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RIGIDITY OF IMMOBILIZATION OF OBLIQUE FRACTURES

By

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The present study of the rigidity of immobilization of oblique diaphysis fractures is a sequel to a corresponding one on transverse diaphysis fractures (*Lindahl* 1962). From the mechanical standpoint there are many similarities in the immobilization of these two types of fractures but there are also a number of differences, among which are the following:

1) Displacement of the ends of an oblique fracture usually occurs in the axial direction; in a transverse fracture, however, there is no such movement after the fragments have been set.

2) There is a marked difference in the ease with which an oblique fracture can be bent in different directions. Bending in the plane that is perpendicular to the plane of fracture sets up a compression, whereas bending in any other direction will tend to cause a rotational displacement between the fracture surfaces. Transverse fractures are symmetric in this respect.

3) There are many more ways of immobilizing an oblique fracture than a transverse fracture—for instance, screws and cerclages may be used.

4) The use of screws presents a particular problem, namely, what direction of the screws will provide the greatest rigidity. Since, however, similarities between the two types of fractures predominate over the dissimilarities, the reader is referred to the earlier paper, which deals with the problems and method. The present article is concerned chiefly with the details of the method that differ from those of the previous study.

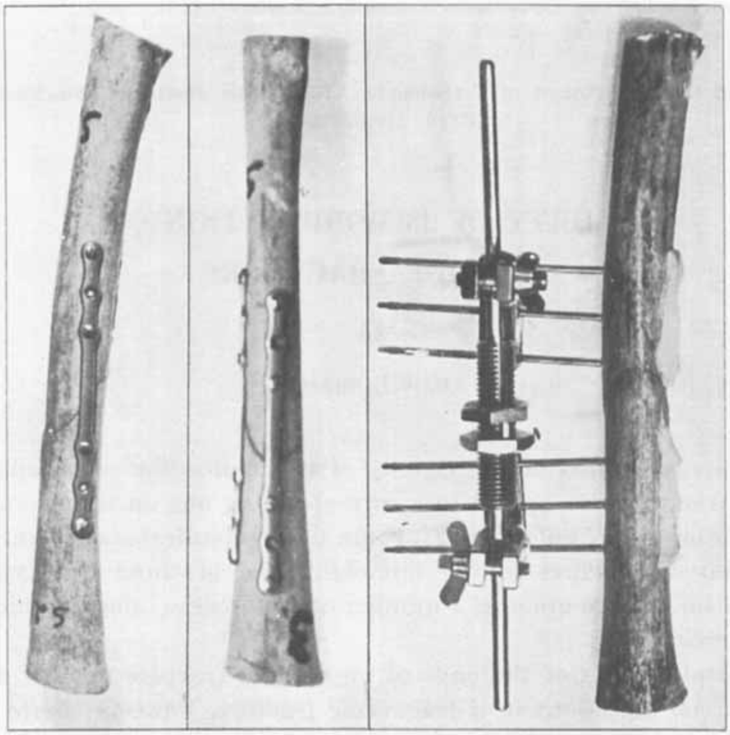
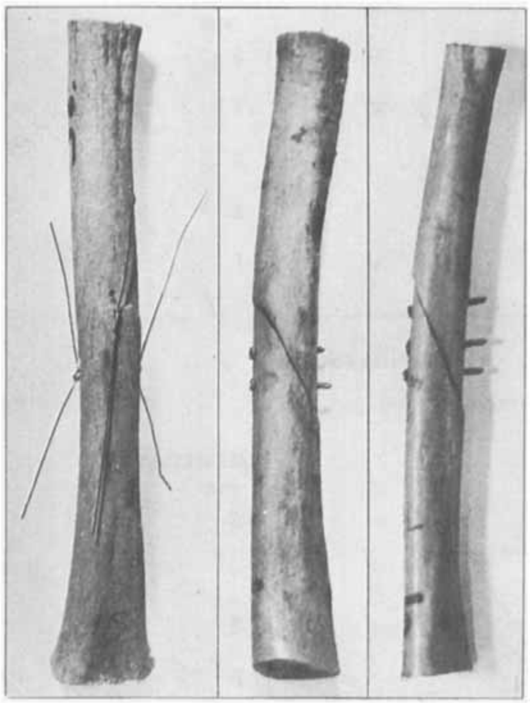


Fig. 1.
Immobilization of fractured femoral shaft.
A, one Sherman plate; B, two Sherman plates; C, Hoffmann instrument.

