# Fixation of rabbit osteotomies with biodegradable polyglycolic acid thread

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In 68 rabbits, osteotomies of the femoral medial condyle were fixed with either liquid n-buty-2-cyanoacrylate, bone cement and biodegradable polyglycolic acid (PGA) thread, or PGA thread only. Follow-up times were 1, 3, 6, 12, 24, and 48 weeks. Macroscopic, radiographic, histologic, microradiographic, and oxytetracycline labeling studies were performed. Microscopically, the medial condyles fixed with the combined materials healed in 8 of 34 rabbits and with PGA threads in 22 of 34.

In the fixation of pathologic fractures, polymethylmethacrylate (PMMA) bone cement is used to enforce metallic devices (Harrington et al. 1972). Few have attempted to use only bone cement for fracture fixation (Charnley 1966), because the strength of the bond depends solely on the mechanical contact of surfaces (Kilpikari 1980).

Biodegradable polyglycolic acid (PGA) threads have proved satisfactory for both experimental (Cutright et al. 1971) and clinical (Roed-Petersen 1974) mandibular fracture fixation. I have compared a combination of cyanoacrylate, PMMA, and PGA thread with PGA thread only in fixation of rabbit osteotomies.

## Material and methods

*Experimental animals and fixation devices.* Sixty-eight rabbits of both sexes weighing at least 2.5 kg were operated on. Under anesthesia the right knee was exposed medially, and the patella was dislocated laterally. Transverse 2-mm holes for thread fixation were drilled at the proximal and distal aspects of a horizontal osteotomy. A sagittal osteotomy followed, and fixation of the medial condyle (Figure 1) was obtained with either (Group A) n-butyl-2-cyanoacrylate (Histoacryl®), bone cement (CMW®), and biodegradable, polyglycolic acid (PGA) thread (Dexon®, 0–0) or (Group B) biodegradable threads only. The wound was closed in layers. In pilot operations, it was noticed that unfixed fragments of the femoral medial condyle dislocated completely, and all the rabbits had to be killed a few days after the operation.

The rabbits were kept in cages and allowed to walk without external support until they were killed with an overdose of Hypnorm® at 1, 3, 6, 12, 24, and 48 weeks (Table 1). During follow-up the general condition of the rabbits, wound healing, and the degree to which the rabbit was able to stress the operated limb were observed. Four and three days before death, the rabbits were injected with Vendarcin® 50 mg/kg daily intramuscularly for oxytetracycline (OTC) labeling studies (Milch et al. 1958).

*Examination methods.* Radiographs were taken after death in anteroposterior and lateral projections. The distance between the roentgen tube (Bi 125/30/50 RG) and target was 90 cm; the exposure factors were 40kV, 12 mAs, and 0.03 s. The distal 3 cm of each femur was removed and prepared free of soft tissues. The macroscopic examination included the manipulation of the osteotomized medial condyle. If any movement of the fragment was noticed, the fixation was considered unstable. The specimens were fixed in 70 percent alcohol

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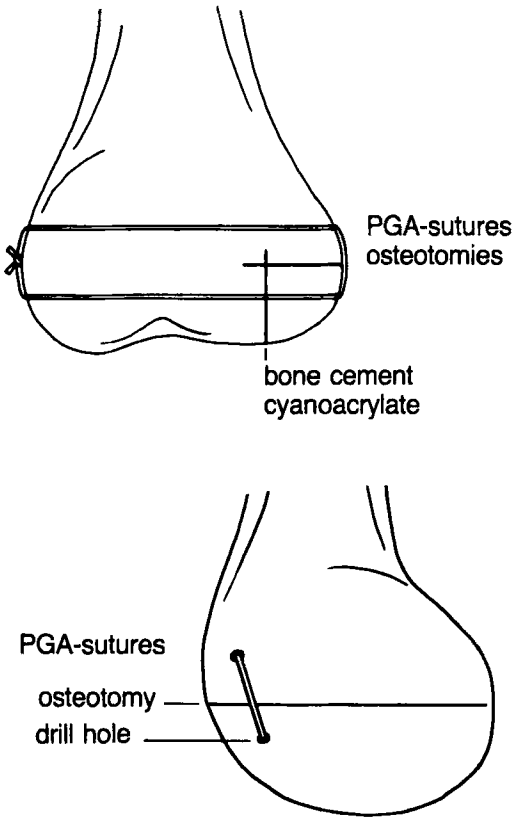


