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MEASUREMENTS OF STABILITY OF CRURAL FRACTURES TREATED WITH HOFFMANN OSTEOTAXIS

1. *Method and Measurements of Deflection on Autopsy Crura*

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The present paper forms part of the elaboration of a mechanical method of measurement which can be used in the daily clinic for the estimation of the stability of healing crural fractures. The method can only be used on crural fractures treated with the Hoffmann apparatus, as this is a constituent part of the mechanical construction of the measuring equipment (Hoffmann 1961). The main importance attached to the method is that it is easy to handle and resembles the classic clinical way of examining fractural instability, and it furthermore does not demand complicated measuring instruments and calculations.

The principle of the method is to measure how much a fractured bone bends at a known load (the bending moment). When a fractured bone is affected by a bending moment, the total bending (the total deflection) will consist of two components, a bone deflection and a fracture deflection. To obtain a measure of the fracture deflection only it is thus necessary to know the normal bone deflection, which for good reasons cannot be measured without mutilating operations on the patient. The exact bone deflection is thus to be regarded as unknown, but a practical estimation of the size and variation may be obtained. Therefore the method is used in this study to examine intact autopsy crura. In order to estimate how much the soft tissue affects the measurements, comparable measurings were performed at different planes on crura with or without soft tissue.

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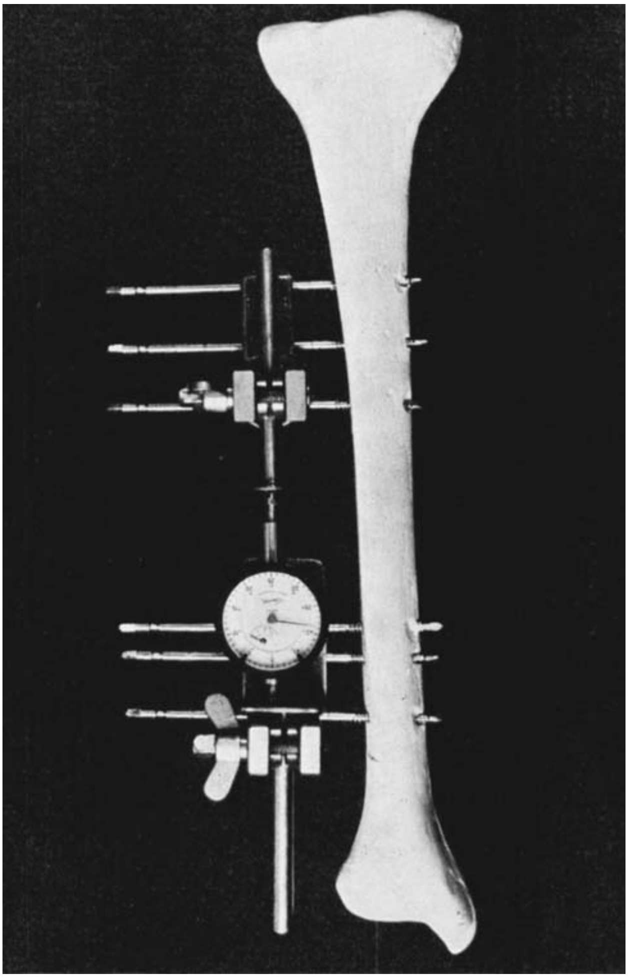


Figure 1. Hoffmann apparatus with measuring instrument mounted on a bone model.

MATERIAL AND METHODS

Notation and Formulae

Bending moment: force in kgf × lever in metre = kgfm. Bone deflection + fracture deflection = total deflection. The deflection is expressed in figures as radians to simplify the calculation and in degrees to get a generally known measure.

$$1° = \frac{2 \times \pi}{360} \text{ rad} = 1.745328 \times 10^{-2} \text{ rad. } 1 \text{ rad} = 57.29579°.$$

Bone deflection = the angle described in the plane of the force when a 12 cm long bone specimen, fixed at one end, is moved from one position (+) to the

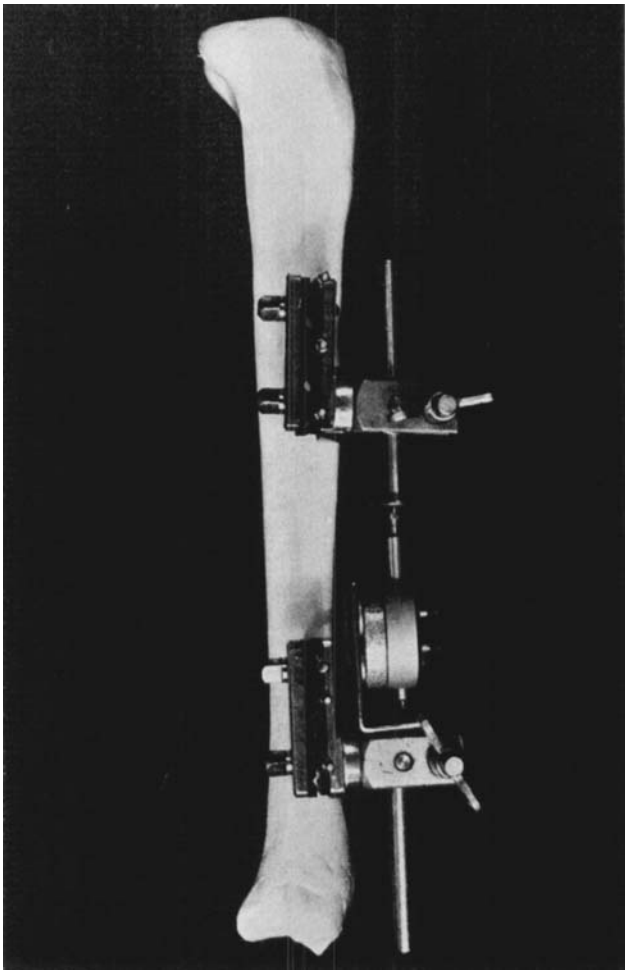


Figure 2. Hoffmann apparatus with measuring instrument mounted on a bone model.

opposite position (—). Then bending moment at the fixed bone end is: ± 5 kgf × 0.18 m = ± 0.9 kgfm (Figures 3 and 4).

