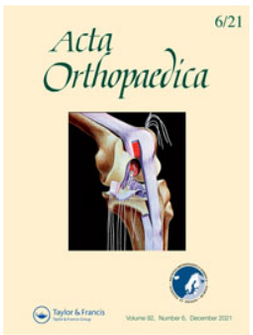

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THE EFFECT OF DELAYED INTERNAL FIXATION ON FRACTURE HEALING

An Experimental Study

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In the application of internal fixation to certain closed fractures the rationale for early surgery has long been accepted (Murray 1941), and the proper use of improved internal fixative devices, particularly those employing compression or rigid intramedullary nails, may result in a rapid return of function and very low rates of non-union. Nevertheless, there is now abundant clinical evidence that delayed internal fixation, performed after a waiting period, produces a significant drop in the overall incidence of non-union. This conclusion is based on the operative results of different surgeons working with differing fixative devices (Charnley 1961, Emery 1965, Lam 1964, Smith 1959, 1964, Borden & Smith 1952).

The waiting period constitutes a time interval of one to three weeks after fracture; though some reports indicate a period longer than this.

Published material allows no such conclusions in the case of compound fractures. Furthermore, there is clinical evidence that in the case of femoral shaft fractures, delayed internal fixation may be followed by an increase in callus formation (Charnley & Guindy 1961).

The discovery that closed fractures heal more readily if operated upon "late" rather than "early" must mean that, after a delayed period, healing is rendered more efficient. This can only be due to effective callus, itself the result of local, or possibly remote, factors. Some consideration must also be given to variations in operative technique; for example, although procedures for internal fixation may often be more effective as a formal operation than as an emergency measure, the broad scope of the clinical series does not support the

Figure 1. Instron testing machine.

mechanical factor as being of major importance (Lam 1964). It is the possibility of a "second injury" (Stager & Smith 1959) phenomenon in callus that prompted this experimental investigation.

MATERIALS

Rabbits were used in the experiment, the stock being Belgian Whites. All were grown but not fully mature. A standard diet of purina rabbit kibble was provided.

Closed fracturing of a limb introduces so many variables that it was decided to section the radius surgically under general anaesthetic. This was achieved by inserting a nasal septum saw through a small skin incision, which was then sutured. (In experimental animals there is no evidence that a delay in fracture-healing results from such operative exposure (Herms & Blount 1964).

Maximum sterile precautions were maintained, the skin in each leg being shaved and bared by a chemical epilator before being painted with surface antiseptic.

In this way, a fracture was produced at a similar site in each animal. Splinting

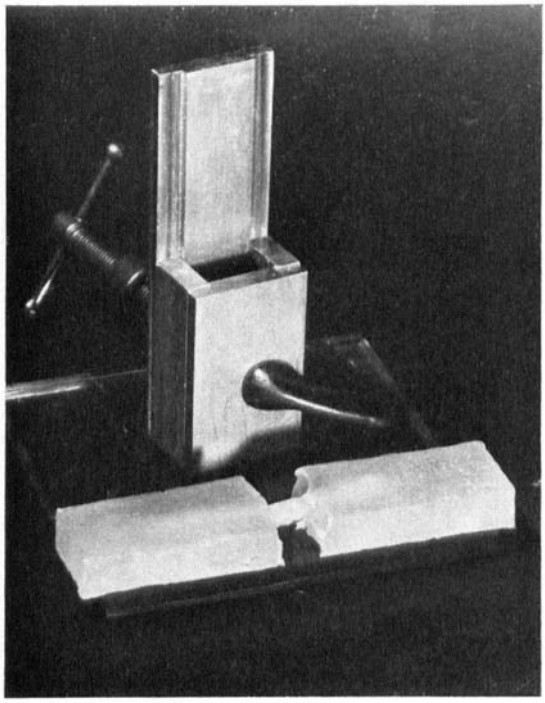


Figure 2. Aluminium mould and a radius mounted in acrylic resin.

was not required for the rabbit radius which is very tightly bound to the ulna by the interosseus membrane.