Figure 1. The operating technique.
In one group the cancellous surfaces of the longitudinal osteotomy were cleaned, dried, and treated with a thin cyanoacrylate layer. PMMA was pressed into the longitudinal osteotomy crack. The horizontal osteotomy was left free of PMMA. The medial condyle was reduced and the cancellous surfaces were compressed against each other. After polymerization of PMMA, the fixation was secured with PGA threads.
In the other group the fixation was created after reduction with pure PGA threads pulled through the drill holes around the fragments.

and kept there until methylmethacrylate blocks were made (Schenk 1965). Histologic sections were cut with a microtome (Jung, Polycut S) at 5 μm thickness and stained with the Masson-Goldner (1938) method. For microradiography and OTC-labeling, sections were made with a saw microtome (Leitz 1600) at 80 μm. For microradiography, Kodak high resolution film (So 343) was used with a 24-cm tube target distance and exposure factors of 50 kV, 9 mAs, and 12 min. Fluorescence microscopy was performed using a HBO 220 UV lamp and BG 812/6 primary filter, which permitted the passage of 3660 UV radiation.

The chi-square test was used for comparison of the fixation methods.

## Results

Instability of the osteotomy was noticed in 15 rabbits in Group A and in 5 in Group B, always with malposition of the medial condyle (Table 1). The amount of external callus increased with the instability, being abundant in 20 of the Group A rabbits and in 10 of the Group B rabbits (Figure 2).

*Microscopic results.* According to histologic, microradiographic, and OTC-labeling, the medial condyles healed normally in 8/34 and 22/34 in Groups A and B, respectively.

*One week.* After combined fixation, histologic and microradiographic studies showed no new bone in the osteotomies, and OTC-labeling was

Table 1. Macroscopic and radiographic findings of the fixation of experimental osteotomies of the femoral medial condyle with cyanoacrylate, bone cement, and biodegradable thread (A), or with pure biodegradable thread (B) in rabbits

| Follow-up time (weeks) | Number of rabbits | | Instability of the fixation | | Delayed or nonunion | | External callus | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | None | | Moderate[a] | | Abundant[b] | |
| | A | B | A | B | A | B | A | B | A | B | A | B |
| 1 | 5 | 5 | 2 | 0 | – | – | – | – | – | – | – | – |
| 3 | 5 | 5 | 1 | 1 | – | – | 1 | 0 | 1 | 5 | 3 | 0 |
| 6 | 5 | 5 | 4 | 2 | 4 | 2 | 0 | 0 | 1 | 2 | 4 | 3 |
| 12 | 6 | 5 | 1 | 0 | 4 | 0 | 0 | 3 | 3 | 2 | 3 | 0 |
| 24 | 5 | 4 | 4 | 1 | 4 | 1 | 0 | 0 | 1 | 3 | 4 | 1 |
| 48 | 8 | 10 | 3 | 1 | 4 | 4 | 0 | 2 | 2 | 2 | 6 | 6 |
| Total | 34 | 34 | 15 | 5 | 16/24 | 7/24 | 1 | 5 | 8 | 14 | 20 | 10 |

[a] Periosteal new bone being less than the thickness of the cortex.
[b] Periosteal new bone exceeding the thickness of the cortex.

