur served as a control. All rabbits were given penicillin prophylaxis. The animals were sacrificed at 2,3,4,6,8 and 12 weeks. There were six animals in each group. The operated knee joint was exposed and observed for fluid collection and gross appearance of the synovium and articular cartilage. Synovial tissue was obtained for histology from both knees and both femora were harvested. Femoral length of the operated and the control side was measured after stripping the soft tissue away. A vernier caliper was used for measurement. X-rays of both femora were obtained and their radiological lengths were compared. Histologic sections of the distal femur were obtained after decalcification and fixation in 70 percent alcohol, and stained with Haematoxylin and Eosin.

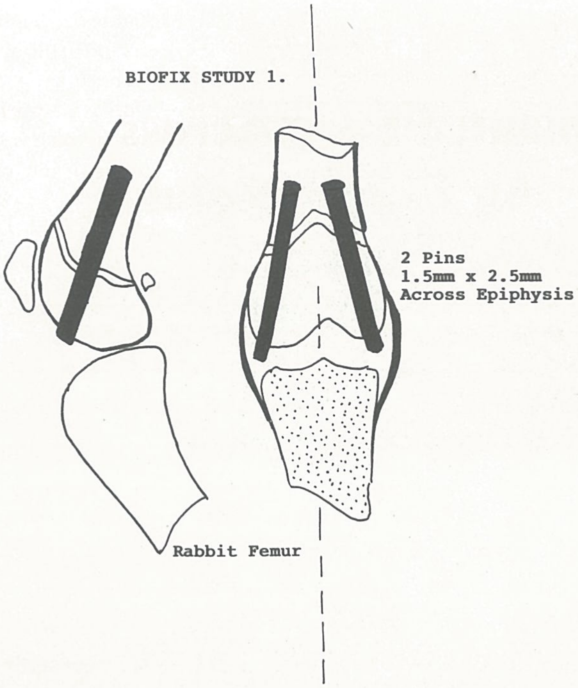

Figure 1. Diagram showing placement of polyglycollic acid rods across distal femoral epiphyses.J Bone Joint Surg (Br) 1987; 69 : 615-19.

RESULTS OF ASSESSMENT

Measurements of femoral length

According to Masoud,a difference in femoral length of 0.6 mm is within normal limits[4]. In our study differences of over 1.5 mm were considered significant. Femoral shortening of 2.5 mm was observed in 3 rabbits, at 6 weeks and 12 weeks respectively. The knee joints showed normal alignment except one which was found to have a thirty degrees valgus angulation at the distal femur at 4 weeks. In this case,there was an accompanying shortening of 1 mm in the femur.

Fluid collection

Three of the operated knees had a blood-stained fluid collection when examined at 2 weeks,similar fluid collection was observed in another 4 rabbit knees, 2 knees at four weeks, and 2 each at six and eight weeks after surgery. This fluid was sterile on culture and microscopic examination revealed fragments of the polyglycollic acid implant as birefringent material. Polymorphonuclear cells were also observed suggesting the possibility of an inflammatory process. Synovium was obtained from each of the operated knees and histologic examination revealed presence of birefingent material surrounded by macrophages and polymorphonuclear infiltration(Fig.2). This was seen only in two specimens at 4 weeks and 2 specimens at 6 weeks.

Histologic observations

Sagittal and cross sections were studied. At 2 weeks, the

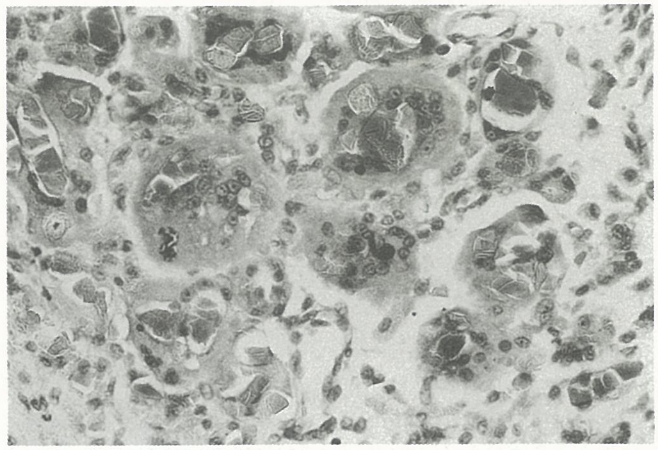

Figure 2. Synovium showing presence of birefringent material surrounded by macrophages and polymorhphonuclear cells. Magnification 40x12.

