

RIGIDITY OF IMMOBILIZATION OF TRANSVERSE FRACTURES

By

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The prime importance of immobilization in the treatment of fractures is reflected in the following quotations from major works in this field: "The aligned fragments must be *fixed immovably* in their correct position until the bones are properly united" (*Böhler*). "Protection of the growing cells from injury of movement by *complete immobilization* of the fracture is essential" . . . "There is only one cause of non-union of fractures with a continuous haematoma between the fragments—the cause of non-union is *inadequate immobilization*" (*Watson-Jones*). "Non-union is in most instances due to *incomplete fixation* of fragments" (*Cave*). "Since fractures heal by formation of new bone around the bone ends, it is important that the *immobilization be as nearly absolute as possible*. Every movement between the fragments results in an injury to the callus" (*Key & Conwell*). "The most common causes for delayed union are: (1) *Inadequate immobilization*, permitting rotation and shearing stress to act at the fracture site. (2) Failure to maintain adequate immobilization until union is complete" (*De Palma*). (Author's italics).

While it is thus generally accepted that immobilization is of greatest importance if union of a fracture is to be ensured, it is obvious that immobilization is not in all cases a condition of union. Fractures of the ribs and clavicle heal almost invariably without proper immobilization and during constant, though small, movements. The same is true of, for instance, fractures of the femur treated by traction. The statements quoted above should therefore be interpreted as implying that immobilization will ensure a smaller risk of pseudarthrosis the more complete the immobilization is.

What is actually signified by the term immobilization? In the sense in which it is commonly used it means that the bone fragments are held

absolutely still so that movement of one in relation to the other is prevented. In the sense in which the term is used in mechanics, complete immobilization cannot be reasonably achieved. When a union is acted on by even quite small forces, there will always be some movement, although it may not be measurable by the usual techniques. A more realistic approach to the problem would probably be to examine how large movements are permissible for the fracture still to be united in the most rapid and reliable way.

Martz measured the force required to deform transverse fractures immobilized with Lane and Sherman fracture plates. This, however, touches only the periphery of the problem. The immobilization of fractures by external means (with plaster or splints) or internally (by osteosynthesis) would seem to have been little investigated.

This article reports a study of the stability of transverse fractures of femur shafts immobilized by various osteosynthesis techniques.

MATERIAL

Since it was intended in the first place to compare different methods of immobilization, a pilot study was performed with pine-wood rods of round section, 30 mm. in diameter and 400 mm. long. These were sawn in half at right angles to the longitudinal axis, after which they were immobilized in the following ways: (i) One fairly thin Sherman fracture plate with 4 holes (no. 6); (ii) two such plates of heavier type with 4 holes (no 5); (iii) one Sherman plate of heavier type with 6 holes (no. 2); (iv) two such plates with 6 holes; (v) three staples. Further tests were conducted with fresh femurs from autopsy subjects. The bone was bared of muscle and tendons and the marrow was washed out with hot water. These shafts were sawn into two parts perpendicular to the axis and the fragments were immobilized with (vi) one Sherman plate of heavier type with 6 holes; (vii) two such plates with 6 holes; (viii) three staples; (ix) Hoffmann transfixation instrument. Furthermore, (x) a tibia was immobilized with a Hoffmann instrument after a transverse fracture with splintered ends had been caused by breaking. (xi) a Küntscher medullary clover-leaf nail. When 2 Sherman plates were used they were always set at right angles to one another. The plates, screws and staples were of vitallium, the nails and Hoffmann instruments of stainless steel. All the immobilizations were performed with usual surgical instruments. A mechanically better immobilization could be made with the specimens than would be possible during an actual operation.

