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Evaluation of fracture stability

A mechanical simulator for assessment of clinical judgement

To test the surgeon's clinical ability to detect small movements in fractures, a simulator with elastic behaviour was constructed. The bending moment required to produce a certain deflection was adjusted at four different levels. With the lowest stiffness, all surgeons in the test series reported that the fracture was unstable at a deflection of 3–4°. With increasing stiffness, an increase in stability was reported – the registered deflection, however, was always 3–4°. These observations confirm that manual tests of fracture stability are uncertain.

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One of the major problems in the treatment of tibial shaft fractures is to decide on clinical examination when the fracture is stable enough to bear the patient's weight without external support (Brown 1974, Jones 1912, Watson-Jones & Coltart 1943). Manual tests of stability may cause a characteristic pain in the fracture region, and this is usually interpreted as incomplete union. If no pain is elicted, the surgeon's skill in detecting small movements by inspection or palpation remains an important clinical basis upon which the decision to abandon or continue cast immobilization has to be made (Matthews et al. 1974). Further help can be had from radiographic appearances, although such assessment has proved unreliable (Sarmiento et al. 1977, Nicholls et al. 1979).

The present study was designed to get some idea of the surgeon's ability to detect small movements by manual examination and to assess the degree of deflection at which the surgeon will be able to determine whether the fracture is stable (united) or unstable (not united).

Material and methods

A model simulating a mid-diaphyseal tibial fracture was constructed (Figure 1). The basic structures were made from an aluminum alloy (dural). In principle, the device comprises two separate parts, a proximal and a distal, which can be moved independently about two central axes (movement centre). The total length of the fracture simulator is 43 cm and the distance from the distal end to the central axis (simulated fracture) 23 cm; this corresponds to a mid-diaphyseal tibial fracture in an adult. In the proximal part there is an operating wheel with three cam disks by means of which one, two, or three cylindrical steel rods (diameter 5 mm) can be introduced into the distal part and fixed there between two ball-bearings (Figure 2). Each steel rod is equipped at the proximal end with a spring that releases the rods one by one as the operating wheel is turned. Posteriorly, there is a locking device to block all movement about the central axis, thereby simulating a stable fracture. Anteriorly there is an indicator for determining the deflection between the proximal and distal parts about the central axis. On either side of the angle indicator there are two accompanying indicators that record the maximum deflections in both directions ($\pm$ 7°). The method allows measurements with a precision of $\pm$ 0.25°. The fracture simulator is covered with plastic foam of the type used in leg prostheses to simulate soft parts (Otto Bock, Orthopädische Industrie, K. O. Duderstadt/Man, West Germany).

Calibration of the three unstable positions was done with the aid of a precision spring dynamometer. The ultimate surface yield stress for the bending rod was calculated to 5312 KP/cm^2 (5.21 $\times$ 10^8 N/m^2). Within the range of 0 $\pm$ 7° deflection, the deformation was purely elastic (Figure 3).

Design of the experiment

Twenty-eight orthopaedic surgeons with 2–15 years' experience in the field were instructed to regard the