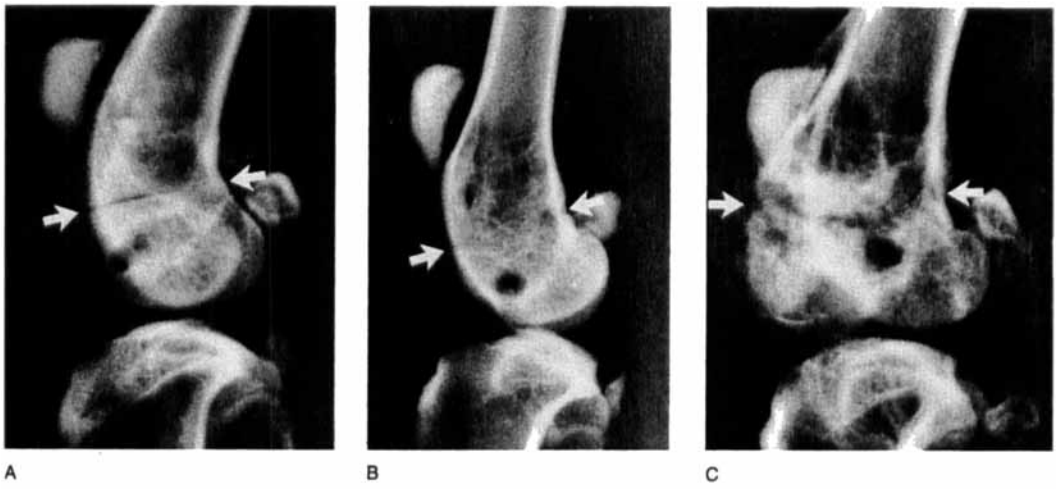


Figure 2. Radiographs of tibial osteotomies.
A. Medial view of an osteotomized knee at 1 week after operation fixed with PGA threads. Horizontal osteotomy (arrows) is clearly visible.
B. After 12 weeks, fixation with PGA threads. Osteotomy has united.
C. After 12 weeks, fixation with cyanoacrylate, PMMA, and PGA threads. Osteotomy (arrows) is open and medial condyle in malposition. Abundant callus formation.

weak in one case near the horizontal osteotomy in 1 rabbit only. After fixation with PGA threads, only new bone was observed in the osteotomies and extracortically around the medial condyle in 3 rabbits. Weak OTC fluorescence was observed in 3 rabbits near the horizontal osteotomy and outside the medial condyle.

*Three weeks:* After combined fixation, callus had developed at the proximal site of the horizontal osteotomy in 3 rabbits, and granulation tissue covered PMMA in the longitudinal osteotomies. In 3 rabbits there was weak uptake of OTC on both sides of the osteotomies. After PGA-thread fixation, there was callus in the osteotomies and extracortically near the medial condyle (Figure 3) in 3 rabbits, and in 2, granulation tissue was seen in the osteotomies between cancellous surfaces; moderate uptake of OTC fluorescence was observed there and outside the medial condyles.

*Six weeks:* After combined fixation, histologic and microradiographic studies showed that none of the osteotomies had healed (Figure 3). Callus was noticed on both sides of the horizontal osteotomy in 1 rabbit, and granulation tissue had developed between bone fragments and PMMA in all the rabbits. After fixation with pure PGA threads, two osteotomies had healed, and in the other 3 rabbits there was callus and granulation tissue extracortically at the site of the horizontal osteotomy.

*Twelve weeks:*After combined fixation, one osteotomy was partly healed, extracortical new bone was noticed in 4 rabbits, and granulation tissue between bone fragments in 5 of the 6 rabbits. OTC-labeling indicated moderate uptake extracortically. After fixation with pure PGA threads, four osteotomies had healed, and in one there was granulation tissue between bone fragments.

*Twenty-four weeks:* According to histologic and microradiographic studies after combined fixation, one osteotomy had healed, and in 4 cases granulation tissue had formed between bone fragments. Weak uptake of OTC was observed in one horizontal osteotomy. After pure PGA thread fixation, two osteotomies had healed (Figure 3) and granulation tissue was observed at the other two.

*Forty-eight weeks.* After combined fixation, granulation tissue had formed at all seven osteotomies, and only one had healed. No OTC-fluorescence was observed. After pure PGA-thread fixation, 5/10 osteotomies had healed, and granulation tissue was present between bone fragments in the others. No uptake of OTC fluorescence was observed.