METHOD

The rigidity of immobilization of a fracture can be tested by measuring the deformation resulting from the application of different forces, for instance, compression, traction, torsion and bending. Fractures are usually not subjected to traction, and the compressive force of muscular tonus is taken up entirely by the

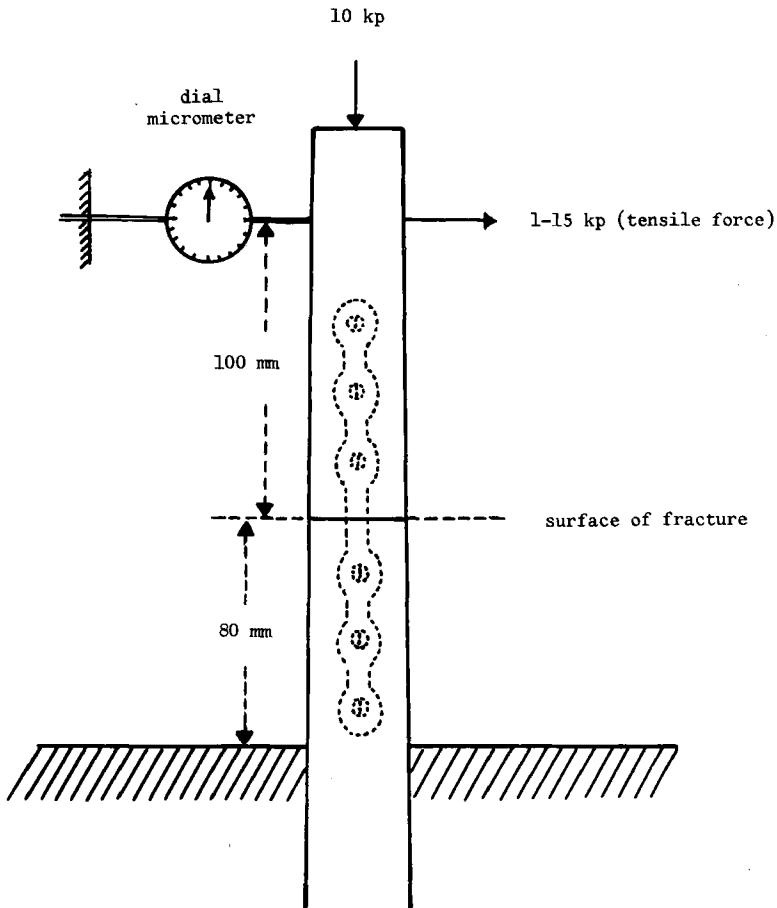


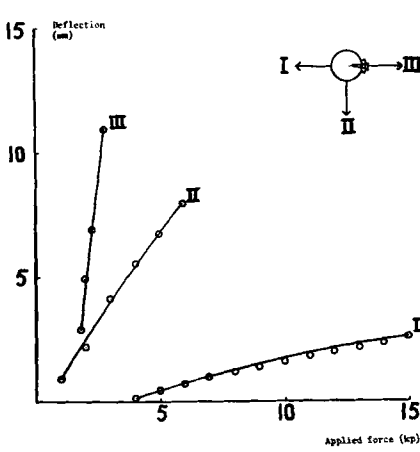
Fig. 1.

Arrangement for measuring the deflection of fractured femur and wooden shafts immobilized with various osteosyntheses.

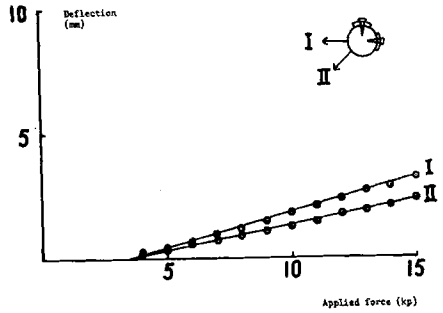
bone in the case of transverse fractures. The effects to be tested were therefore those resulting from bending and rotation.