The fracture deflection: the angle described in the plane of the force when a fracture is moved from one position (+) to the opposite (—). The bending moment of the fracture, provided this is found in the middle of the bone specimen, is ± 5 kgf × 0.12 m = ± 0.6 kgfm (Figures 3 and 4).

Method of Measurement

A solid connection between the bone and a mechanical measuring bridge is a prerequisite for measuring the deflection of a loaded bone. This is obtained by combining the Hoffmann apparatus with a dial micrometer, which makes a very stable mechanical measuring bridge (Figures 1 and 2).

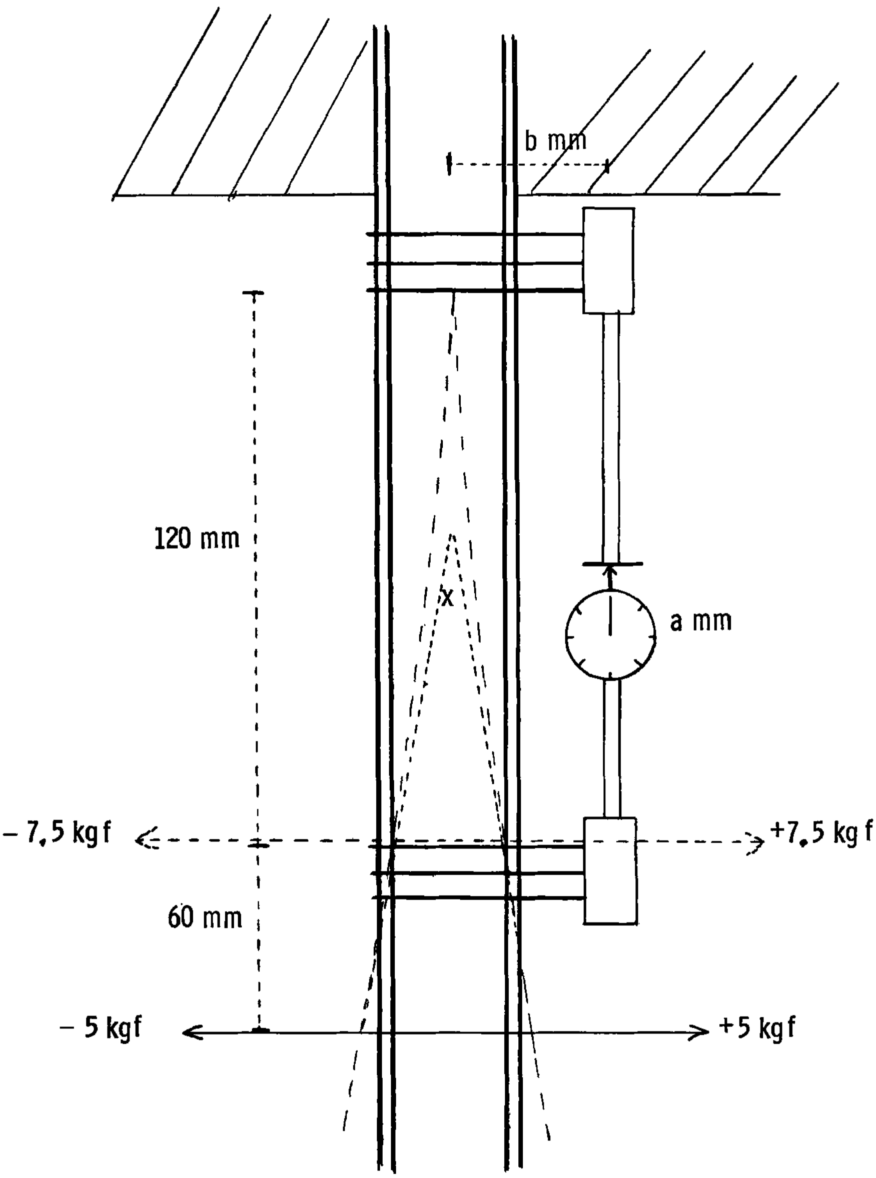


Figure 3. Diagram illustrating the principle of measuring the bone deflection in the anteromedial/posterolateral plan. The force +/— 5 kgf is applied 6 cm distally to the Hoffmann screws, i.e. the force at the level of the screws is ± 7.5 kgf. The bending curves and the deflection x are shown in the diagram.

