METHODS OF FIXATION OF OLECRANON FRACTURES
AN EXPERIMENTAL MECHANICAL STUDY
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This study was designed to compare the rigidity of the more commonly used techniques of internal fixation of fractures of the olecranon. Cadaveric elbow joints were mounted in a jig and controlled osteotomies performed to simulate transverse, oblique or comminuted fractures.

Five techniques of internal fixation were tested by measuring movement at the fracture site after applying a bending moment to the ulna. At transverse osteotomies tension-band wiring with two tightening knots allowed least movement even at high loads. Intramedullary cancellous screw fixation gave erratic results; adding a tension band with a single knot was little better. In oblique osteotomies, no statistically significant difference was shown between one-third tubular plate fixation and double-knot wiring. Comminuted osteotomies were held most rigidly by contoured one-third tubular plate fixation.

Joseph Lister, the father of antiseptic surgery, pioneered internal fixation for a fractured olecranon in 1883 (Howard and Urist 1958). Since that time innumerable devices and techniques for the surgical treatment of this fracture have been described.

Early mobilisation of the injured elbow has been advocated repeatedly since as early as 1789 (David 1789; Lucas-Championnière 1889). The recent work of Salter and his co-workers has highlighted the possible benefits to be gained by early movement of injured joints (Salter et al. 1982). Obviously, to achieve early active movement of the fractured elbow, internal fixation must be rigid enough to resist the disturbing influence of the flexor and extensor muscles if joint congruity is to be preserved.

This study reports experimental work comparing techniques of internal fixation of various patterns of olecranon fracture in terms of resistance to distraction. The emphasis was on methods using the tension-band principle (Pauwels 1965).

METHOD AND MATERIAL
The effect of embalming on the strength of human bone was studied by Calabrisi and Smith (1951) who showed that preserved bones showed strengths within the limits for normal bones. Cadaveric tissue preserved for periods of six to nine months by a standard technique was therefore used. The elbow joints were stripped of all soft tissue except the triceps tendon and the joint capsule.

Standard osteotomies were performed with a fine-bladed saw (0.6 mm) using two jigs. This gave three groups of fracture pattern—transverse, oblique and a combination which we term comminuted (Fig. 1).

In order to achieve a fair comparison of those methods of fixation tested, an adapted torque screw-
driver and wire-tightener were used to a total torque of 80 N-cm, the level of torque normally achieved by standard instrumentation.

Five techniques of internal fixation were tested in the transverse osteotomy group (Fig. 2).

1. Tension-band wiring, with one knot: two 2 mm trocar-pointed stainless steel Kirschner wires and a 1.0 mm tension-band wire loop were used (Weber and Vasey 1963; Müller et al. 1979); a tension of 80 N-cm was applied at a single point.

2. Tension-band wiring with two knots (Deliyannis 1973) also was tested; the same dimension wires were used but each side of the figure-of-eight wire was tightened to 40 N-cm, using the adapted torque screwdriver.

3. A contoured one-third tubular five-hole plate was applied with compression as a tension band; all screws were tightened to 80 N-cm, those close to the osteotomy each penetrating only one cortex.

4. A 90 × 6.0 mm AO cancellous screw with a washer was inserted along the medullary cavity of the ulna and tightened to 80 N-cm.

5. The same screw and washer were also tested after being reinforced by a tension-band loop, with one knot tightened to 80 N-cm.

The positions of the Kirschner wires were determined by the osteotomy jigs which also functioned as drill guides. The tension-band wire loops were anchored to the shaft of the ulna 3 cm beyond the osteotomy site in a 2 mm drill hole.

Some of the above methods resulted in no significant physical distortion of the bone. The testing was not to destruction, and it was therefore possible to repeat the experiment on the same elbow using a different method.

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**Fig. 2**

Three of the five methods of internal fixation which were tested: two K-wires and a tension-band wire with a single knot; a one-third tubular plate applied as a tension band; and a single screw with a wire tension band.

**Fig. 3**

Diagram to explain the testing jig. All the cadaveric specimens used had freely mobile elbow joints despite preservation.
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of fixation. This allowed direct statistical comparisons. Techniques producing distortion were allocated to specimens randomly and the analysis of the results adapted accordingly.

A diagrammatic representation of the jig for the mechanical testing is shown in Figure 3. It was adjusted so that each elbow was tested in 90° of flexion. All elbows proved freely mobile about this position, despite preservation, once the soft tissue had been excised.