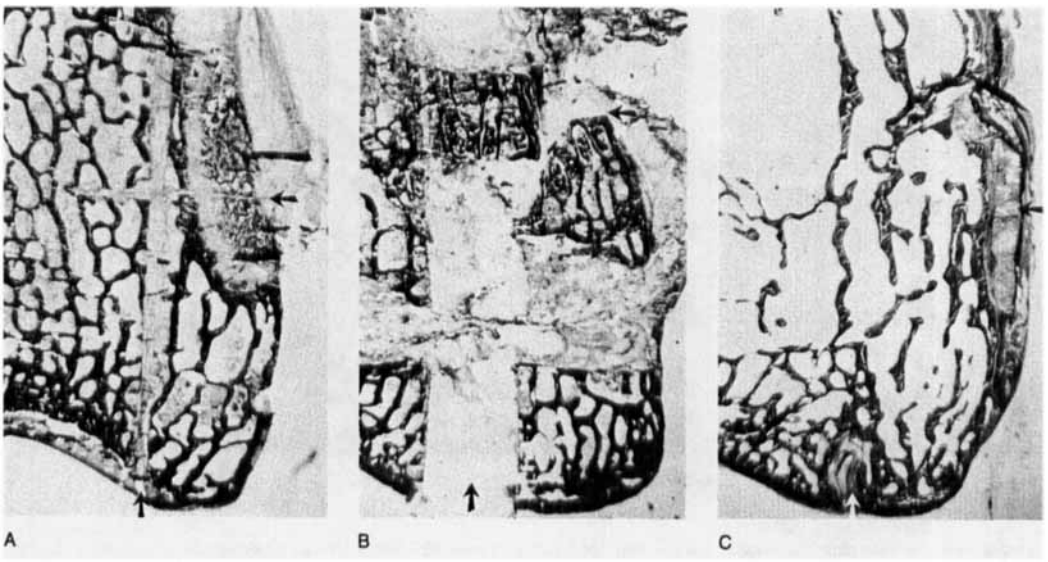


Figure 3. Photomicrographs, X 7.
A. Osteotomies (arrows) fixed with PGA threads 3 weeks after operation. New bone is observed (upper arrow).
B. Malpositioned medial condyle fixed with cyanoacrylate, PMMA, and PGA threads 6 weeks after operation. Osteotomies (arrows).
C. Healed osteotomies (arrows) fixed with PGA threads after 24 weeks. A small remnant of the sagittal osteotomy is seen (lower arrow).

The macroscopic and radiographic results of biodegradable thread fixation were better ($P < 0.005$) than those of combined fixation. In the microscopic results the difference was even more clear ($P < 0.0005$). The callus formation was more abundant ($P < 0.005$) after the fixation with cyanoacrylate, bone cement, and PGA thread combined.

## Discussion

Human fractures have been shown to heal around PMMA provided that the reduction is stable and fracture surfaces are not completely occluded with cement (Charnley 1966). In the improvement of adhesion between cortical bone and plastics (PMMA, composite resin), the benefit of intermediary material (liquid acryl) has been reported in vitro (Vainio et al. 1979, Kilpikari 1980) and in vivo in rats (Lapinsuo et al. 1986). PGA threads have a high initial tensile strength (98 kg/mm$^2$, 3–0 thread; Herrman et al. 1970), which gradually disappears due to hydrolysis during 4 to 6 weeks (Reed and Gilding 1981).

The fixations of the present series were subjected to weight bearing immediately after anesthesia, since walking of rabbits was allowed freely without external support. Microscopic studies showed normal healing in 8 of 34 osteotomies fixed with cyanoacrylate and bone cement, and after 6 weeks the radiographs revealed eight unions of 24 osteotomies. In most of the cases the fixation materials could not provide adequate stability for bone healing, and the medial condyle dislocated under weight bearing so that the contact was lost between bone fragments at the horizontal osteotomy, with ingrowth of granulation tissue. The instability of the fixation caused abundant callus formation, yet insufficient to stabilize the osteotomy. This happened to a greater extent in the present study than in our previous work (Vihtonen et al. 1986).

Results of a recent study (Lapinsuo et al. 1986), where osteotomies of the diaphyseal tibiae of rats were fixed with liquid acryl and composite resin, appeared to be better than those of the previous study without intermediary material (Vainio and Rokkanen 1978). Furthermore, the bonding strength of liquid acryl used in the present study, n-buty-2-cyanoacrylate, to cancellous cadaver bone is only one fifth of its bonding strength to cortical cadaver bone (Weber and Chapman 1984). This fact might explain why the treatment

of cancellous surfaces of the longitudinal osteotomy with cyanoacrylate did not adequately strengthen the adhesion between living cancellous bone and PMMA.

The fixation of the medial condyle osteotomy with only biodegradable PGA thread gave better results; the osteotomies of 22 of 34 rabbits were healing normally, and radiographs showed union in 17 of 24 osteotomies after 6 weeks. The results were promising when taking into account the substantial forces to which an osteotomized medial condyle was subjected immediately after the operation. The difference between microscopic and macroscopic results is explained by the stiffness of the granulation tissue bond between bone fragments in unhealed cases where malposition of the medial condyle was not observed.

In two recent experimental studies, a distal femoral osteotomy was fixed with bone cement and cyanoacrylate (Vihtonen et al. 1986) and pure biodegradable threads (Vihtonen et al. 1987). According to these investigations the results produced with PGA thread were better than those produced with adhesives. The strengthening of the pure thread fixation with biodegradable rods (Törmälä et al. 1984, Vainionpää et al. 1986) led to healing of similar femur osteotomies in all 19 rabbits.

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