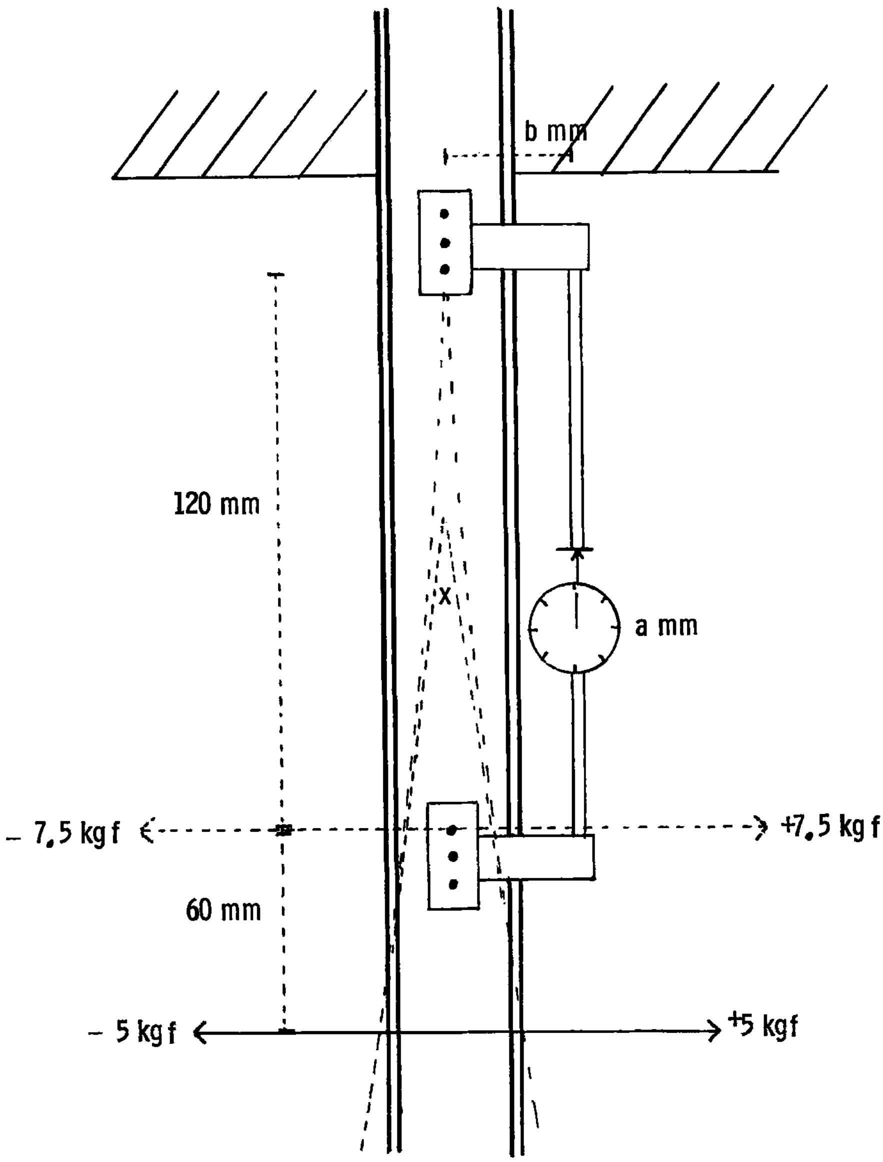


Figure 4 .Diagram illustrating the principle of measuring the bone deflection in the anterolateral/posteromedial plane.

Figures 3 and 4 give a schematic view of a bone with the Hoffmann apparatus and a measuring bridge. The bone is fixed at one end while the unfixed end is submitted to a known load. By this the bone will bend the most at the fixed end and the least at the unfixed end, due to the variation of moment.

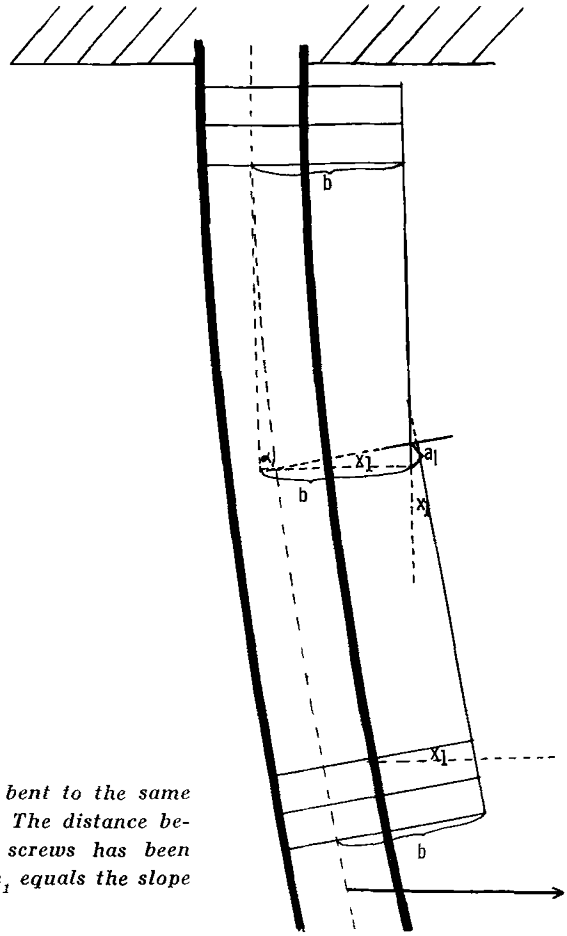


Figure 5. Diagram of a bone bent to the same side as the Hoffmann screws. The distance between the free ends of the screws has been diminished by a_1. The angle x_1 equals the slope at the free end of the bone.

The bone deflection can be expressed as the slope at end of the bone. The deflection angle is identical with the angle formed between the proximal and distal Hoffmann screws (Figures 5 and 6). When the bone is bent to the same side as the Hoffmann screws, the distance between the free end of the screws will diminish (Figure 5); if, however, the bone is bent to the opposite side this distance will increase (Figure 6). The changes in these distances are equivalent to the bone deflection and may be measured by means of the bridge (Figure 3).

Figure 5 shows the bone with the measuring bridge bent to the same side as the Hoffmann screws. The angle x_1 may be calculated as $tgx_1 = \frac{a_1}{b - \alpha_1}$, where a_1 is recorded on the dial micrometer, and b is the distance from the measuring bridge to the axis of the bone. α_1 is the distance originating from the axial displacement of the dial micrometer and the measuring sheet.