MATERIAL

Fresh femoral shafts from autopsies were used after they had been freed from soft tissues and the marrow had been washed out with hot water. The shaft was sawn in two by an oblique cut at an angle of 30° to the axis. The bone was sawn in a downward and backward direction so that the surface of fracture was perpendicular to the sagittal plane. The following methods of immobilization were used:

(1) Three cerclage wires (one millimetre thick and secured with a surgical knot), (2) one no. 2 Sherman plate (of the heavier type) with 6 holes, (3) two Sherman plates of the same type, (4) Hoffmann instrument, (5) three osteosutures (3 mm. drill holes, one-millimetre wire secured with a surgical knot), (6) two screws perpendicular to the shaft axis, (7) two screws perpendicular to the plane of fracture, (8) three

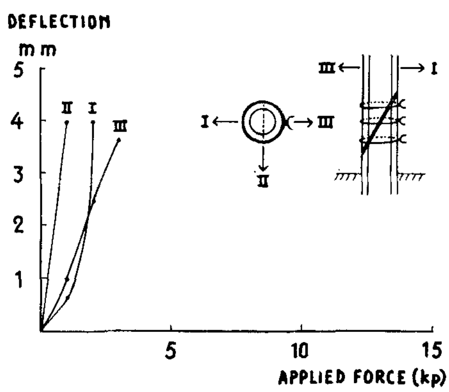


A B C

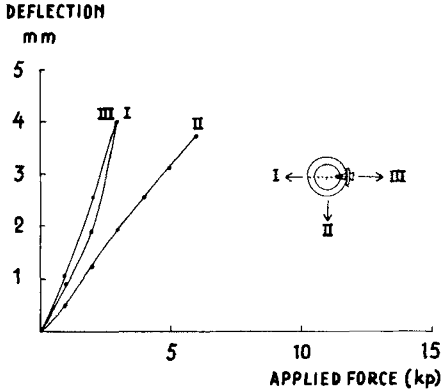
Fig. 2.
Immobilization of fractured femoral shaft.
A, three osteosutures; B, two screws; C, three screws.

screws perpendicular to the shaft axis, (9) three staples, (10) Küntscher nails (Figs. 1 and 2).

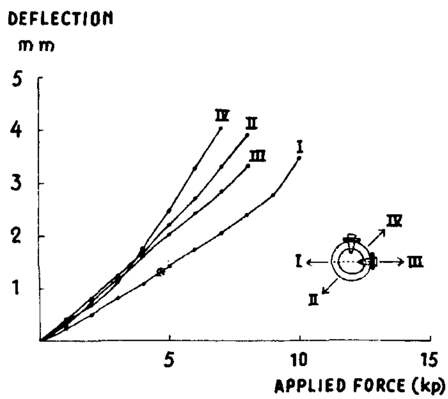
The plates, screws and staples were of Vitallium, and the nails, Hoffmann instrument and wires of stainless steel. The cerclage wires were placed symmetrically over the fracture. The single plate was placed on the lateral aspect of the bone, and when two plates were used the other was placed on the anterior aspect; the Hoffmann instrument was placed on the lateral aspect, the staples and osteosutures were placed on the medial, lateral and anterior sides, and the screws were inserted from the anterior side. Surgical instruments were employed and the various immobilizations could be performed better than at an actual surgical operation. Since the stability was tested in more directions than for the transverse fractures in the previous study, duplicate specimens were usually made for each method of immobilization; a total of 14 specimens were used.