With the bone held perpendicular in a vice 80 mm. below the fracture, a tensile force was applied perpendicular to the bone at a point 100 mm above the fracture. The deflection at this point was recorded on a dial micrometer (Fig. 1). The force was applied in two, three or four directions, depending on the type of immobilization. The effect of torsion was examined in a similar manner, the angle of rotation for different moments being recorded. In all cases the specimen was compressed axially with a force of 10 kp¹, corresponding approximately to the force due to the tonus in the thigh muscles.

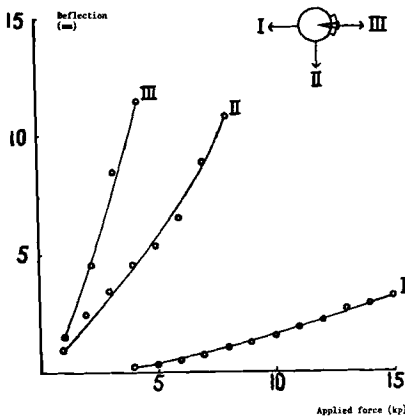
¹ One kilopond (kp) = 9.80665 newtons.



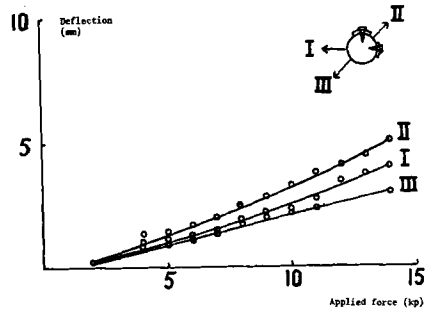
A Wooden rod.
One 4-hole Sherman plate



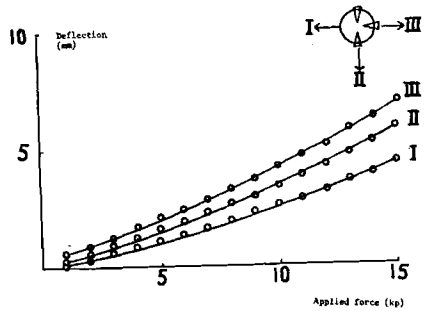
B Wooden rod.
Two 4-hole Sherman plates



C Wooden rod.
One 6-hole Sherman plate



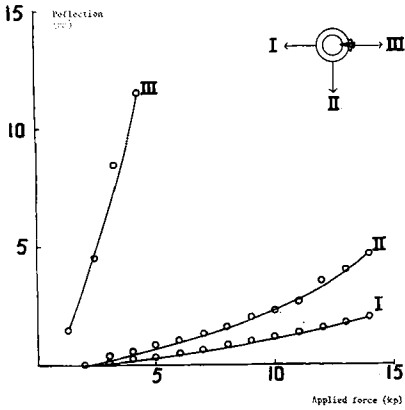
D Wooden rod.
Two 6-hole Sherman plates



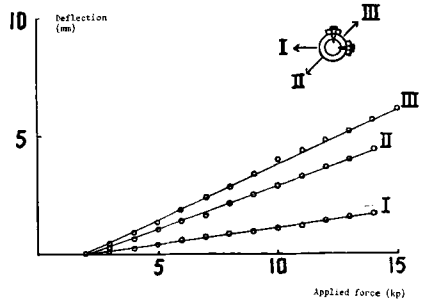
E Wooden rod. Three staples

Fig. 2. A-E

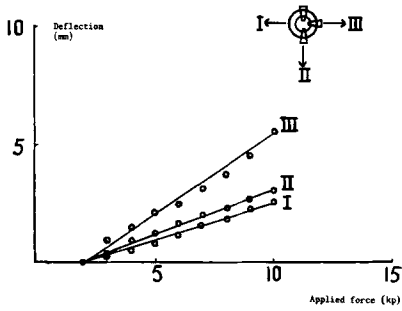
Relation between bending force applied at a point 10 cm from the surface of fracture of the wooden rod and the deflection at the same point. Directions of loading are indicated in the plan.