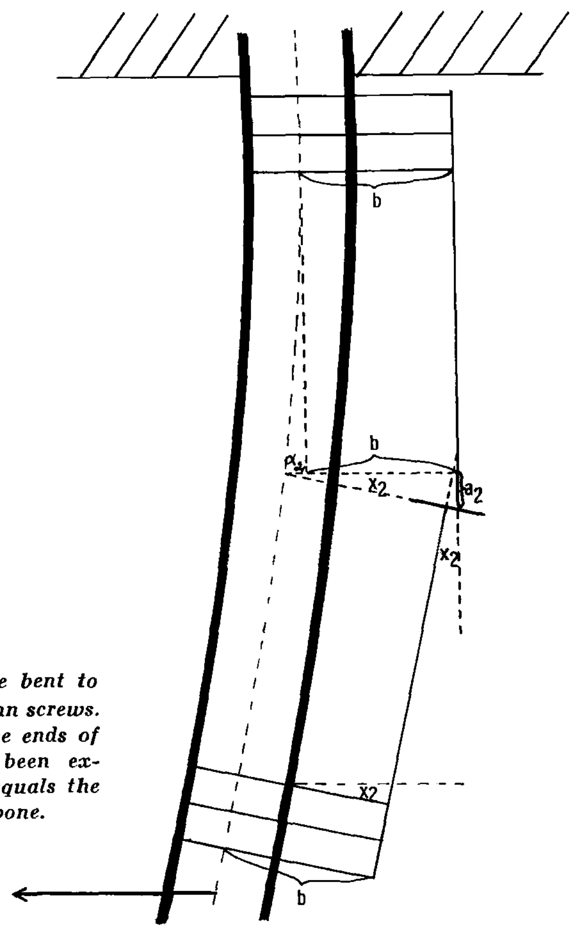


Figure 6. Diagram of a bone bent to the side opposite the Hoffmann screws. The distance between the free ends of the Hoffmann screws has been extended by a_2. The angle x_2 equals the slope at the free end of the bone.

In Figure 6 the bone is bent opposite to the Hoffmann screws. The angle x_2 is here calculated as $tgx_2 = \frac{a_2}{b + \alpha_2}$, α_2 also originates from axial displacement. Since the angles x_1 and x_2 are very small, the tangent of the angles equals the angles themselves.

The bone deflection $x = x_1 + x_2 = \frac{a_1}{b - \alpha_1} + \frac{a_2}{b + \alpha_2}$. α_2, and α_2 are less than a_1 and a_2, which in practice do not exceed 0.25 mm. b = 30 to 60 mm. In the equation $x_1 + x_2 = \frac{a_1}{b - \alpha_1} + \frac{a_2}{b + \alpha_2}$, α_1, and α_2 will tend towards elimination. Provided the bone deflection is calculated $x = x_1 + x_2 = \frac{a_1 + a_2}{b}$ rad, the

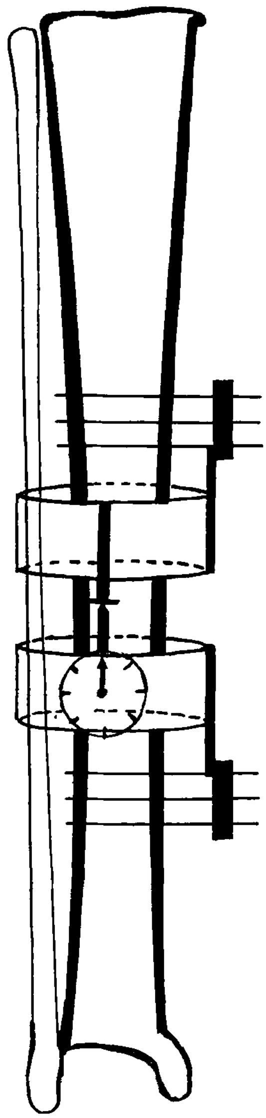


Figure 7. Diagram illustrating the principle of measuring the bone deflection in several planes. Two metal cylinders, the centers of which are located in the longitudinal axis of tibia, are fixed at the proximal and distal Hoffmann screws, respectively.

error will be less than 0.5 per cent. In practice this means that at minor bendings of the bone the deflection may be estimated to take place in one point in the middle of the bone and in its axis.

In priciple these calculations are valid in all the planes shown in Figures 3, 4, 5, 6 and 7. It is emphasized that with the method described the deflection is only measured in the direction of the force. Torsion or deflection of the bone in other directions than in the plane of the force are not registered by the above method of measurement.

The Requisite Equipment. (Figures 1 and 10)

6 Hoffmann screws (120 mm).

2 ball-joint grips.

Dial micrometer (Rambold) diameter 40 mm, height 25 mm, maximum amplitude 3 mm. 360° deflection corresponds to 0.5 mm. The bottom plate is magnetic.

L-shaped grip for the dial micrometer.

An 8 mm bar with a ground flat sheet (diameter 15 mm).

A spring balance 0 to 5 kg (10 kg).

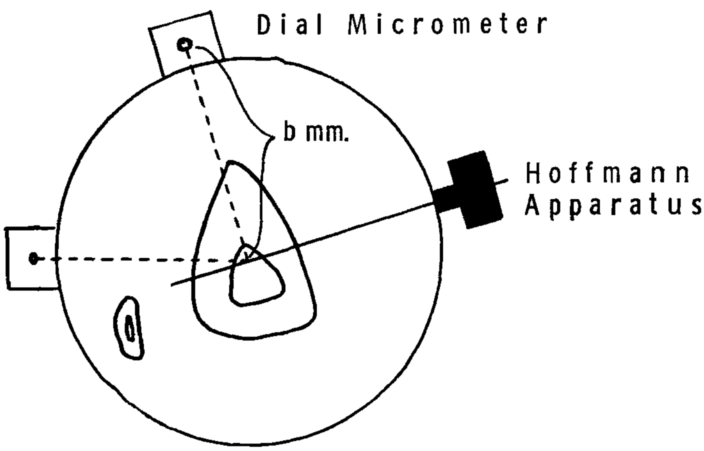


Figure 8. Cross section of the measuring bridge in Figure 7. The dial micrometer can be removed to different positions on the metal cylinder.