Exclusive of animals used in a preliminary pilot project, there were available two hundred and ten rabbits providing approximately twice this number of specimens although some were un-united, comminuted, or infected and thus rejected.

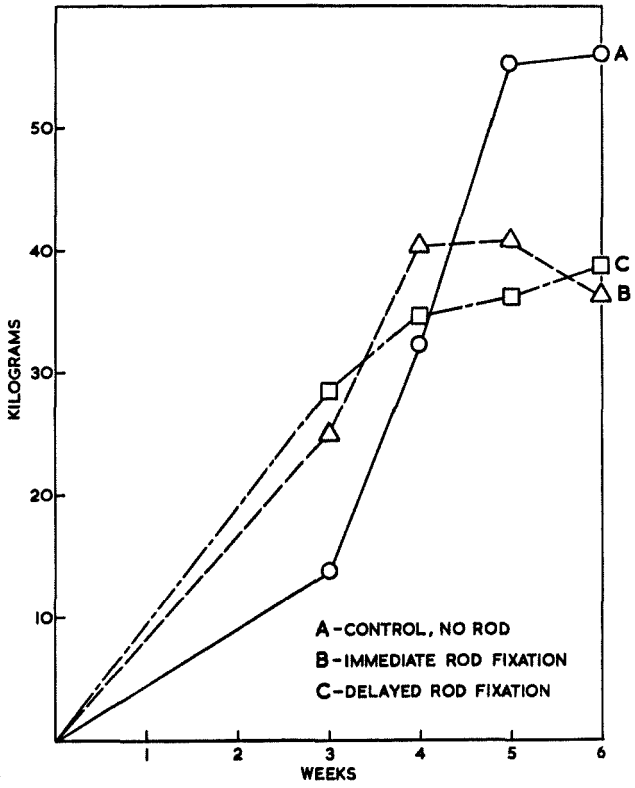
PREPARATION OF SPECIMENS

In each animal after sacrifice the radius was removed and dissected free of soft tissues. Initially the specimen was immersed in formalin. A pilot study performed on fractures prepared in this fashion indicated that formalin rendered specimens brittle, a factor previously noted by other workers (McElhaney, Fogel, Byars & Weaver 1964). Subsequently, each specimen was wrapped in cellophane and placed in the deep-freeze compartment of a domestic refrigerator.

Designation of Tests

Group A. These consisted of fractures surgically produced as described and designated A specimens. (No intramedullary fixation applied.) These rabbits were sacrified three, four, five, and six weeks after fracturing.

Group B. These were obtained three, four, five, and six weeks after fracturing



Graph 1. Fracture strength.

where an intramedullary K wire has been introduced through the wound at the time of wounding. This was immediate intramedullary fixation (B specimens).

Group C. These were obtained by sacrificing animals at the same time periods as Group B. In these, the intramedullary K wire was introduced *a week after* the fracture by re-opening and re-suturing the wound (C specimens).

Testing Procedures

The strength of callus was tested in tension as by Falkenberg (1961). The work was performed on an Instron testing machine (Figure 1). The ends of each unfrozen bone were mounted in acrylic resin, using an aluminium mould (Figure 2). The radius mounted in this manner was inserted between the jaws of the Instron tester and pulled in tension.

The maximum loads at which fracture of the callus occurred are shown in Graph 1.

The two fragments of each specimen were retained. One was preserved in formalin for future histological examination and one served for computation of the cross-sectional area of the callus at the fracture site and of its porosity. To assure

the best possible accuracy, the fractured end of a callus was polished flat and a photomicrograph was made with the aid of a standard metallurgical microscope. From the photomicrograph the porosity of the callus was estimated and its cross-section measured with a planimeter. The results are shown in Graph 2 and Graph 4. Finally the total volume of callus in each specimen was calculated by approximating its shape to that of an ellipsoid, Graph 3.

