

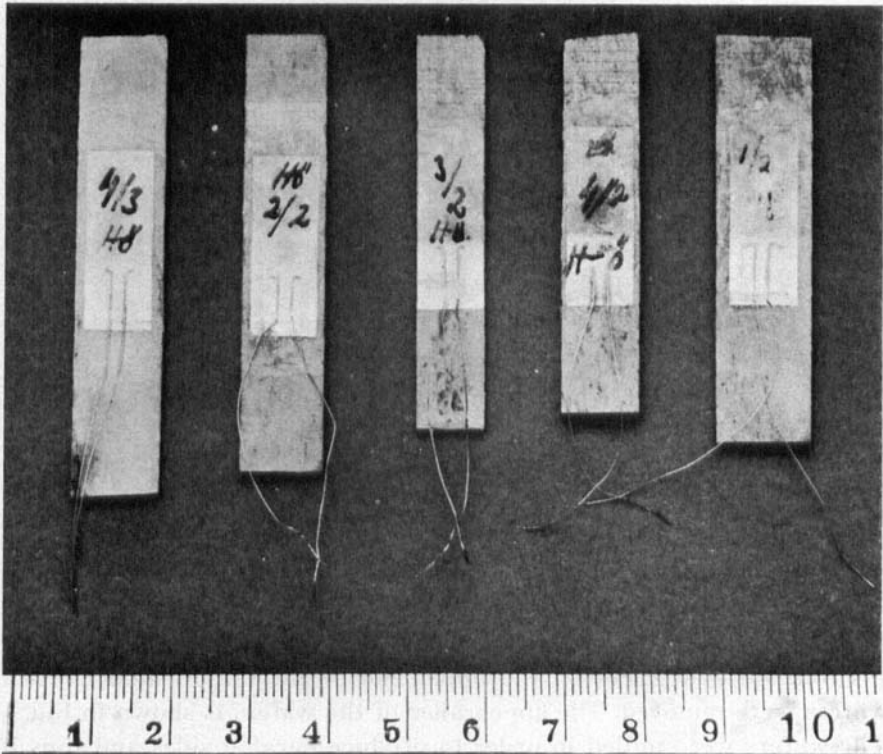
## DETERMINATION OF ELASTICITY MODULUS OF BONE

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It is felt that many of the osteosynthesis methods most frequently used today, as well as the methods of attaching prosthetic material in arthroplasties, are unsatisfactory from the point of view of stability and strength and that the reconstructions achieved do not attain the weight bearing capacity of the normal bone. It seems evident that attachment of osteosynthesis material to a part of the skeleton should as far as possible be carried out in those areas that are mechanically best fitted. However, our knowledge of the skeleton's mechanical structure is imperfect. Bone tissue has been subjected to extensive anatomical, histological and biochemical studies, but comparatively little attention has been paid to bone biomechanics. Although some work has been done in this field, most of it is concerned with measurement of conventional strength characteristics, such as various degrees of resistance to fracture and of elasticity. The foundation for this work was laid as long as some 75 years ago. Rauber's and Messerer's contributions are classical and still valid today. Since then no really new studies have been added until the very last decade. The reason for this stagnation should be sought primarily in the lack of suitable and sufficiently accurate measuring apparatus existing up till that time.

The swift technical progress of the past few years has been instrumental to the development of new and better methods of measuring strength. Many of these are applicable to bone tissue.

The stress-coat and strain-gauge techniques are based on the principle that they permit direct recording of the strain a given material shows when exposed to stress. Knowledge of the elastic properties of the material permits mathematical calculation of the local strains that occur. The problem is simplified where homogeneous materials with constant elastic properties are concerned. In biomechanics one has to



