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A device for producing experimental fractures

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A device is reported for the production of transverse fractures of canine tibiae by a three-point bending technique. With strain-gauged load arms, the device enables simultaneous measurement of the bend strength of the intact bone. Results from a series of 14 dogs confirm the reproducibility of this technique.

Several different animal fracture models have been used for the study of fracture healing, each with inherent advantages and disadvantages. The compromise has been between the reproducibility of osteotomy and the realism of actual fracture. Generally, the production of real fractures increases the risk of variation in fracture site and location, which can make retesting difficult.

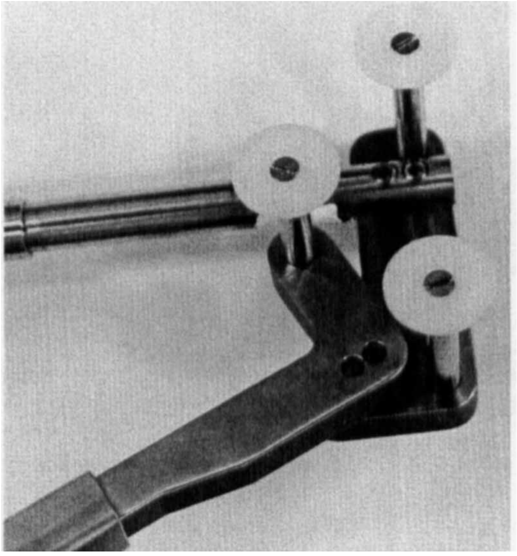
Because of the difficulties involved in gripping a whole bone in vivo, the most common fracture process has been bending (Eskelund and Plum 1949, Kernek and Wray 1973, Ashhurst et al. 1982, Davy and Connolly 1982), when the bone can be supported against two rests and a load can be applied from the opposite side. Various mechanisms have been used for application of the load (Jackson et al. 1970, Rhinelander 1974, Sarmiento et al. 1977, Bonnarens and Einhorn 1984). When a single nose is used, the location of the fracture is determined by the loading nose, and the mode is styled "three-point bending." A more even stress distribution over the tested section can be achieved by using two parallel loading points within the test span, styled "four-point bending," but the exact location and direction of the fracture is not so well controlled. Rather, the bone will fracture at the weakest section, as it would in normal service (Burstein and Frankel 1971).

We present a fracture model that enables comparison of the fracture strengths of individual long bones before and after treatment.

Method

The device was designed on the basis of three-point bending, two fixed loading noses being mounted in the main body at a span of 80 mm, while a third loading nose midspan was operated by a lever acting on a pivot on the same body (Figure 1). Strain gauging of the lever arm to the main body enabled measurement of the reaction force. The mechanical advantage of the lever was chosen to suit the expected loads of 3,000 to 4,000 N and travel less than 10 mm. Round-bar loading noses were chosen to minimize soft-tissue damage, and conical end stops were added upon experiencing that the leg tended to be ejected from the loading section when in use.

All the components were manufactured from surgical grade stainless steel. The strain gauges were coated with nitrile rubber encapsulant, and the strain gauge leads were passed down the hollow handle to protect against mechanical damage. A strain gauge amplifier unit conditioned the signal for a single-pen chart recorder, enabling continuous monitoring of the forces produced during operation.



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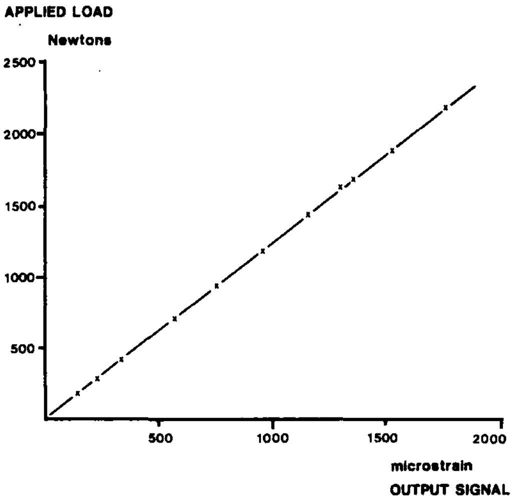

Figure 2. Calibration curve for fracture device. Force applied at the loading noses versus indicated arm strain.

For calibration the handles were strapped together and perpendicular forces were applied to the loading noses with an Instron materials testing machine, reproducing the reactions at the loading points in service. Thus, the mechanics of operation of the assembly were reproduced in reverse. The calibration curve (Figure 2) showed good linearity.

In practice, the animal was anesthetized and positioned reclining on one side. The device was offered up to the tibia of the reclining side and was positioned midshaft with the two outer supports on the lateral aspect of the limb. Fracture was thus produced in a mediolateral direction while the handles of the device were directed vertically upwards from the table. Firm hand pressure on the handles produced the fracture, generally in less than 1 second of load application. The animal was turned on the other side, and the procedure was repeated for the contralateral limb.