RESULTS

Fracture Strength

Graph 1 shows that the radii from the group of animals having no intramedullary nail attained the greatest strength five and six weeks after fracturing (Group A). The statistical level of significance of difference between this group and C specimens (rod inserted one week after fracture) was 0.30.*

The fracture strength for B and C groups increased in approximately the same manner.

Fracture Cross-sectional Area and Callus Volume

Graph 2 indicates that in the initial stages of healing (up to 3 weeks) Group C has developed a greater cross-sectional area than the other groups. The calculated level of significance of difference between Group C and Group A was 0.25.

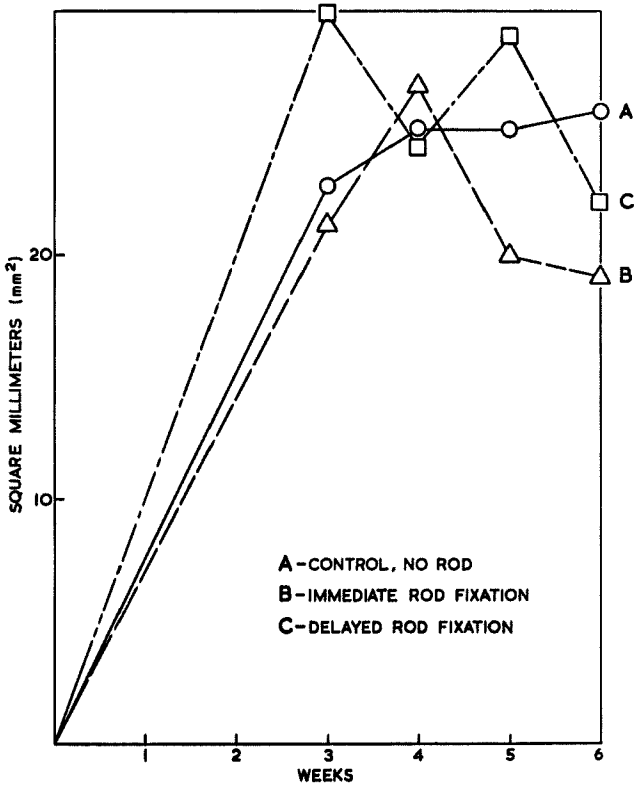
Graph 3 supports this evidence and shows a much greater volume of callus at the same period. The level of significance of difference between Group C and Group B was 0.001. A surprisingly high value was attained in three weeks by the control Group A.

In both graphs the large initial cross-sectional area and volume tapered off to about the same value after a period of 5 to 6 weeks.

Porosity of Callus

Graph 4 partly justifies the values indicated on the previous graphs at the critical period of three weeks. The low strength of the callus having a large cross-section may be explained by the greater porosity at this period. Again the greatest porosity is displayed by Group C.

* The level of significance is calculated from the "t" test for the estimated standard error of the difference between two sample means. It signifies that there is 70 per cent probability that the value for Group A is higher than the value for Group C.



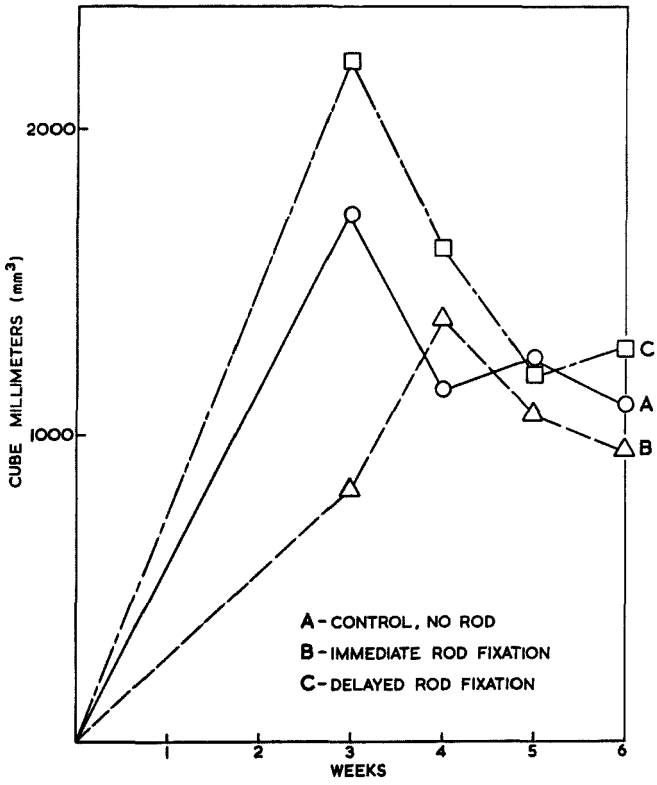
Graph 2. Callus cross-sectional area at the fracture site.