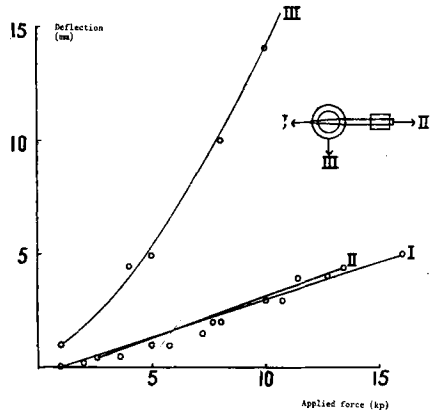
A Shaft of femur
One 6-hole Sherman plate



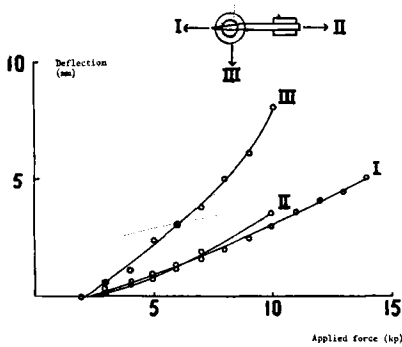
B Shaft of femur
Two 6-hole Sherman plates



C Shaft of femur. Three staples



D Shaft of tibia. Hoffmann
instrument



E Shaft of tibia. Hoffmann
instrument

Fig. 3. A-E
Relation between bending force applied at a point 10 cm from the surface of the femur shafts (A-D) and tibia (E), and the deflection at the same point. Directions of loading are indicated in the plan.

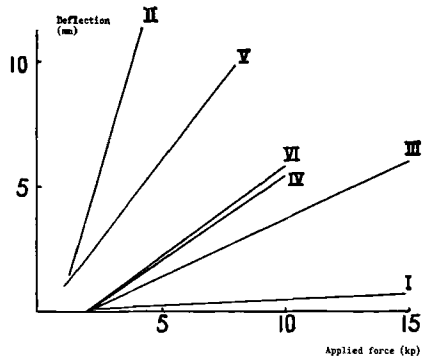


Fig. 4.

Comparison between osteosynthesis methods showing relationship between applied force and deflection of bone shafts: (I) unfractured shaft of femur, (II) fractured shaft of femur immobilized with one 6-hole Sherman plate, (III) two such plates, (IV) three staples, (V) a Hoffmann instrument (sawn, even fragments) and (VI) fractured shaft of tibia (splintered fragments) immobilized with a Hoffmann instrument. The lowest recorded values (that is, for bending in the direction of the least strength) have been taken as representative of each method.

Similar tests were performed with intact shafts of femur to find to what degree these were deformed by bending and torsional forces.

In many cases the immobilization of the fracture was poor, and because of definite deformation of the immobilization device the test had to be discontinued when the bending force was quite small. In other cases a force of up to 15 kp was applied at a point 10 cm from the fracture; this is equivalent to a bending moment of 150 kp cm. It may be noted by comparison that when a straight leg with a femur fracture in the middle of the shaft is raised horizontally, the immobilization device is subjected to a bending moment of 200 kp cm, through the weight of the leg.

RESULTS

The deformation resulting from bending stress in different directions is shown in Figs. 2-3 A-E. It is seen that the rigidity depended on the direction of the applied force, but that it varied little for a particular immobilization technique, whether applied to the wooden rods or bone. This indicates that the immobilization device was the weakest link in the system and that both wood and bone were stronger than this under the conditions of the experiments.