Practical Method for Measuring the Deflection

The Hoffmann screws are inserted perpendicularly to the anteromedial facies of the tibia, so that the distance between the two sets of screws amounts to 12 cm (Figures 9 and 10). The measuring sheet is mounted on the proximal screws, and the dial micrometer with the angular grip is mounted on the distal screws. The pelotte of the micrometer is adjusted so that it is perpendicular to the ground flat sheet. Just distal to the lowest set of Hoffman screws (6 cm distal to the measuring object) the spring balance is placed with the curved clevis. The crus is held firmly with one hand proximal to the screws. Then a 5 kg load is pulled antero-medially (perpendicular to the facies antero-medialis tibiae) and afterwards the load is pulled postero-laterally. The difference on the micrometer is read at the same time.

Then the measurements are repeated in the antero-lateral plane as well as in the postero-medial plane. Thus the 12 cm long bone section was loaded at the unfixed end with $\pm$ 5 kgf $\times \frac{18 \text{ cm}}{12 \text{ cm}} = \pm$ 7.5 kgf. (Figures 3 and 4).

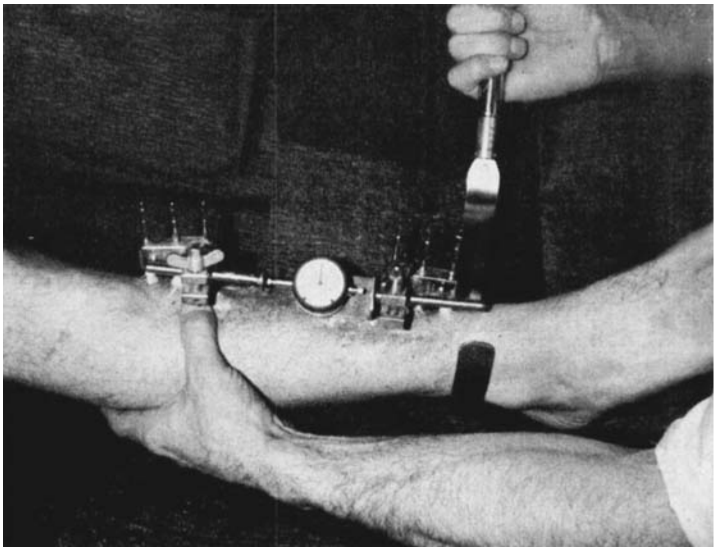


Figure 9. Posterolateral measurement of the deflection.

The corresponding bone deflection was:

$$\frac{\text{Deflection on the micrometer in mm}}{\text{Distance from the measuring axis to the bone axis}} \text{ rad.}$$

$$\text{Example: } \frac{0.2 \text{ mm}}{50 \text{ mm}} = 0.004 \text{ rad} = 0.23°.$$

In the examinations where the bone deflection is measured on crura without soft tissue, a metal cylinder (diameter 10 cm) is mounted on either of the two sets of Hoffmann screws (Figures 7 and 8). The micrometer with the corresponding measuring sheet may then be moved to various measuring positions, which all have the tibial axis as their centre (Figure 8). The crural bone is fixed vertically in a vice, proximal to the screws.

With the spring balance tibia may be exposed to bending loads and the bone deflection measured in the direction of the force in relation to the longitudinal axis of the tibia. (All measurements are performed in relation to the longitudinal axis of the tibia.) The principle and the calculation of the deflection follow the above described rules.

Measuring Error

Measurements have been performed on 12 specimens in the anteromedial/posterolateral plane (perpendicular to the anteromedial facies of the tibia.) Measurements were repeated three times at each examination, a total of 36 measurings. The variance was 2.428×10^{-8}.

$$\mu = \sqrt{2.428 \times 10^{-8}} = 1.55 \times 10^{-4} = 0.000155 \text{ rad.}$$

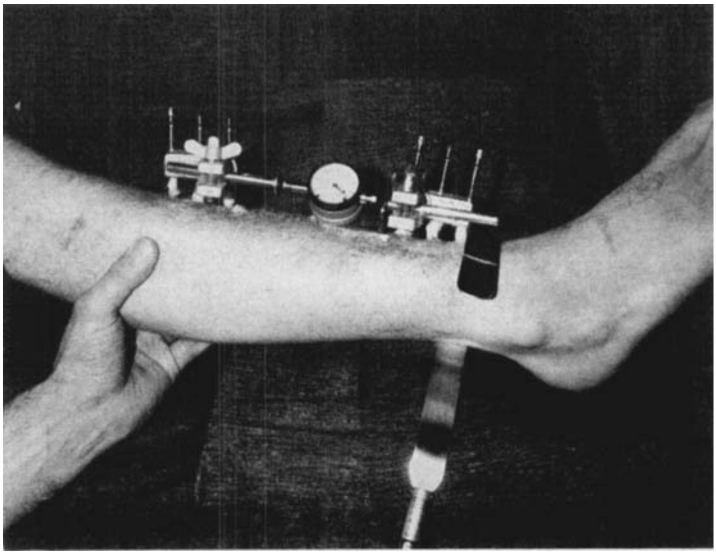


Figure 10. Anteromedial measurement of the deflection.

$$\text{Measuring error in per cent: } \frac{1.55 \times 10^{-4} \times 10^{2}}{4.769 \times 10^{-3}} = 3.2 \text{ per cent.}$$

Material

The deflection examinations were performed on autopsy specimens 9 to 32 hours post mortem. The room temperature during the measurings was 20°C. The bone specimens were kept humid till the completion of the measurings.

The examinations fell in two series:

1. *Comparative measurings in several planes on autopsy crura with or without soft tissue were performed on two specimens.*

Specimen A: 81-year-old male, medium build, previously well and mobile. Died suddenly from coronary infarct.

Specimen B: 18-year-old male, solid build, previously good physical health, mobile. Suicide.