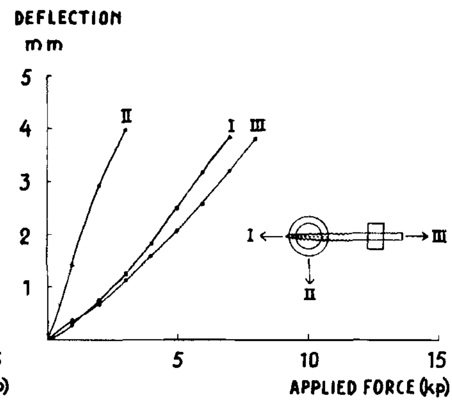
A 3 cerclage wires.



B one Sherman plate.



C 2 Sherman plates.



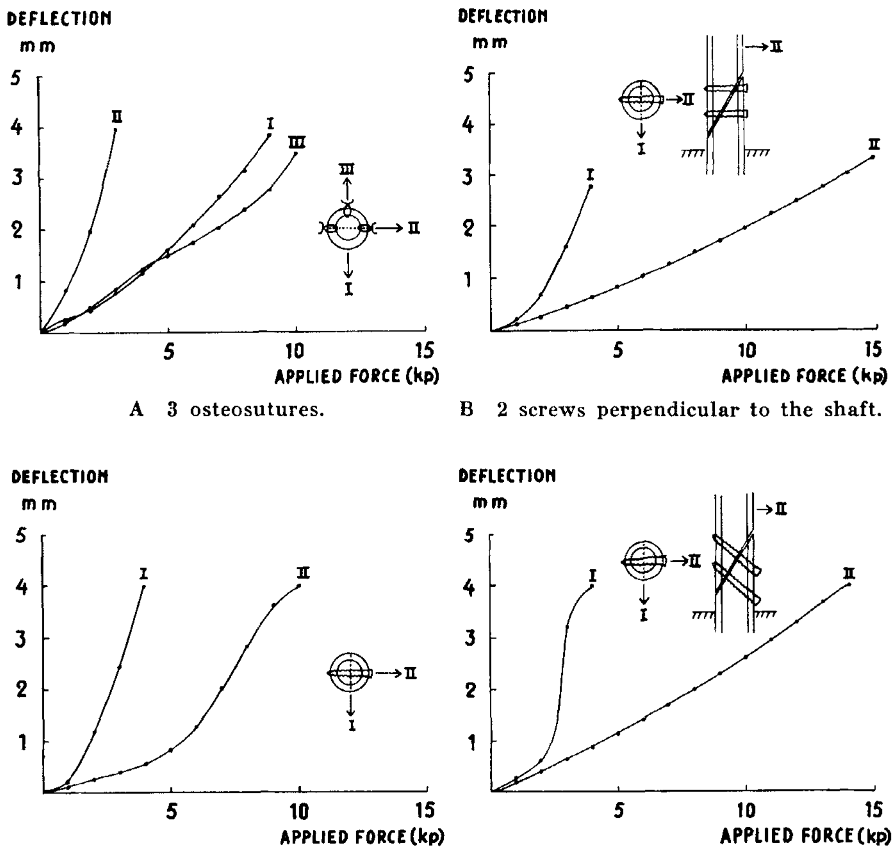
D Hoffmann instrument.

Fig. 3.

A–D. Relationship between bending force, applied at a point 10 cm. from the mid-point of the oblique fracture, and the deflection at the point of application. The directions of loading are indicated in the plan.

METHOD

The method was the same as that in the foregoing study (*Lindahl* 1962, Fig. 1, p. 239) except that the specimen was not subjected to axial compression. The reason for this difference is that the oblique fractures were usually more difficult to immobilize, and that, even when the load was small, there was a tendency for rotational displacement in the surface of fracture. As a result the axial compressive force gave rise to a bending moment, which was added to the applied bending moment; this complicated the interpretation of the results. As in the previous



A 3 osteosutures.

B 2 screws perpendicular to the shaft.

C 3 screws perpendicular to the shaft.

D 2 screws perpendicular to the plane of fracture.