A comparison of the different methods of immobilization, where the lowest values for each method was recorded, showed that the technique involving 2 Sherman plates set at right angles to one another provided the greatest rigidity, but that, even so, the rigidity was considerably

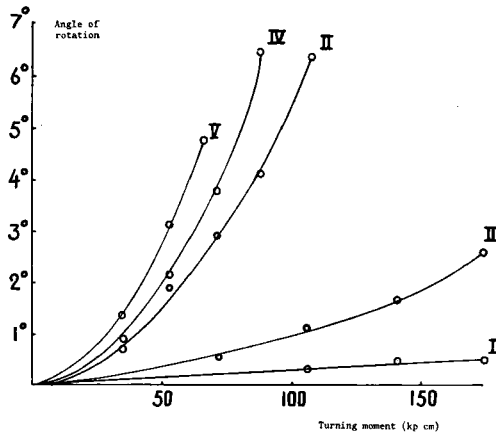


Fig. 5.

Comparison between osteosynthesis methods showing relationship between turning moment and resulting angle of rotation of (I) unfractured shaft of femur, (II) fractured shaft of femur immobilized with one 6-hole Sherman plate, (III) two such plates, (IV) three staples, and (V) a Hoffmann instrument. The forces were applied, and the angle of rotation recorded, in the same plane as that in which the tensile force was applied (see Fig. 1).

lower than that of the bone itself (Fig. 4). Comparison of the torsional rigidity for the different methods of immobilization also showed that the use of two plates provided the best results (Fig. 5).

It proved impossible to stabilize three available femur specimens with Küntscher nails, for the marrow space was wider than the diameter of the largest nail available—11mm; moreover, the space gradually widened distally, so permitting the distal part of the femur to be greatly angled, rotated and displaced laterally for several millimetres (Fig. 6).

DISCUSSION

The experiments show that from a purely mechanical aspect the immobilization obtained with different osteosynthesis devices was far from perfect. It is probably not unusual for a femur fracture shortly after operation to be subjected to a stress corresponding so that provided when the leg is raised from the bed. The forces applied in these tests were considerably smaller than this and yet in several cases they gave rise to a displacement of more than 10 mm at a point 10 cm from the fracture.

What is the effect of such a distortion at the site of fracture? When a femur fracture immobilized with one Sherman plate was subjected to

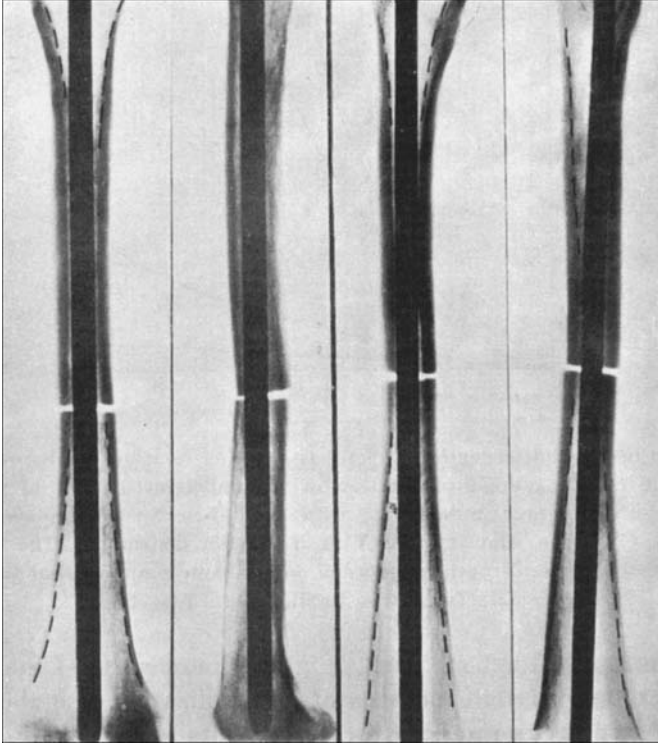


Fig. 6.

