Fracture healing monitored with strain gauges

External fixation of 7 humeral neck fractures

Bjarne Kristiansen and Arne Borgwardt

We measured healing in 7 cases of surgical neck fracture of the humerus by applying a strain gauge measuring bar between the external fixation pins. Repeated measurements provided a healing curve for the individual cases. The gradual decrease in deflection of the fracture zone reached a plateau of about 50 percent after 2 to 4 weeks in 6 cases. Removal of the frame at this time proved safe, as solid healing occurred. In one fracture no such decrease was seen and nonunion developed.

Department of Orthopedics, Rigshospitalet, DK-2100 Copenhagen, Denmark. Correspondence: Dr. B. Kristiansen, Department of Orthopedics T, Gentofte Hospital, DK-2900 Hellerup, Denmark. Tel +45–31 65 1200. Fax –31 68 1698
Submitted 92-05-15. Accepted 92-07-17

In fractures treated with external fixation, it is possible to monitor the stiffness by applying a strain gauge measuring bar between the fixation pins. This method has been used in tibial fractures (Jernberger 1970, Jørgensen 1972, Burny 1979). The introduction of external fixation of surgical neck fractures of the humerus (Kristiansen 1987, Kristiansen and Kofoed 1987) has given us the opportunity to follow the healing process. We describe the method and report our experiences in 7 cases.

Patients and method

As described by Kristiansen and Kofoed (1987), the fracture is externally fixed with a 5-mm bar. Strain gauges are placed on opposite sides of the bar in the plane of the humerus (Figure 1). The frame has a constant bending stiffness unless the stiffness of the fracture zone changes. Increasing values in bending stiffness of the frame can, in theory, only be caused by increasing stiffness in the fracture zone. The system is loaded by suspending the upper arm at the olecranon so that the arm is horizontal with 45 degrees inward rotation. Thus, for constant loading by gravity, the strain of the bar will decrease progressively as the stiffness of the callus increases.

The set-up consists of the bar, which is compatible with the 5 mm bars used in clinical routine. In the middle the measuring bar has two opposite plane areas for the strain gauges, which are connected as a half bridge and thus compensate for the effect of the temperature changes (Vaughan 1975). We used a 3 mm foil strain gauge, type QFLA-3, with a resistance of 200 ohms.

Patients

The method was applied to displaced surgical neck fractures in 6 women and 1 man of 67–85 years of age. All were treated by transcutaneous reduction and external fixation. The upper arm was raised to the horizontal with 45 degrees of inward rotation by manually supporting the elbow. The absolute value of deformation was recorded. The measurements were repeated 10 times at each session. Measurements were performed at regular intervals starting immediately postoperatively, day 0. The deformation of the bar (median and range) was expressed in percentage of the day 0 measurement.

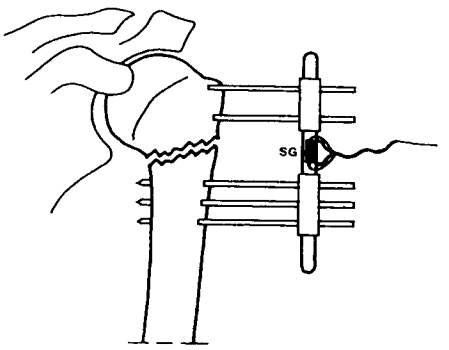
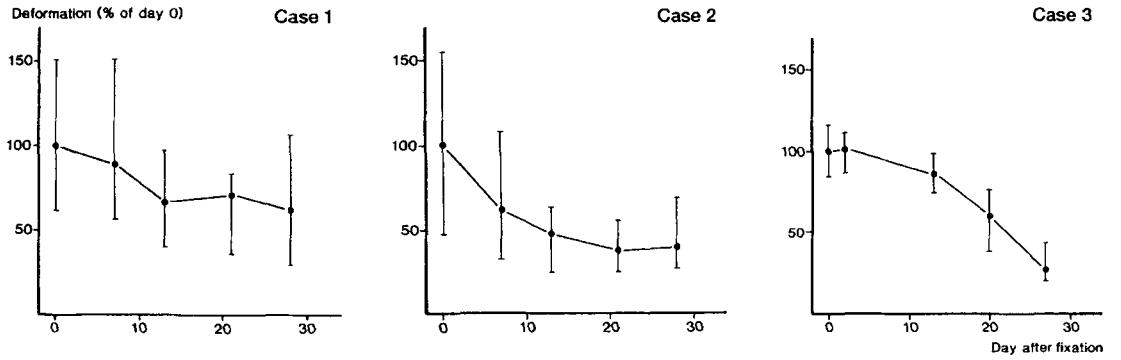


Figure 1. The set-up illustrating the position of the strain gauge (SG) in anterior-posterior view.