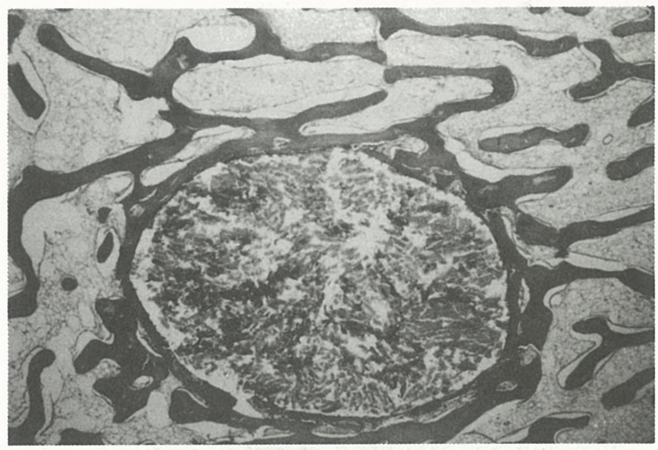

Figure 3a. Cross section of femur at the diaphyseal region showing fragmented polyglycollic acid implant surrounded by a layer of new bone. Sections at 4 weeks after implantation. Magnification 16x142.

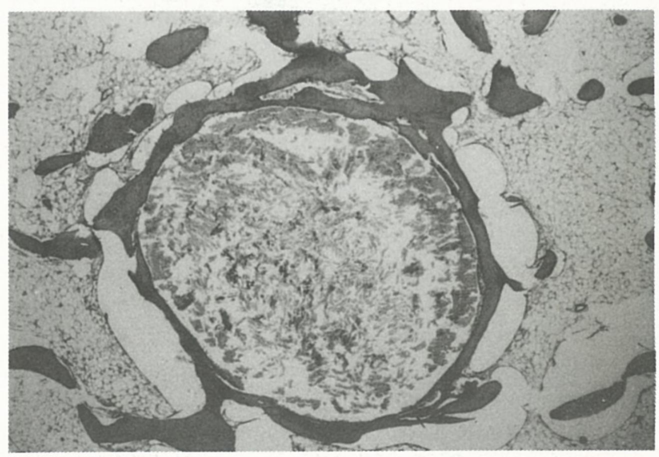

Figure 3b. Cross section of epiphyseal region showing a degrading implant surrounded by new bone. Section taken at 6 weeks. Magnification 16x12.

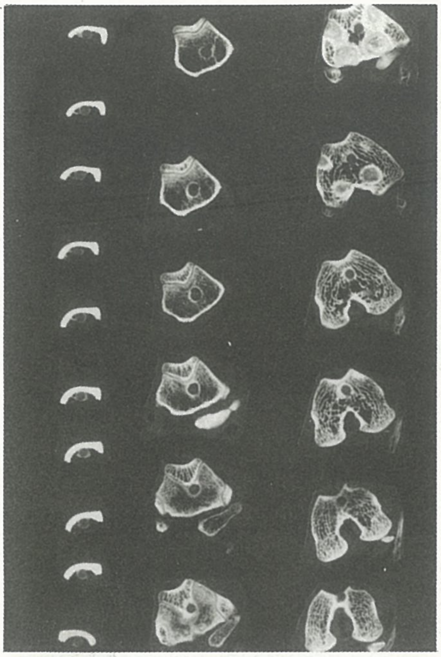

Figure 4 Micro-radiograph showing implant surrounded by cuff of new bone.

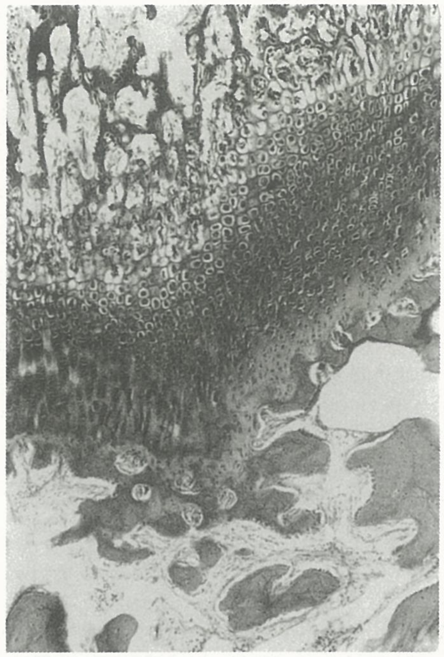

Figure 5a. Sagittal section of distal femur showing decrease in height of the hypertrophic zone of the epiphyseal growth plate at the area immediately adjoining the PGA rod. Magnification 16x12.

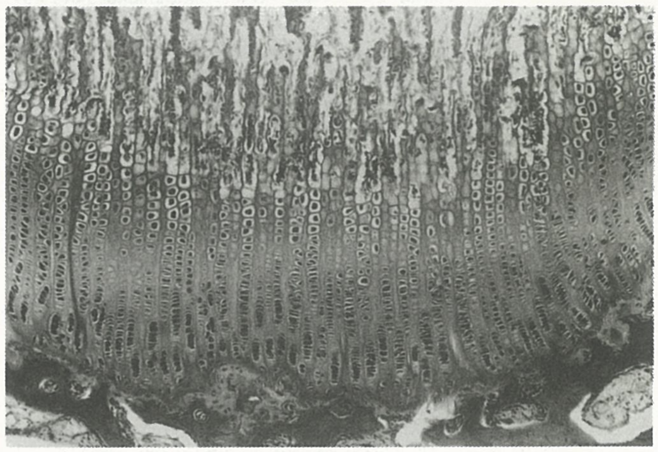

Figure 5b. Control Specimen (16x12).