Fig. 4.
A–D. As for Fig. 3 A–D.

study, the torsional rigidity was tested, and in addition the resistance to compression. So as not to cause permanent deformation of the immobilizing device or damage to the bone, the bending tests were discontinued at a deflexion of 4 mm., and in the torsion experiments at an angle of rotation of 3°. This usually enabled the specimens to be used for more than one test. The compressive strength was tested up to 3 mm. deformation or a load of 180 kp[1]. The movement was recorded after the load had been applied for 10 seconds. The tests were performed at the Swedish National Testing Laboratories.

[1] One kilopond = 9.80665 newtons = 2.2046 pounds weight.

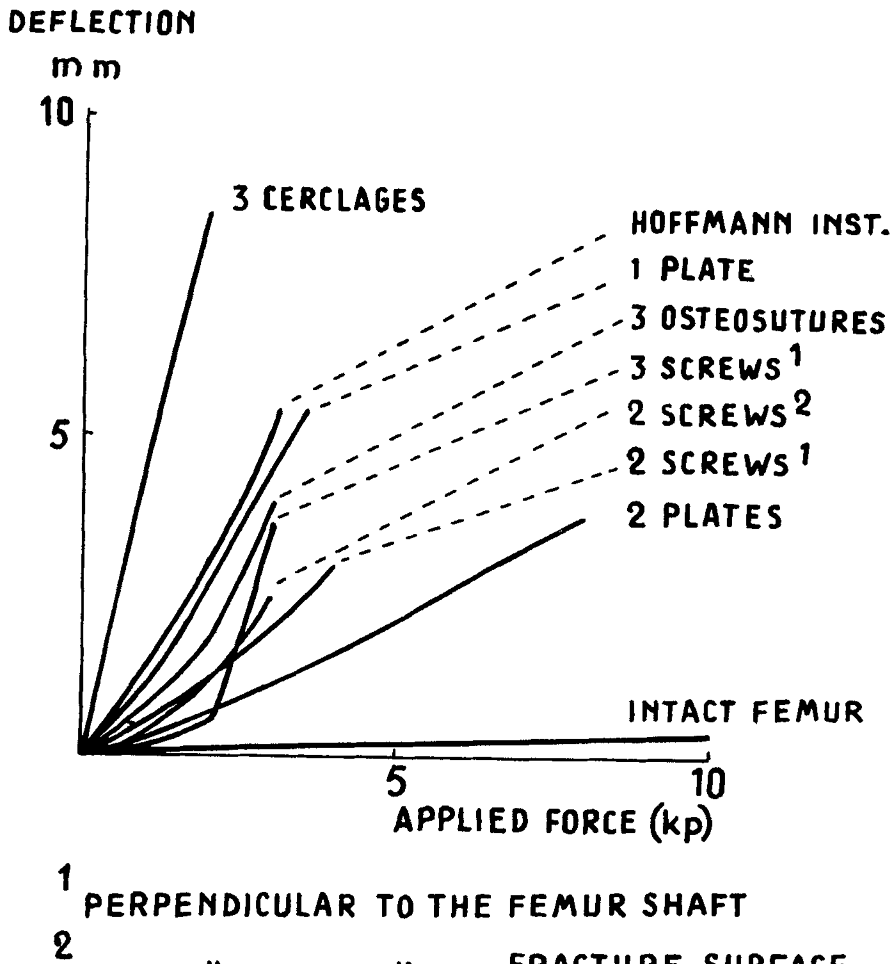


Fig. 5.
Comparison between different methods of osteosynthesis. The lowest recorded values have been taken as representative of each method.