Figure 11. The bone deflections on specimens A and B with and without muscles are shown in diagram. The principle in Figure 7 was used at measurings without muscles, whereas the principle in Figure 9 and 10 was used at measurings with muscles. The deflection diagrams show that crura bend the most in the plane perpendicular to the facies medialis tibia. In practice muscles appear to have no effect on the deflection measurements in this plane.

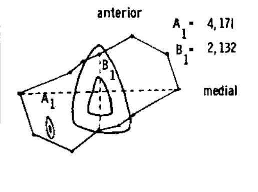
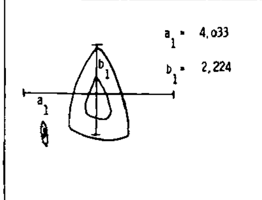
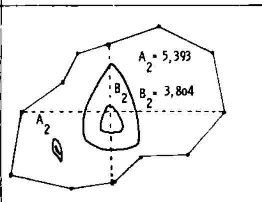
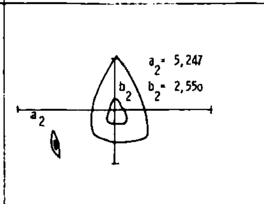
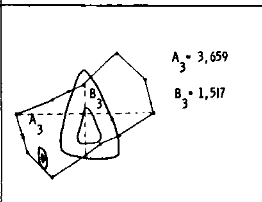
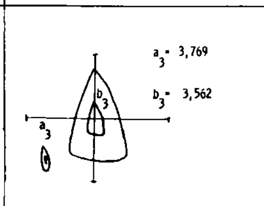
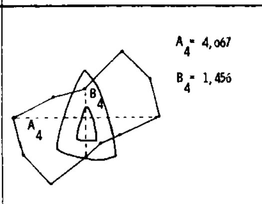
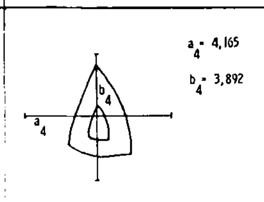
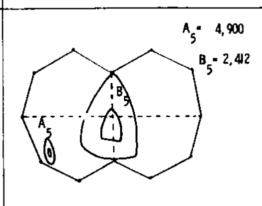
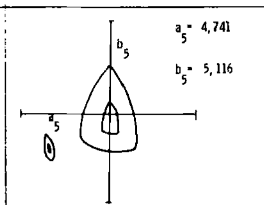
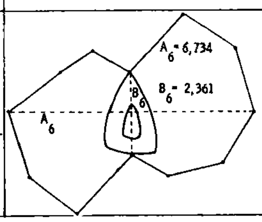
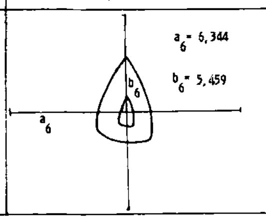
SPECIMEN	PART OF CRUS	DEFLECTION OF 12-CM CRUS WITHOUT MUSCLES. DEFLECTION: RADIAN x 10^{-3}	DEFLECTION OF 12-CM CRUS WITH MUSCLES. DEFLECTION: RADIAN. x 10^{-3}
A	MIDDLE	 anterior; A_1 = 4,171; B_1 = 2,132; medial	 a_1 = 4,033; b_1 = 2,224
A	DISTAL	 A_2 = 5,393; B_2 = 3,804	 a_2 = 5,247; b_2 = 2,550
B	MIDDLE	 A_3 = 3,659; B_3 = 1,517	 a_3 = 3,769; b_3 = 3,562
B	MIDDLE. FIBULA RESECTED.	 A_4 = 4,067; B_4 = 1,456	 a_4 = 4,165; b_4 = 3,892
B	DISTAL	 A_5 = 4,900; B_5 = 2,412	 a_5 = 4,741; b_5 = 5,116
B	DISTAL. FIBULA RESECTED.	 A_6 = 6,734; B_6 = 2,361	 a_6 = 6,344; b_6 = 5,459

Figure 11.

Table 1. Measurements of deflection on crura in the anteromedial/posterolateral plane.

Specimen and localization	Bone deflection on crus with soft tissue removed (radians) Single measurement	Mean	Bone deflection on crus with soft tissue (radians) Single measurement	Mean	Mean value of bone deflection on crus with and without soft tissue (radians) Mean value of 6 measurements
	4.310×10^{-3}		4.00×10^{-3}		
A Middle	4.202×10^{-3}	4.171×10^{-3}	4.00×10^{-3}	4.033×10^{-3}	4.102×10^{-3}
	4.00×10^{-3}		4.098×10^{-3}		
	5.495×10^{-3}		5.208×10^{-3}		
A Distal	5.128×10^{-3}	5.393×10^{-3}	5.405×10^{-3}	5.247×10^{-3}	5.320×10^{-3}
	5.556×10^{-3}		5.128×10^{-3}		
	3.636×10^{-3}		3.802×10^{-3}		
B Middle	3.636×10^{-3}	3.659×10^{-3}	3.802×10^{-3}	3.769×10^{-3}	3.714×10^{-3}
	3.704×10^{-3}		3.704×10^{-3}		
B Middle	4.00×10^{-3}		4.201×10^{-3}		
fibula	4.00×10^{-3}	4.067×10^{-3}	4.00×10^{-3}	4.165×10^{-3}	4.116×10^{-3}
resected	4.201×10^{-3}		4.292×10^{-3}		
	4.854×10^{-3}		4.608×10^{-3}		
B Distal	5.128×10^{-3}	4.900×10^{-3}	4.808×10^{-3}	4.741×10^{-3}	4.821×10^{-3}
	4.717×10^{-3}		4.808×10^{-3}		
B Distal	6.667×10^{-3}		6.211×10^{-3}		
fibula	7.042×10^{-3}	6.734×10^{-3}	6.410×10^{-3}	6.344×10^{-3}	6.539×10^{-3}
resected	6.494×10^{-3}		6.410×10^{-3}		

F = Variance ratio (6.24) = 2.464. $F_{90} < F < F_{95}$.