implant was lined by a layer of granulation tissue. At 4 and 6 weeks, a thin layer of cancellous bone surrounds the polyglycollic acid implant(Fig.3). The 8 and 12 weeks specimens show a similar cuff of cancellous bone. Microradiography confirmed the presence of a thin cuff of cancellous bone surrounding the implant(Fig.4). The cellular elements of the hypertrophic zone of the epiphyseal plate showed uniform hypertrophy except at the junction between implant and the growth plate. Decrease in the hypertrophic zone was appreciable at 4 and 6 weeks, at areas adjacent to the degradable implant (Fig.5). No changes of ingrowth plate thickness were observed. At 8 and 12 weeks the hypertrophic zone was uniform. The degradation and fragmentation of the implant was completed at 12 weeks, the lacunae left behind was occupied by granulation tissue. However the site of penetrationby the degradable implant was replaced by regenerating cartilage and cancellous bone. This was observed in all of the 6 specimens sacrificed 12 weeks after implantation. No premature closure of epiphyses was observed in any of the rabbits in this series.

DISCUSSION

Degradation of polyglycollic acid is not only a chemical process of hydrolysis in an aqueous environment. Cellular enzymes around the implant material enchance the breakdown of PGA polymer. Our histologic findings in bone and synovium are typical of a non-specific foreign body reaction, and similar findings have been reported by various investigators[5,6]. Formation of new bone around the implant is perhaps a manifestation of this inflammatory reaction. Degradation of the polymer is accompanied by the formation of polymeric debris[7], some of which has been seen as birefringent material surrounded by an inflammatory infiltrate of cells. Increased vascularity and subsequent new bone formation may be a part of the biologic response to the cellular degradation of the polyglycollic acid implant.

The presence of an inflammatory reaction has had no detrimental effects on the physiology of the growth plate in our experiments. The femoral shortening reported is statistically insignficant, and in all these rabbits the histology did not show evidence of any osseous bridge across the growth plate resulting in epiphyseal growth arrest. The growth palte structure and development remained normal. Growth disturbance has been attributed to the size of the implant that crosses a growth plate with respect to the overall cross sectional area of the growth plate[3]. We have used the smallest diameter of implants in order to minimize the damage to the growth plate. While none of our experimental animals showed any clinical evidence of an unfavorable reaction, such inflammatory reactions have been reported in 6 percent of patients following treatment with degradable implants[7]. Cystic changes in bone resulting in a soap bubble appearance have been noted in the rabbit, and similar changes have been observed by us after the use of degradable implants in hand fractures. Such reactions probably represent one end of spectrum of the natural biological response to the polymer. The potential for such inflammatory reactions however, should be borne in mind while using degradable implants across the growing epiphyses. The use of such implants in children has been reported recently[7]. However sufficient clinical experience and information on the long term effects in the human physes is not yet available at present.

CONCLUSION

The use of polyglycollic acid implants has had no effect on the growth of the distal femoral epiphyses in rabbits, in this particular study. Our histologic findings indicate that the natural biological response to the implant is in the form of a non specific inflammatory reaction. The structure and growth of the distal femoral epiphyses remains unaffected even in the presence of a polyglycollic acid implant. Our present study and previously reported studies have shown the safety of such implants in small animals.

REFERENCES

1. Bostman O, Vainionpaa S, Hirvensalo E, et al. Biodegradable internal fixation for malleolar fractures : A prospective randomised trial. J Bone Joint Surg (Br) 1987;69:615-19.
2. Bostman O, Hirvensalo E, Vainionpaa S et al. Ankle fractures treated using biodegradable internal fixation. Clin Orthop 1989;138:195-203.
3. Makela EA, Vainionpaa S, Vihtonen K, et al. The effect of a penetrating biodegradable implant on the epiphyseal plate : An experimental study in growing rabbits with special regard to Polyglactin 910. J Paediatric Orthop 1987;7:415-20.
4. Masoud I, Shapiro F, Moses A. Tibial epiphyseal development : A cross- sectional histologic and histomorphometric study in the New Zealand white rabbit. J Orthop Research 1986;4:212.
5. Cutring DE, Hunsuck EE. The repair of fractures of the orbital floor using biodegradable polylactic acid. Oral Surg 1972;33:28-34.
6. Hollinger JO, Battistone GC. Biodegradable bone repair materials : Synthetic polymers and ceramics. Clin Orthop 1986;207:290-305.
7. Bostman O, Hirvensalo E, Makinen J, et al. Foreign body reactions to fracture fixation implants of biodegradable synthetic polymers. J Bone Joint Surg(Br) 1990;72:592-6.