Force and displacement transducers were constructed using foil strain gauges (Kywa-5-C1.23). The force transducer was connected to a Wheatstone bridge circuit with two gauges under compression and two under tension (Fig. 4). The displacement transducer was

![Diagram of force transducer and displacement transducer](image)

**Fig. 4**

On the left, the specially constructed force transducer with its calibration curve. On the right, the displacement transducer with its calibration curve, which is effectively linear up to 2 mm displacement (which exceeds the maximum encountered in the tests).

![Diagram of electrical equipment and chart recorder](image)

**Fig. 5**

Diagram of the electrical equipment and a specimen trace from the chart recorder.
Transverse osteotomy.
Figure 6—Transverse osteotomy with tension-band wiring. Note the more consistent and more rigid fixation achieved with two knots.

Figure 7—Transverse osteotomy with the five-hole AO one-third tubular plate or with an intramedullary 90 x 6 mm cancellous AO screw. The addition of a tension-band wire did not improve the wide scatter of results. Neither method is recommended.

Figure 8—The average results of all tests for each method of fixation of a transverse osteotomy. Note the superior rigidity of tension-band wiring with two knots.
modelled on Walton's design (Boniface, Brodie and Walton 1953), with two 0.83 mm steel pins which were inserted 2 mm below the subcutaneous border of the ulna to allow rigid fixation of the device to the bone on either side of the osteotomy. The force transducer was calibrated by applying known loads, and the displacement transducer by using a vernier caliper. The calibration curves shown in Figure 4 are linear and reproducible.

A simple circuit diagram of the test equipment and an example of one experimental test run is shown in Figure 5. The loads applied are thought to be comparable to those likely to be encountered in the clinical situation of early active mobilisation of the elbow after internal fixation of a fracture. Note that at these levels of applied force the displacements produced were small and not disruptive. The exact distance from the fracture site to the point of application of force on the distal ulna was measured, allowing calculation of moments for comparison of elbows.

Moments were calculated in newton metres and plotted against displacement (in millimetres) produced.

RESULTS
The results for 10 separate testings in transverse osteotomies fixed by the one-knot technique of tension-band wiring are shown in Figure 6. The more horizontal lines represent more rigid (less distractable) fixation. The wide scatter of results can be seen. Figure 6 also shows the improvement achieved by the use of two tightening knots to the same total tension. Figure 7 shows the intermediate rigidity achieved in the transverse osteotomy series by the use of a five-hole AO one-third tubular plate. A single cancellous screw provided extremely erratic fixation (Fig. 7). Only five such tests were performed as the method proved to be unsatisfactory. No appreciable improvement resulted from the use of an additional single-knot tension-band loop to this technique.

Figure 8 shows the average results achieved for each of the various methods tested in transverse osteotomies. A statistical comparison of matched pairs was carried out using Student's t-test at 5 and 10 N-m of applied moment. This confirmed that for oblique osteotomies tension-band wiring using double-knot fixation was significantly stronger than with the single-knot technique ($P<0.001$) or AO plating ($P<0.02$).

On the basis of these results it was decided to test only the two more effective methods with oblique and comminuted osteotomies. Tension-band wiring using two knots, and plating both gave impressively rigid fixation of the oblique osteotomies; the difference between the two was statistically insignificant in this group (Fig. 9).

The results for comminuted fractures fixed either by double-knot tension-band wiring or by a five-hole plate are shown on averaged graphs in Figure 10. Again, both show acceptably rigid fixation (though with considerable scatter before "averaging"); the AO plate was slightly stronger in this group (at 5 N·m 0.01 > $P<0.001$, and at 10 N·m 0.05 > $P<0.02$, i.e. statistically significant).

DISCUSSION
Our results show that for at least those patterns of osteotomy investigated, tension-band wiring using two tightening knots or a contoured five-hole one-third tubular plate can give fixation which will not allow movement under the forces involved in active mobilisation of the elbow immediately after operation.

Clinical experience bears this out. Elbow function after tension-band fixation is very good or excellent in the majority of patients (Holdsworth and Mossad 1984).

We found that a single cancellous screw gave the most erratic results. This appeared to be related to the correlation between the size of the screw thread and the diameter of the medullary cavity. Neither the single screw nor the screw plus a tension-band wire are recommended.

The results in the comminuted osteotomies suggest that marginally more rigid fixation was achieved by a plate. It is debatable whether the small improvement is
worth the extra effort sometimes needed in plating severely comminuted fractures.

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