The level of significance of difference between Group C and Group A was also 0.001. The rapid decrease in porosity in later weeks indicates a vigorous rate of remodelling of callus.

COMMENT

It was not the purpose of this study to investigate the factors responsible for callus changes in fractures treated by delayed internal fixation, rather it has been an attempt to illustrate that such changes do in fact occur. In the clinical series describing the phenomenon, there is speculation about the existence of general and local hormonal factors in operation. The response of a fracture twice disturbed resembles that of a wound re-sutured after a waiting period.

Local mechanical factors undoubtedly influence the process but we find it hard to believe that an immediate operative internal fixation



Graph 3. Total volume of callus.

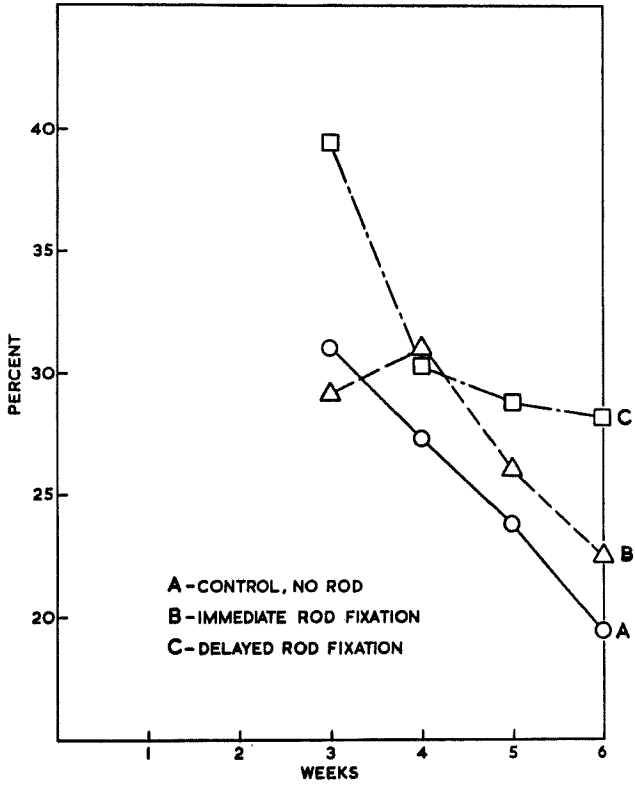
creates more tissue damage than a delayed procedure. Possibly the periosteum and soft tissues strip more widely in the immediate operation.

The experimental material so far presented has supported the clinical observation that callus forms rapidly and in increasing bulk following a delayed surgical internal fixation where this is necessary. Prior wounding failed to result in stimulated callus. The indications are that delayed intervention has a local stimulatory effect on the normal reparative process.

Further work is in progress in an attempt to clarify this issue.

SUMMARY

The findings in these animal experiments indicate a stimulation of callus production in fractures treated by delayed internal fixation.



Graph 4. Porosity of callus.

This effect is at its maximum after the insertion of the fixative device. Thereafter, the callus becomes remodelled in a similar fashion to the callus forming after immediate open reduction.

In the critical healing periods such delayed surgery does not appear to confer any increased callus strength when specimens are tested in tension.

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A pilot study was performed by Dr. A. J. Phares, lately of the Toronto Western Hospital and now at Beirut, Lebanon.

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