RESULTS

It is seen from Figs. 2 and 3 A–D that the rigidity varied widely with the direction of the applied tensile force and that it was usually lowest for the direction in which there was a rotatory displacement between the fracture surfaces. The rigidity was extremely low in this direction. Attempts to immobilize an oblique fracture with three staples were unsuccessful, the reason being that in the oblique fracture, in contrast

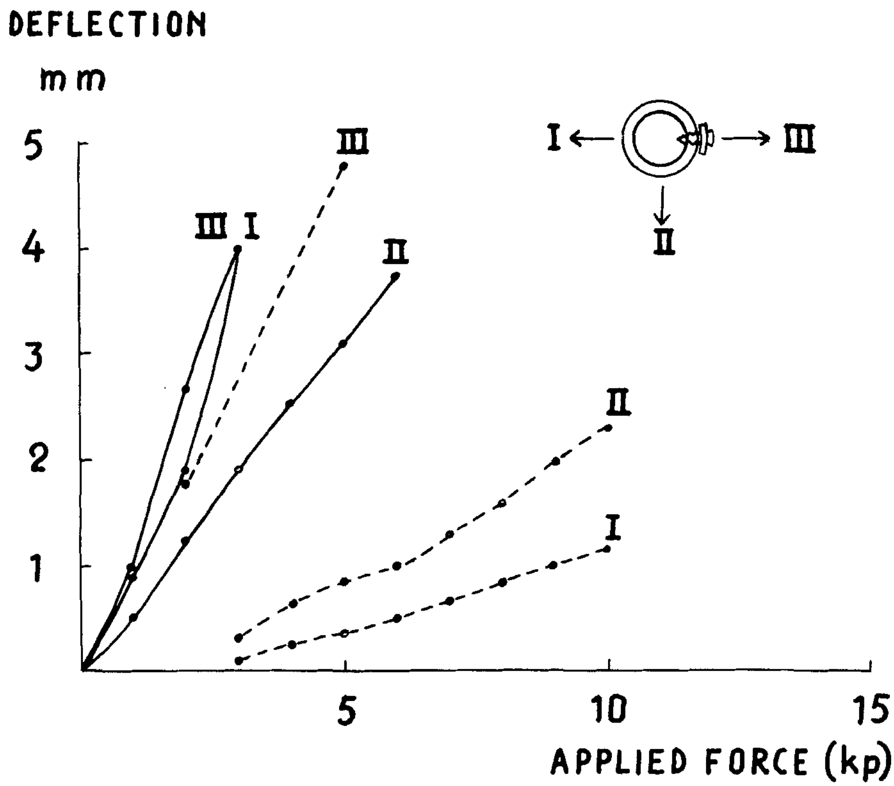


Fig. 6.
Comparison between the rigidity of immobilization obtained with one Sherman plate in the case of an oblique fracture (*continuous lines*) and a transverse fracture (*broken lines*) of femur shafts. The directions of loading are indicated in the plan.

to the transverse fracture, there can be a shortening, and consequently the staples must resist both tensile and compressive forces. The staple itself can tolerate both, but when it is not properly fixed in its holes it will rotate and there will be a dislocation of the fracture.

All 14 femur specimens were subjected to tests with Küntscher nails but, as with the transverse fractures, in no case was a real immobilization obtained; this was because the marrow space was always wider at the fracture than the largest available nail—11 mm.

Comparison of the different methods of immobilization, based on the rigidity recorded in the least satisfactory direction, showed that two plates placed at 90° to one another provided the greatest rigidity (Fig. 5).