Radiographs of femur specimens which were immobilized with Küntscher nails. The contour of the marrow space is indicated with broken lines.

a force parallel to the plate surface (that is, in the direction of the greatest strength), a bending moment of only 100 kp cm (one half of the moment acting when the leg is raised) was enough to cause a lateral deflection of 2.5 mm at the point of application of the force. This caused the fracture to open 750 μm on the side opposite to that to which the force was applied; this distance corresponds to one hundred times the diameter of a red blood corpuscle. It is hardly surprising that such large movements often prevent the formation of a bridge of callus and lead to resorption of the bone fragments. In this situation the subsequent course of healing will probably be different according to the osteosynthesis technique used. A Hoffmann instrument ensures constant application of a certain pressure and hence continuous contact between the fragments, so that these can gradually heal in spite of small movements. The same applies to the Küntscher nail method. On the other hand, a

plate fixed in each of the bone ends will prevent contact between them after resorption has occurred, and the steady course of healing will therefore be retarded. One of the explanations of the poor results obtained with plates is probably that they were not stable enough to prevent small movements and resorption, and then only prevented optimal contact between the bone fragments. Of the other methods of immobilization it might be said that while they probably do not contribute to healing by stabilization of the union, nor do they directly obstruct healing. The fractures probably heal despite, rather than because of, this "immobilization".

For internal immobilization which provides rigidity as poor as that observed in this study, the term alignment or coaptation would seem to be more appropriate, the term immobilization being reserved for methods in which the rigidity approaches that of the bone.

Is there, in fact, any technique of stabilization that can be termed immobilization in this sense? The two-plate method gave the best results of those tested, but still movements occurred that were three times greater than those permitted by intact bone. From this standpoint none of the methods tested could be regarded as effective means of immobilization. In some special cases a Küntscher nail can be considered to provide such rigidity—namely, when it completely occupies the marrow space on each side of the fracture; this can occur only if the nail is of the same diameter as the space, and if the fracture is situated within the upper third of the femur, where the diameter may be constant for a distance of up to 10 cm. It may thus be said that there is practically no experience of what chance there is of a shaft fracture healing, and how rapidly, if it were *completely* immobilized, as is so strongly recommended in the text-books. From the theoretical standpoint, it would seem that such immobilization would provide the best results.

On the basis of these results a bone fracture plate has been designed that should provide a rigidity of an immobilized shaft fracture equivalent to that of the bone itself. Tests on this plate are in progress and will be published in due course.

SUMMARY

Experiments have been performed to compare the rigidity of different osteosynthesis devices (Sherman plates, staples, Küntscher nails and Hoffmann instruments). Tests have been made in which transverse fractures of wooden rods and femur shafts immobilized by these different methods have been subjected to bending and torsional forces. For

all the techniques the rigidity was low and unsatisfactory from a mechanical standpoint. The best immobilization was obtained with 2 Sherman plates set perpendicular to one another.

RESUME

Il a été effectué des expériences dans le but de comparer la rigidité du matériel utilisé pour l'ostéosynthèse (plaques Sherman, crampons, clous Küntscher et instrument Hoffmann). Des essais ont été faits dans lesquels des fractures transversales de tiges de bois et de corps du fémur immobilisées par ces différentes méthodes ont été soumises à des forces de flexion et de torsion.

Pour toutes les techniques la rigidité était faible et insatisfaisante du point de vue mécanique. La meilleure immobilisation a été obtenue avec 2 plaques Sherman placées perpendiculairement l'une par rapport à l'autre.

ZUSAMMENFASSUNG

Versuche wurden ausgeführt um die Widerstandskraft verschiedener Vorrichtungen zur Osteosynthese (Shermanplatten, Haspen, Küntscher Nägeln und Hoffmann Instrumenten) zu vergleichen. Proben wurden vorgenommen, in denen Querbrüche von Holzstäben und Femurschäften, die mittels dieser verschiedenen Methoden fixiert worden waren, beugenden und drehenden Kräften unterworfen wurden. Bei allen Techniken war die Widerstandskraft gering und vom mechanischen Gesichtspunkt unzufriedenstellend. Die beste Ruhigstellung wurde mittels zweier Shermanplatten erreicht, die senkrecht aufeinander gesetzt waren.

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