Table 1. Strength in bending of paired canine tibiae measured with the device. Asymmetry means difference between pairs expressed as percentage of mean

Subject	Fracture strengths (Nm)		Asymmetry (%)
	L	R	
1	72	70	1,7
2	52	50	3,9
3	74	68	8,3
4	82	83	1,5
5	64	69	7,5
6	83	79	4,9
7	78	77	1,8
8	67	67	0
9	53	56	4,4
10	78	75	3,9
11	70	68	2,9
12	58	62	6,2
13	64	66	3,1
14	72	71	1,4

Results

In the initial trial series, both tibiae of 14 adult (15–25 kg) mongrel dogs were fractured using the device. All the fractures produced were simple, transverse, anatomically similar fractures located at the mid-diaphysis, with no evidence of comminution (Figure 3). In the series of 28 closed fractures, soft-tissue damage was induced in only two fractures, in the form of a superficial tear of the skin. These lesions healed without incident. One fracture required manual reversed bending to complete, but the resulting fracture was straight and transverse.

The fracture strengths were measured and the difference between contralateral limbs was expressed as a percentage of the mean, as described by Alexander et al. (1984; Table 1). These discrepancies show less than 10 percent variation between contralateral limbs (P <0.01).

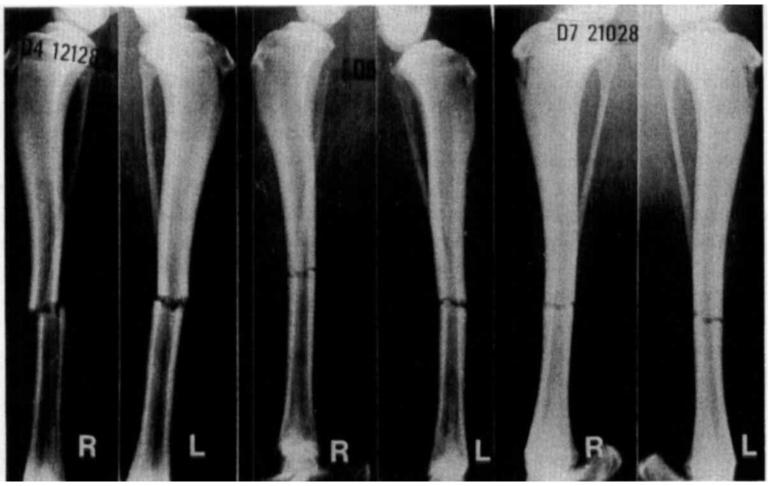

Figure 3. Radiographs of fractures produced in 3 animals.

Discussion

Our device has been found to be simple to use and reproducible in its effects. Measurement of the strength of the long bone before (or during) fracture enables expression of the recovery of strength with fracture healing as a fraction of the intact strength. With other techniques the contralateral limb must be tested intact as a control, and is thus not available for experiment. Using the present technique, paired contralateral limbs can be used to compare treatments (Skirving et al. 1987), and the precision of such comparisons can be increased. At the same time, the number of experimental subjects needed is reduced.

The mean of the differences between paired limbs (Table 1) was 3.7 percent, with a standard deviation for this series of 2.3 percent. These figures compare favorably with the results of Bechtol et al. (1959; Figure 4), 2.4 percent; Mather (1967), 3.6 percent; and Henry et al. (1968), 5.6 percent, who used bending tests on paired bones.

Alexander et al. (1984) reviewed all the extant studies of paired limbs and reported a range for standard deviation of load or torque of 3.9 to 9.4 percent, including studies of torsional fracture and bending. Two studies with greater standard deviations were thought to be affected by excessive measurement errors. Since the results of our study fall between their own results and those of the other authors quoted by Alexander et al. (1984), we concluded that the measurement errors of our device are of the order of previously reported techniques.

FREQUENCY DISTRIBUTION OF ASYMMETRY

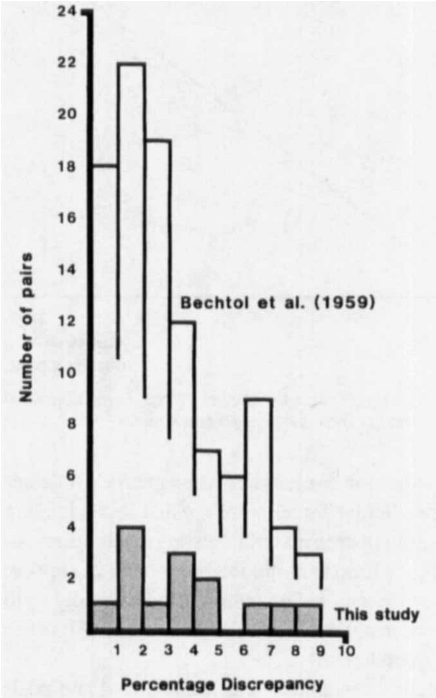

Figure 4. Nomogram comparing results of this study with those of Bechtol et al. (1959).

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