In specimens A and B the deflection was measured on the right crus on the middle part (10 to 22 cm below the knee), and on the distal part (6 to 18 cm above the ankle joint). After the resection of fibula the measurements were repeated on specimen B. Then the left crural bones were removed in both specimens and measurements were performed on the middle and the distal parts of the bones. Here the measurings were made full circle at intervals of 30° between the direction of the force. The results are given in Tables 1 and 2 and in Figure 11.

2. *Measurements in the anteromedial/posterolateral plane (perpendicular to facies medialis tibia) in 15 autopsy crura.*

The material is collected in Table 3 and comprises a mixed male/female material. On purpose the material is selected to be as inhomogeneous as possible to obtain the greatest possible dispersion in the deflection values. The measurements were performed on the middle and/or the distal part of intact crura. The measurements were performed only in the anteromedial/posterolateral plane.

Statistic Analysis (Tables 1, 2 and 4)

Series No. 1: On the 5 per cent level of significance a one-sided analysis of variance showed that there were no differences in the antero-medial/posterolateral plane in the same specimen with or without muscles. On the other hand, significant differences were found in the anterolateral/posteromedial plane in the same specimen with or without muscles.

Series No. 2: Student's test showed a strong significant difference ($p < 0.0001$)

Table 2. Measurements of deflection on crura in the anterolateral posteromedial plane.

Specimen and localization	Bone deflection on crus with soft tissue removed (radians)		Bone deflection on crus with soft tissue (radians)		Mean value of bone deflection on crus with and without soft tissue Mean value of 6 measurements
	Single measurement	Mean	Single measurement	Mean	
A Middle	2.198×10^{-3} 2.00×10^{-3} 2.198×10^{-3}	2.132×10^{-3}	2.306×10^{-3} 2.00×10^{-3} 2.336×10^{-3}	2.224×10^{-3}	2.178×10^{-3}
A Distal	3.802×10^{-3} 4.00×10^{-3} 3.610×10^{-3}	3.804×10^{-3}	2.531×10^{-3} 2.336×10^{-3} 2.667×10^{-3}	2.550×10^{-3}	3.177×10^{-3}
B Middle	1.456×10^{-3} 1.639×10^{-3} 1.456×10^{-3}	1.517×10^{-3}	3.676×10^{-3} 3.676×10^{-3} 3.333×10^{-3}	3.562×10^{-3}	2.539×10^{-3}
B Middle fibula resected	1.456×10^{-3} 1.456×10^{-3} 1.456×10^{-3}	1.456×10^{-3}	4.00×10^{-3} 4.00×10^{-3} 3.676×10^{-3}	3.892×10^{-3}	2.674×10^{-3}
B Distal	2.463×10^{-3} 2.309×10^{-3} 2.463×10^{-3}	2.412×10^{-3}	5.00×10^{-3} 5.348×10^{-3} 5.00×10^{-3}	5.116×10^{-3}	3.764×10^{-3}
B Distal fibula resected	2.463×10^{-3} 2.309×10^{-3} 2.309×10^{-3}	2.361×10^{-3}	5.348×10^{-3} 5.348×10^{-3} 5.681×10^{-3}	5.459×10^{-3}	3.910×10^{-3}

F = Variance ratio (6.24) = 284.6. $F > F_{99.95}$.

in the bone deflection in men and women (Table 4). Bartlett's test affords no inhomogeneity of variance, and thus the conditions of the analysis should be present.

Method of paired comparisons showed that the crural bone has a greater deflection on the distal part than on the middle part ($0.01 < p < 0.02$). The average age of the female group was 70 years. Average age of the male group was 62 years.

Table 3. Results of measuring the deflection on 15 cruralspecimens. The bending plane is perpendicular to the medial surface of the tibia.

Subject	Age	Sex	Cause of death	Deflection on the middle of crus radians (degrees)	Deflection on the distal part of crus radians (degrees)
1	90	♀	Mb. cordis incomp.	0.009091 (0.5209)	
2	89	♀	Mb. cordis incomp.	0.00625 (0.3581)	
3	78	♀	C. coli inoperable	0.008333 (0.4775)	
4	64	♀	Embolia pulm.	0.0080 (0.4584)	
5	55	♀	C. mammae c. metastasis	0.0080 (4584)	
6	48	♀	Pancreatitis	0.007519 (0.4308)	0.008 (0.4584)
7	87	♂	Coronary infarct	0.005 (0.2865)	
8	81	♂	Coronary infarct	0.004049 (0.2320)	0.005263 (0.3015)
9	81	♂	Coronary infarct	0.002778 (0.1591)	0.004167 (0.2388)
10	75	♂	Chemical pneumonia	0.004 (0.2292)	
11	67	♂	C. pulm. inoperable	0.006667 (0.3820)	
12	63	♂	Acute leukemia		0.0050 (0.2865)
13	51	♂	Coronary infarct	0.004 (0.2292)	0.004292 (0.2459)
14	33	♂	Cerebral aneurysm		0.003003 (0.1721)
15	18	♂	Suicide	0.003774 (0.2162)	0.004762 (0.2728)

RESULTS

1. It is reasonable to assume that the method described for measuring in the anteromedial/posterolateral planes in autopsy crura may be used to measure the bone deflection without the results being affected by the muscles.

2. Figure 11 shows that the examined tibial bones have the least deflection above margo anterior tibiae and the largest deflection at the facies medialis tibiae.

3. The crural deflection is found to be larger in women than in men. (women: 0.52 to 0.36 (mean: 0.45), men: 0.38 to 0.16 (mean: 0.25 degrees).