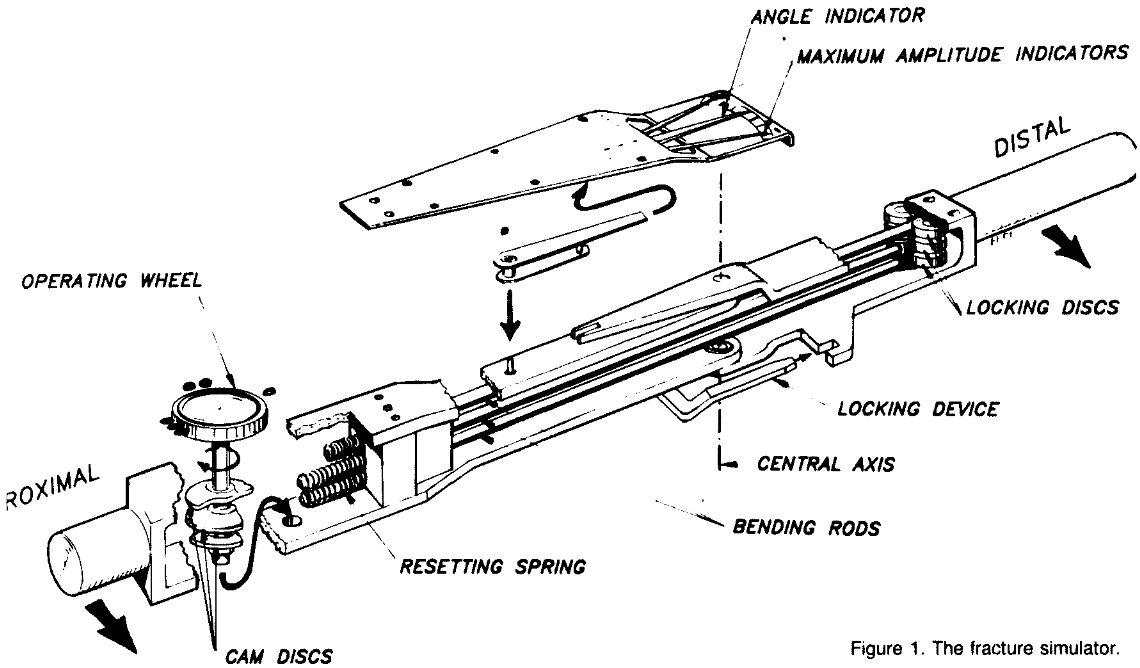

Figure 1. The fracture simulator.

simulator as a tibial fracture with an unknown degree of union.

Each surgeon was asked to use the same method and the same amount of force as when examining a true tibial fracture. The examiner was to decide whether the fracture was stable or unstable. He was informed only that the fracture was diaphyseal, no details of type, treatment, interval since fracture, or degree of radiographic union being given. Positions I–IV were selected at random and were not known to the examiner. After making himself acquainted with the most unstable and fully stable positions, he made 12 consecutive assessments. The original 14 groups of registered deflections (interval 0.5°) were reduced to seven (interval 1.0°). Deflections exceeding 6.75° were grouped together. After 1–5 weeks, the experiment was repeated. Altogether, 24 assessments were made by each of the 28 surgeons.

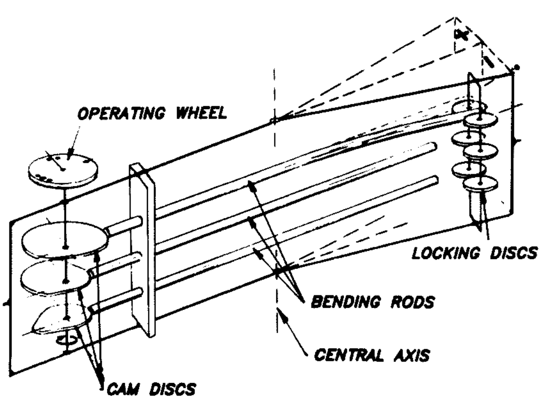

Figure 2. Working principle of the fracture simulator.

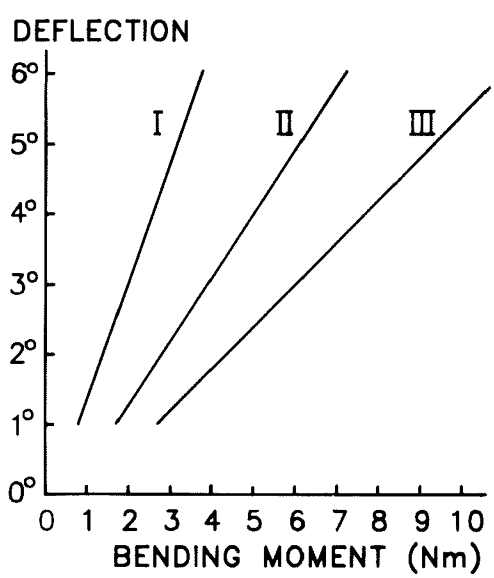

Figure 3. Deflection-load diagram for model fracture. The Roman numerals I, II, and III represent the three different positions when one, two, or three bending rods are involved.