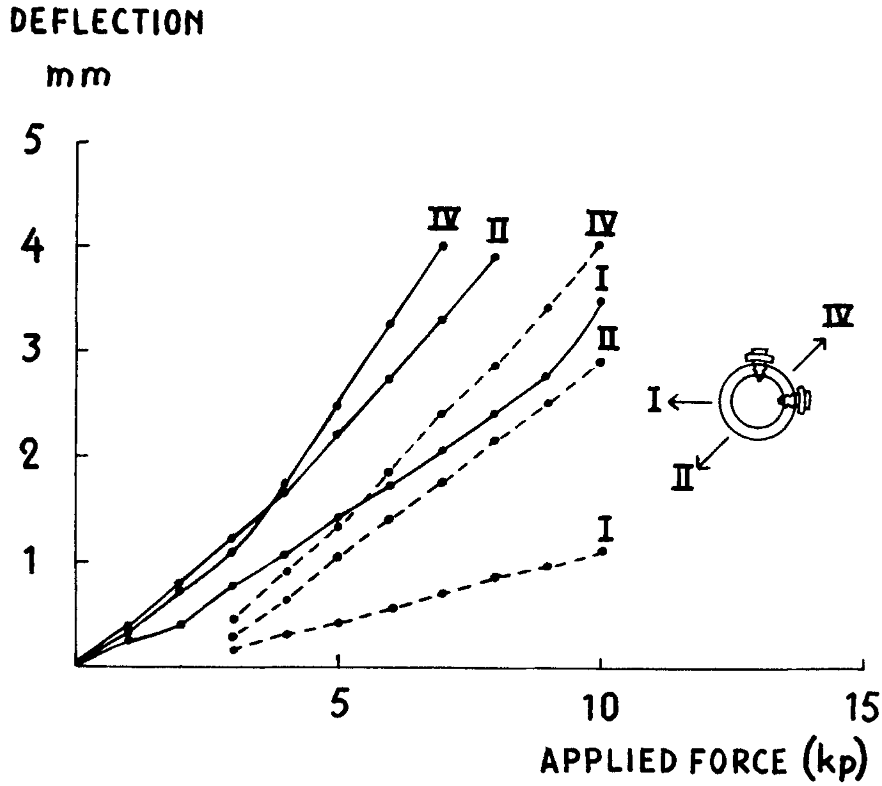


Fig. 7.
As for Fig. 6, but with 2 Sherman plates.

Comparison of transverse and oblique fractures as regards the rigidity achieved with the same means (one or two plates) showed that the results were slightly poorer for the oblique fracture (Figs. 6 and 7). The reason for this is probably that a transverse fracture cannot be compressed, whereas this is possible in the case of an oblique fracture, in which the fracture surfaces can slide against one another.

In general there is an association between the rigidity for torsion and bending but it should be noted that screws provided greater rigidity to torsion than plates (Fig. 8). As regards the compressive strength (Fig. 9), the Hoffmann instrument offered extremely little resistance to pressure; this is in accordance with clinical experience that this method is unsuitable for immobilization of oblique fractures. The greatest compressive strength was provided by two plates, but screws gave as great rigidity for loads up to 80 kp. Comparison of the rigidity obtained with different numbers and directions of screws shows that the resistance

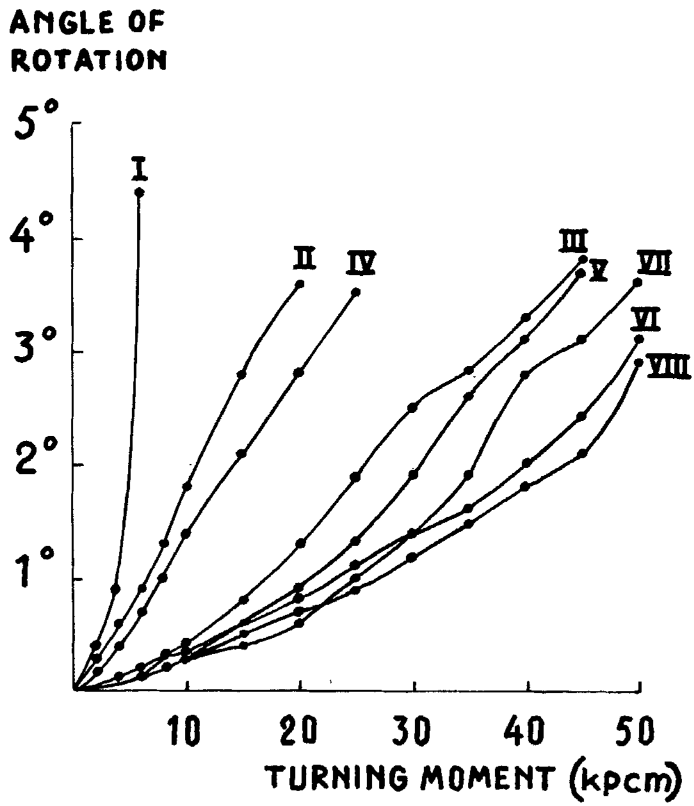


Fig. 8.