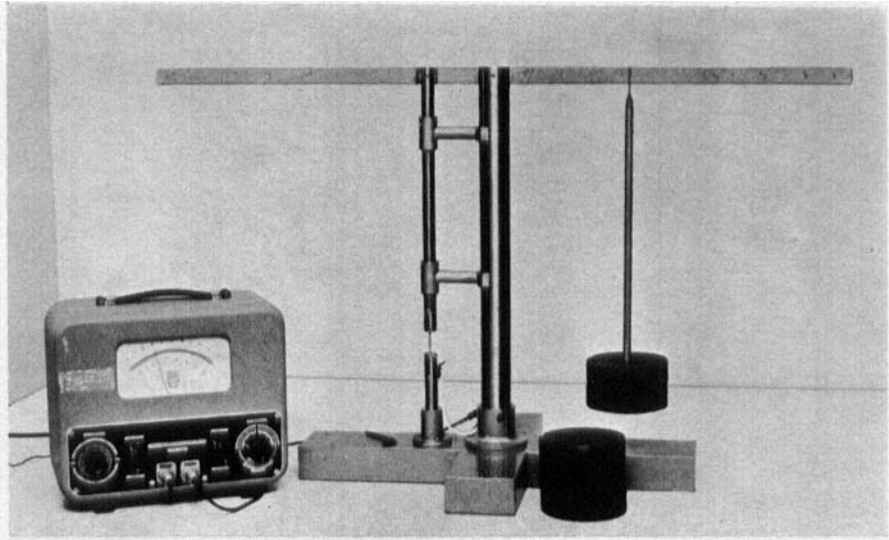
*Fig. 1.*

Strain gauges glued to cortical wafers removed from the upper end of a femur.

work with heterogeneous substances. Calculation of the local strains in bone which is exposed to stress is, therefore, possible only if the conditions of elasticity prevailing in the areas where these strains occur are known.

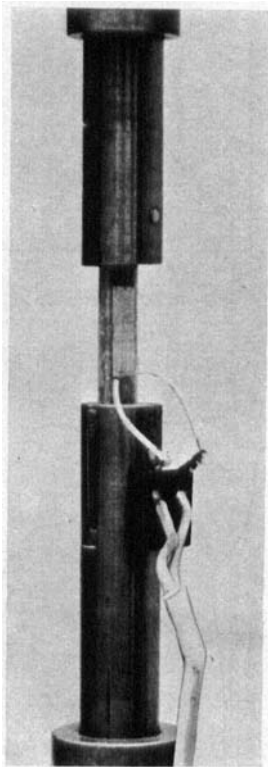
At the Biochemical Laboratory of the Orthopaedic Clinic in Upsala a method has been adopted which, using resistance strain-gauges, permits determination of elasticity constants within different small, limited areas on the surface of the bone. Special attention was devoted to the upper end of the femur.

A strain-gauge consists in principle of a very fine resistance wire wound in a special way and bonded to a thin paper cover. In a strain-gauge the electric resistance changes in direct ratio to a strain or compression in its longitudinal direction. If a strain-gauge is glued to a loaded body the strain or compression caused by the loading force can be determined directly by measuring the change in resistance.



*Fig. 2.*  
Loading device and measuring bridge.

From various places on the upper end of the femur small cortical wafers were removed. The appearance of the wafers is shown in Fig. 1. The wafers were milled in order to produce parallel sides and thus to permit exact calculation of the cross-sectional area. This is important for calculation of the strain in the cross-section. A strain-gauge was glued to each bone wafer. In an apparatus constructed for this purpose (Fig. 2) the specimens were exposed to increasing loads directed so as to obtain both strain and compression. Fig. 3 shows a close-up of the mounting. It is important that the load be applied in the longitudinal direction of the specimen in order to eliminate extraneous strains. By accurate mounting and exact centering of the specimen holder in the apparatus this source of error was avoided. The load was increased by increments of 5 Kg. at a time from 0 to 25 Kg. The strain was read from a measuring bridge. Each specimen was repeatedly loaded until constant values were obtained and hysteresis values were reduced to a minimum. It was found that in each case the bone wafer showed practically identical elasticity values for both strain and compression. Measuring results were recorded in a coordinate system (Fig. 4). The graph obtained represented in each case a straight line which shows that the relation between loading and change in length is an equation of the first degree. Within a limited loading range the cortical tissue behaves like a normal



*Fig. 3.*

Close-up showing the specimen holder and a mounted cortical wafer.

elastic body, in other words follows the law first set down by the Englishman Hook. This law states that the strain, viz. the load per square unit is directly proportional to the specific strain.

$$\text{Strain} = E \times dl/L.$$

The proportionality constant in the equation is called the elasticity modulus of the material and becomes a measure of its elastic properties. By determining the elasticity modulus of each removed bone wafer it becomes possible to compile the elasticity variations in the cortical layers of a bone.

Fig. 5 shows the upper end of the left femur of a 57 year old woman and of a 64 year old man. The removed cortical parts have been sketched in, together with the appertaining elasticity modulus values.

Certain areas are found to yield higher values than others. This shows that the former tolerate a greater stress before showing the same degree

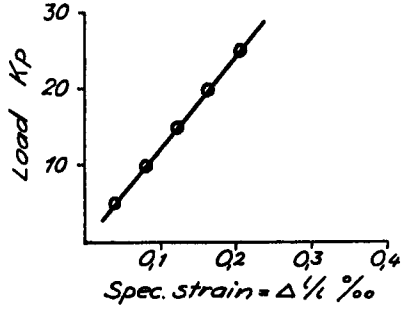


Fig. 4.