Figures 2. Deformation or fracture-healing curves obtained by strain gauge measurements in individual cases. See text.

Results (Table 1)

Two types of curves were seen (Figure 2). In cases 2 and 4 the slope of the curve dropped rapidly and reached a plateau just below 50 percent after about 2 weeks. In cases 3, 5, 6, and 7 a slower decrease in deflexion was evident, as the 50 percent plateau was reached after about 4 weeks. Callus was seen radiographically after 4 weeks.

In case 1, where the decrease in deflexion stopped after 2 weeks at only 70 percent, radiographic evidence of pseudoarthrosis was found after 3 months.

Discussion

Our use of relative values of deformation made it possible to compare the individual cases. The gradual decrease in flexion at the fracture zone reached a plateau of about 50 percent after 2–4 weeks. This is compatible with the normal healing process with radiographically visible callus after 4 weeks and evidence of union after 3 months, as seen in 6 of our 7 cases.

Removal of the external fixator, when reaching this level allowed normal activity of the humerus; no refractures occurred. One case of non-union, retrospectively, could have been predicted as a decrease to only 70 percent was reached. This case was the only one where exact reduction was not possible, probably because of soft tissue interposition. This is in agreement with a study of 28 cases, that exact reduction is mandatory for external fixation (Kristiansen 1989).

In agreement with theoretical (Bourgois and Burny 1972) as well as clinical studies (Burny 1979), the mechanical characteristics of frame deflexion will remain constant, when the fracture mobility is reduced to about 50 percent. The elasticity of the fixation system mainly depends on the transcutaneous pins. Cyclic movements of the pin may cause pin loosening with decreased deformation of the bar, giving a false impression of healing. A careful monitoring of the fixator system, should diminish this source of error.

Table 1. Median absolute (relative) values of strain gauge measurements in relation to time after fixation of surgical neck fracture

Case	Days after fixation					
	0	7	14	21	28	35
1	45	40 (89)	30 (67)	32 (71)	28 (62)	–
2	38	23 (61)	18 (47)	14 (37)	15 (39)	–
3	95	–	82 (86)	57 (60)	23 (24)	–
4	48	27 (56)	24 (50)	20 (42)	–	–
5	58	55 (95)	48 (83)	36 (62)	24 (41)	23 (40)
6	77	74 (96)	68 (88)	42 (55)	–	24 (31)
7	72	78 (108)	69 (96)	45 (63)	36 (50)	35 (49)

References

Bourgois R, Burny F. Measurement of the stiffness of fracture callus in vivo. A theoretical study. J Biomech 1972; 5 (1): 85–91.

Burny F. Stain measurements of fracture healing. In: External Fixation, The Current State of Art (Ed. Edwards A. F. H) Williams And Wilkins, London 1979: 371–81.

Jernberger A. Measurement of stability of tibial fractures. A mechanical method. Acta Orthop Scand (Suppl 135) 1970.

Jørgensen T E. Measurements of stability of crural fractures treated with Hoffmann osteotaxis. 2. Measurements on crural fractures. Acta Orthop Scand 1972; 43 (3): 207–18.

Kristiansen B. External fixation of proximal humerus fracture. Clinical and cadaver study of pinning technique. Acta Orthop Scand 1987; 58 (6): 645–8.

Kristiansen B. Treatment of displaced fractures of the proximal humerus: transcutaneous reduction and Hoffmann's external fixation. Injury 1989; 20 (4): 195–9.

Kristiansen B, Kofoed H. External fixation of displaced fractures of the proximal humerus. Technique and preliminary results. J Bone Joint Surg (Br) 1987; 69 (4): 643–6.

Vaughan J. Application of B and K equipment to strain measurements. Bruel & Kjær, Copenhagen 1975.