Results

The mean values for each examiner's 24 deflections varied from 1.6 ± 0.4° to 8.8 ± 2.0°, range 1.0–12.5°. The mean for all 544 deflections was 3.9 ± 1.7°.

In Position I, all examiners reported the fracture to be unstable on all 162 occasions, and the angle at which instability was recorded had a mean value of 4–4.5°. In Position II, 194 tests were done, and in 12 stability was reported. In Position III the corresponding figures were 44 of 188 tests (Tables 3 and 4). The frequency of reported stable fractures increased on changing from Positions I to II, from I to III, and from II to III. In Position IV (fully stable fracture), instability was reported in 22 of 128 assessments. No correlation could be found between clinical experience and the degree of deflection registered.

Discussion

The results show that a deflection of 3–4° is the smallest that can be detected as a movement. However, no simple relationship existed between the force applied and the ability to detect movement by inspection or palpation. A probable explanation is that with increasing force, the ability to detect movement is reduced. This assumption is also justified by the fact that a significant increase in number of stable fractures was reported with increasing stiffness of the model, but at a deflection which was identical to that when instability was reported. These findings could indicate that deflection values even higher than those obtained in this study will be the least that a surgeon can detect.

Table 1. Deflections when "fractures" were judged to be unstable in Position I, II, and III, classified in seven groups.

Deflection	I	II	III	Total
0.75–1.75	18	27	22	67
1.75–2.75	31	51	38	120
2.75–3.75	22	29	41	92
3.75–4.75	34	28	12	74
4.75–5.75	22	27	10	59
5.75–6.75	23	3	11	37
>6.75	12	17	10	39
Total	162	182	144	488

Table 2. Deflections in Position II and III when "fracture" was judged to be stable. In Position I, all "fractures" were judged to be unstable.

Deflection	II	III	Total
0.75–1.75	–	4	4
1.75–2.75	–	21	21
2.75–3.75	3	14	17
3.75–4.75	8	3	11
4.75–5.75	–	2	2
5.75–6.75	–	–	–
>6.75	1	–	1
Total	12	44	56

Matthews et al. (1974) described a fracture simulator with mechanical properties greatly differing from those of a true fracture. The deflection recorded in the simulator to determine whether a fracture had or had not united showed considerable variation. Another of their conclusions was that the bending moment applied by the examiners in different tests was unexpectedly uniform. This was probably because of the construction of the test model, in which deflection in relation to the applied force was linear up to a breaking point, after which the relation between moment and deflection became unreliable. With a construction of the type used by Matthews et al. (1974), it is probably easier to detect a change in angulation or movement compared to a fracture simulator that gives continuously increasing resistance on increasing deflection and which has no sudden breaking point. Different figures have been reported for the deflection recorded when the fracture has been judged to have united and unprotected weight-bearing can be permitted. Jernberger (1972) showed by an invasive method that a deflection of 2.3° (bending moment; 10 Nm) was compatible with union. Jörgensen (1972), on the other hand, reported a smaller deflection, and gave an upper limit of 1° (bending moment; ± 5.9 Nm) for stability safe enough to allow full weight-bearing without external support. However, with both these methods a constant bending moment was used. By means of a non-invasive method, designed at this hospital, for determining the stability of union of tibial shaft fractures in man, the mean deflection obtained when 157 fractures were united was 0.5° (Hammer et al. 1983).

The site of fracture in the present study was optimum with regard to examination for stability. In a model simulating a fracture near the joint, greater deflection would probably be obtained.

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