Graph to illustrate the direct relation between loading and specific strain.

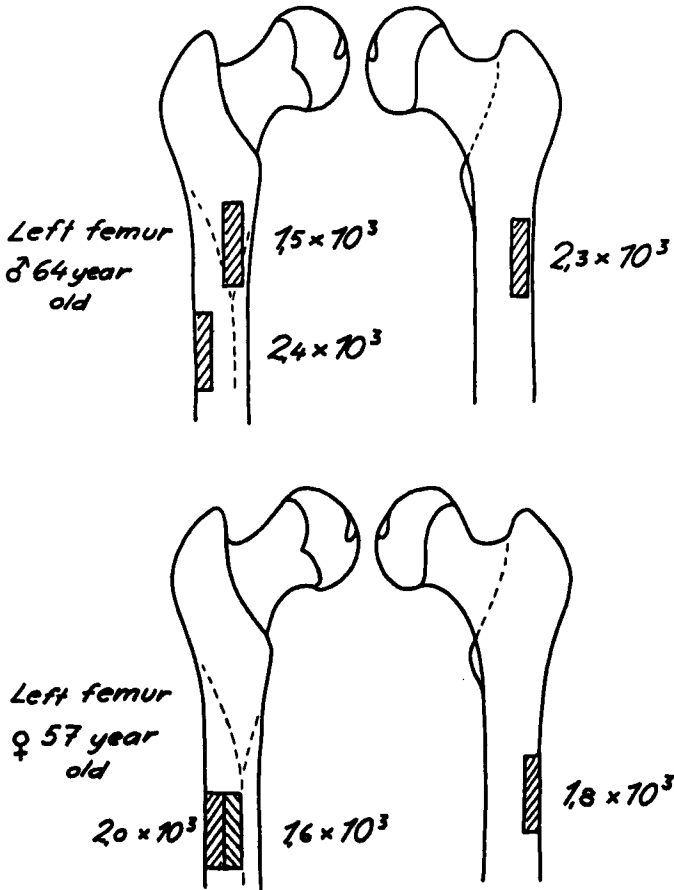


Fig. 5.

The upper end of the left femur of a 57 year old woman and of a 64 year old man. The removed cortical wafers are here sketched in, together with the appertaining elasticity modulus values.

of deformation. Whether these values are identical with the elasticity modulus of the specimens in situ is at the moment impossible to determine. There is much that points this way, especially recent studies on the finer structure of bone tissue.

Determination of the elasticity conditions of bone may enable us to obtain a clearer picture of the mechanical structure and this in its turn may lead us to firmer understanding of the principles of devices for bony repair.

#### SUMMARY

Sections of bone from the upper part of the femur have been tested as to their elasticity modulus.

Measurements were taken by strain-gauges.

Data obtained show that the elasticity modulus varies, indicating that some areas are more likely to stand stress than others because of the physical properties of the bone.

It is possible that studies like this may explain mechanically the anatomical appearance of the upper part of femur and give information as to methods for internal fixation or replacements.

#### RESUME

Des sections d'os de la partie supérieur du fémur ont été examinées par rapport à leur module d'élasticité.

Les mesures ont été prises au moyen d'une jauge de tension.

Les données obtenues montrent que le module d'élasticité varie, ce qui indique que certaines surfaces sont mieux à même de supporter l'effort que d'autres en raison des propriétés physiques de l'os.

Il est possible que des études comme celle-ci pourront expliquer mécaniquement l'apparence anatomique de la partie supérieure du fémur et fournir des renseignements en ce qui concerne les méthodes de fixation interne ou de replacements.

#### ZUSAMMENFASSUNG

Knochenpartien vom oberen Teile des Femurs wurden auf ihren Elastizitätsgrad geprüft.

Messungen wurden mittels Spannungsmessinstrumenten vorgenommen.

Die erhaltenen Daten zeigen, dass der Elastizitätsgrad wechselt, ein Hinweis darauf, dass gewisse Teile wegen der physikalischen Eigenschaften des Knochens, Beanspruchung besser ertragen als andere.

Es ist möglich dass derartige Untersuchungen die anatomische Gestaltung des oberen Femurendes mechanisch erklären können und dass sie Aufschluss über Methoden der inneren Fixierung oder der Erstattungsverfahren geben können.

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