4. The distal part of crus has shown a deflection which is 7 to 28 per cent (mean 18 per cent) greater than the middle crural deflection.

Table 4.

	Middle part of crus	Distal part of crus
Female	A_1	A_2
Male	B_1	B_2

Hypothesis: $A_1 = B_1$
Student test (Therkelsen 1968):
Variance $= s^2 = 1214 \times 10^{-9}$

$$\varepsilon\Delta = \sqrt{\varepsilon_{A_1}^2 + \varepsilon_{B_1}^2} = \sqrt{\frac{1214 \times 10^{-9}}{6} + \frac{1214 \times 10^{-9}}{7}} = 6.1237 \times 10^{-4}$$

$$t = \frac{0.0078 - 0.0043}{6.1237 \times 10^{-4}} = 6 \qquad F_{(5.6)} = 1.7$$

Conclusion: $A_1 \neq B_1$, $p < 0.0001$

Hypothesis: $A_1B_1 = A_2B_2$
Method of paired comparisons (Therkelsen 1968):

$$\text{Variance} = s_D^2 = \frac{451 \times 10^{-8} - 369 \times 10^{-8}}{4} = 20 \times 10^{-8}$$

$$\varepsilon_{\bar{D}} = \sqrt{\frac{20 \times 10^{-8}}{5}} = 2 \times 10^{-4}$$

$$t = \frac{|0 - 0.0008|}{0.0002} = 4$$

Conclusion: $A_1B_1 \neq A_2B_2$ $\quad 0.01 < p < 0.02$

DISCUSSION

When a bone is loaded by bending, deformation occurs, depending on the shape of the cross section of the bone (moment of inertia) and the property of elasticity of the tissue at compression and tension (modules of elasticity). The irregular shape of the cross section of the bone has the effect that the bone is able to resist deformation and that this ability depends on the bending plane.

In order to give the absolute values of the moments of inertia the exact shape of the cross sections must be known. To estimate the modules of elasticity of a material, loading experiments must be made on a test speciment with a known shape (stress-strain).

Problems concerning these matters have been elucidated by measurements on isolated bone specimens (Evans 1957, Sedlin 1965, Sedlin & Hirsch 1966, Lindahl & Lindgren 1967 a, b, 1968). Studies concerning the moment of inertia of the bone were made by Koch (1917), Marque (1945), Blaimont (1968) and Jernberger (1970).

Measurements of the modules of elasticity and calculations of the moments of inertia have been omitted in this paper, as the main purpose was to investigate whether a practically applicable result could be obtained by only measuring the deflection on fractured crural bones.

The deflection of a bone depends on the flexural rigidity, which can be expressed by the product of the modules of elasticity and the moment of inertia. When an irregularly outlined bone like the tibia is bent in various directions, the main part of the deflection in different bending planes will chiefly depend on the moment of inertia. The modules of elasticity is a bone constant only slightly dependent on the bending plane. Figure 11 gives an estimate of the relative size of the reciprocal value of the moment of inertia in the various directions in relation to the longitudinel axis of the tibia. It must be emphasized, however, that the marked deflections in the various directions are only the deflections occurring in the direction of the force itself. The actual bone deflection is only measured where the moment of inertia is minimum, i.e. perpendicular to the facies medialis tibia.

The investigation shows that the minimal moment of inertia is found around the plane perpendicular to the facies medialis tibia. This finding corresponds to the finding of Jernberger (1970).

The resection of the fibula seems to give a slight increase in the deflection of the crura. However, the material is too small for an analysis. The observation is supported by Jernberger's investigation, which showed an almost significant difference ($0.05 > p > 0.01$) in the crural deflection after resection of the fibula. This does not necessarily lead to the assumption that the fibula renders nothing but a small contribution to the stability of the crus. The tibia and fibula are joined together through ligaments and through the membrana interrossea. In either end the two bones are connected with a joint allowing light gliding movements. Only when the tibia is strongly bent may the fibula be expected to hamper the deflection.

The relative great variation in the ratio between the measurements on the middle and distal parts of identical crura must be put down to the fact that the ratio between the moments of inertia of the middle and distal crural parts are not identical from one bone to another.

Comparative measuring on the right crus with soft tissue and on the left crus without soft tissue showed no significant differences in the deflection, which was measured perpendicularly to the facies medialis tibia. The six sets of measurements on the two specimens make it reasonable to assume that muscles on autopsy specimen do not affect the deflection in the plane perpendicular to the facies medialis tibia.

The bone deflection in female crura is found to be significantly larger than in male crura (ratio 1.55). Similarly, Jernberger (1970) found that the ratio between male and female tibial deflection was 149 μ/97 μ = 1.54. The main reason for this is probably that female bones are more frail than male bones.

For several reasons the measurements on autopsy specimens must differ from the measurements on live bones. Among other things it is known that the modulus of elasticity is increased by falling temperature, thus 6 per cent from 37° to 21°C (Sedlin 1965). Even brief dehydration in room atmosphere is sufficient to increase the modulus of elasticity (Smith & Walsley 1959). Thus postmortal changes tend to make the bone less bendable. When the method is to be used on live crural bones, greater values for the bone deflection must be expected.

SUMMARY

A simple method is described and tested for measuring the deflection of autopsy specimens as a preliminary work for measurements of stability on crural fractures treated with the Hoffmann apparatus. The deflectional measurements on the middle and distal parts of autopsy specimens show that the crural bone bends the most in the plane perpendicular to facies anteromedialis tibiae. In this plane the soft tissue of the autopsy crura does not affect the measurements significantly. It is concluded that in the given plane the method described may be used for measuring the bone deflection.

By measuring 15 autopsy specimens it was found that at a given load the bone deflection was approximately 1.5 times greater in women than in men. The bone deflection in the distal part of the tibial shaft is greater than in the proximal part.

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