Comparison between methods of immobilization for oblique fractures of the femur showing the relationship between the turning moment and the resulting angle of rotation recorded for (I) 3 cerclage wires, (II) one Sherman plate, (III) 2 Sherman plates, (IV) Hoffmann instrument, (V) 3 osteosutures, (VI) 2 screws perpendicular to the shaft, (VII) 2 screws perpendicular to the plane of fracture, and (VIII) 3 screws perpendicular to the shaft.

to bending in different planes, to rotation and to compression was the same for small loads whether two or three screws were used, and whether they were inserted perpendicular to the shaft axis or to the fracture surface. For bending in the plane of the fracture and loading over 50 kpcm., however, the rigidity was lower for screws perpendicular to the surface of fracture than for those perpendicular to the shaft axis. For compressions over 150 kp the direction perpendicular to the fracture surface was the less satisfactory.

A mechanical analysis and tests on models showed that the screws

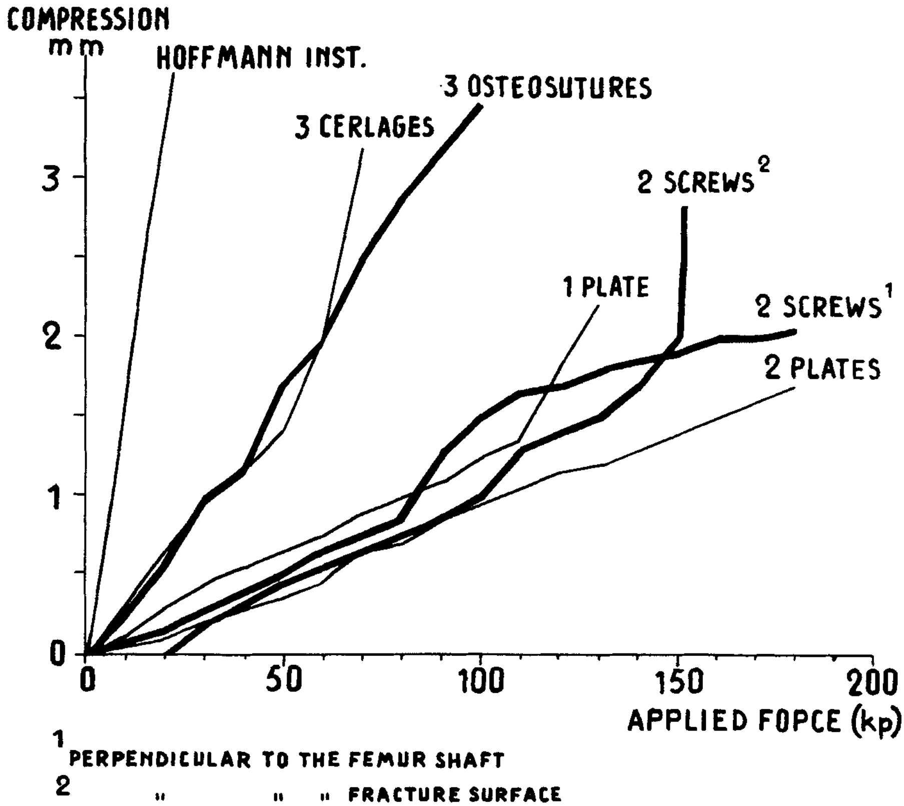


Fig. 9.
Comparison between rigidity on compression of fractured femoral shaft immobilized by different methods of osteosynthesis.

are subjected to a predominantly tensile force if placed perpendicular to the shaft axis, and the smaller the angle the screw makes with the shaft, the smaller the tensile force and the greater the bending moment on the screw as it passes through the cortical bone (Fig. 10). If the screw made a smaller angle to the shaft than perpendicular to the fracture (I) it was subjected to a pure bending stress in the cortical holes, and if these were deformed there was subsequently a movement as a result of which the fracture surfaces were separated.

DISCUSSION

The reader is referred in the first place to the previous article on transverse diaphysis fractures in which the low rigidity obtained with

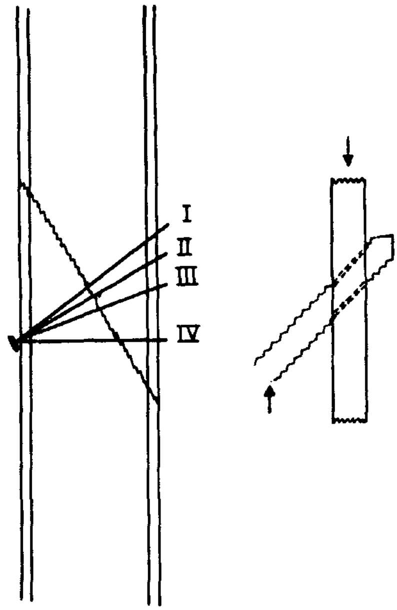


Fig. 10.
Examples of various directions of screwing in immobilization of oblique fractures by means of screws. (I) forming a small angle to the shaft, (II) at right angles to the fracture surface, (III) intermediate position, and (IV) at right angles to the shaft.

internal immobilization is demonstrated and discussed. Although there are several ways of immobilizing oblique fractures and although the greater area of the fracture surfaces should provide better immobilization, it is evident from the findings of the present study that with internal immobilization the rigidity was poorer for oblique than for transverse fractures. The rigidity was particularly low for forces applied in such a direction that the surfaces of fracture rotated against one another.

In both studies the fracture surfaces were fairly even, since they were sawn. In natural fractures the surfaces are often uneven or jagged. Provided that an accurate reduction is effected, the rigidity due to the form of the fracture surfaces will often be considerably greater than was the case in these studies. In spite of this, the rigidity obtained cannot be regarded as satisfactory. One essential reason for the application of the open fracture treatment is the common belief that with it the immobilization would be practically complete. The object of the operation is not only to secure coaptation of fracture ends but rather to prevent them from moving in relation to one another. This object cannot be considered to be achieved with the methods at present used, and further research would seem to be indicated, with the purpose of devising a really rigid method of internal immobilization.

SUMMARY

Experiments have been performed to examine the rigidity of different methods for the internal immobilization of oblique fractures—Sherman plates, staples, Küntscher nails, Hoffmann instruments, screws, osteosutures and cerclages. The experiments were performed on femur shafts and the rigidity was tested by bending in different planes, by torsion and compression. For all the methods the rigidity was unsatisfactory from a purely mechanical standpoint. The best immobilization was obtained with two Sherman plates placed perpendicular to each other.

RESUME

Des expériences ont été pratiquées pour examiner la rigidité de différentes méthodes d'immobilization interne de fractures obliques – plaques et crampons de Sherman, clous de Küntscher, instruments de Hoffmann, vis, ostéosutures et cerclages. Les expériences ont été effectuées sur des corps de fémur et la rigidité a été contrôlée pas des essais de flexion dans différents plans, de torsion et de compression. Pour toutes les méthodes, la rigidité était insatisfaisante, considérée d'un point de vue purement mécanique. La meillure immobilisation a été obtenue au moyen de deux plaques Sherman placées perpendiculairement l'une à l'autre.

ZUSAMMENFASSUNG

Experimente wurden ausgeführt, um die Festigkeit von verschiedenen Methoden der internen Ruhigstellung von Schrägbrüchen zu untersuchen – Sherman Platten, Haspen, Küntscher Nägel, Hoffmann Instrumente, Schrauben, Knochensuturen and Cerklagen. Die Versuche wurden an Femurschäften ausgeführt und die Festigkeit wurde mittels Beugung in verschiedenen Ebenen, unter Torsion und Kompression geprüft. Bei allen Methoden war die Stabilitet von rein mechanischen Standpunkt unbefriedigend. Die beste Ruhigstellung wurde mittels zwei Sherman Platten, die senkrecht zueinander angelegt waren, erreicht.

REFERENCE

Lindahl, O.: Acta orthop. Scandinav. 32: 237–246, 1962.