

## MECHANICAL FACTORS FOR INTERNAL FIXATION OF THE FEMORAL NECK

*By*

VICTOR H. FRANKEL<sup>1</sup>

One hundred years have passed since von Langenbeck performed the first internal fixation of a fresh fracture of the femoral neck using a metal screw in 1858. As recently as 1953 this fracture was being referred to as the "Unsolved Fracture" by Dickson during the President's Address before the American Orthopaedic Association. A large number of fixation devices have been designed, manufactured, tested in vitro and in vivo, some retained and others found wanting.

Out of the many factors responsible for fracture healing, this investigation deals with only the mechanical principles for internal fixation of the femoral neck. As a chain is only as strong as its weakest link so any osteosynthesis is as strong as its weakest component. Several osteosynthesis systems were studied with the object of determining their resistance to vertical forces acting on the head of the femur. An attempt has been made to isolate the various components and to determine the weak link under these experimental conditions.

Many attempts have been made to define and resolve the numerous forces that act on the proximal end of the femur on standing and walking. Notable among these are the works of Pauwels, Inman, and the recent monograph by Backman. However, to date, no one has demonstrated the magnitude and direction of the forces on the proximal end of the femur in a living subject. In order to compare better the elements that make up an osteosynthesis of a fractured femoral neck, that is, the head, the inferior cortex of the neck, the cortex of the shaft, and

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<sup>1</sup> Fellow of the National Foundation, U.S.A.

the metallic appliance, one standard direction of force has been used in all experiments. This direction is a vertical one acting parallel to the shaft of the femur. Fig. 1.

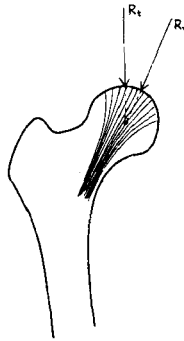


Fig. 1.

Direction of force acting on the femoral head.— $R_v$  - the calculated direction of the force acting on the head of the femur on standing on one limb—after Backman.— $R_t$  - the direction of force used in this experiment.

#### MATERIAL

**Bone:** Proximal halves of the femur were taken at the time of autopsy a few hours after death and immediately frozen in a deep freezer where they were stored until used. The night before testing they were allowed to thaw slowly in a refrigerator and then brought to room temperature. The difference in strength between fresh bone and thawed frozen bone is negligible. All soft tissue was removed from the specimen before use and the experiment performed the day the bone thawed. The age of the bone source was over sixty years in all cases.

**Nail-plate:** The McLaughlin four flanged Vitallium nail-plate was selected as a representative of the Smith-Peterson/Johansson type.

**Screw-plate:** The stainless steel compression screw-plate described by Charnley et al. was tested. It was applied with the full set of instruments designed by its originators.

**Testing-Machine:** This was a standard Amsler Static Compression machine, accuracy within 0.5 %. This device has been used in previous experiments by Hirsch and Brodetti and has a special vice capable of gripping the bone securely. The force was applied by means of a brass appliance which had the shape of the upper part of the acetabulum. All numbers were rounded off to the nearest five.

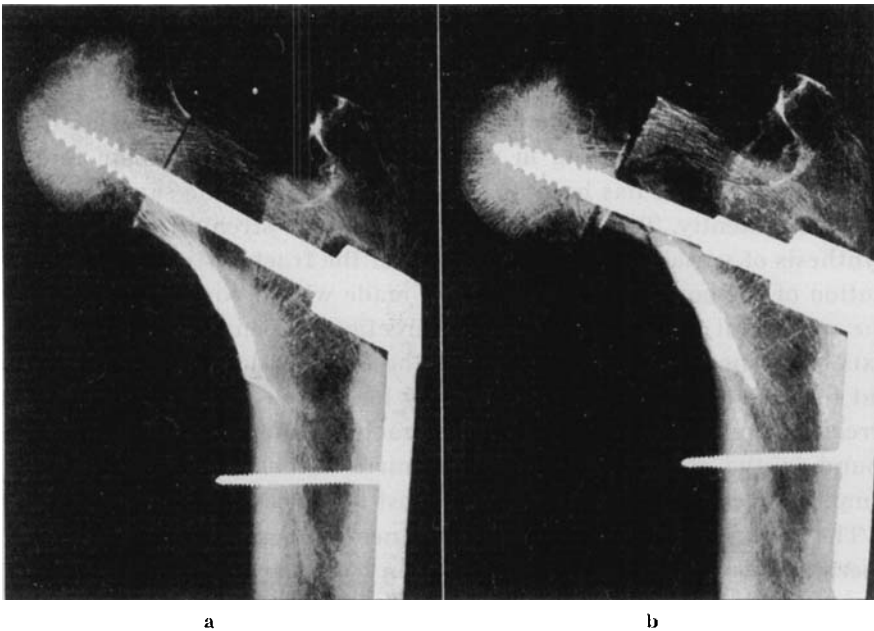
## METHODS AND RESULTS

*Strength of the Osteosynthesis as a Whole.*

Attempts have been made in the past to produce femoral neck fractures by means of loading in various directions by Backman, Smith, and others. No one has been able to produce exactly the same fracture type consistently. To rule out the effects on the strength of the osteosynthesis of variables such as direction of the fracture line and comminution of the bone, all fractures were made with a power saw through the subcapital area of the neck in a direction perpendicular to the long axis of the neck. In a few specimens the cortical shell of the neck was cut through and the neck fractured by loading in order to produce an irregular cancellous surface at the fracture line. No difference was found in the strength of these specimens after internal fixation so simple saw cuts were resorted to in most instances.

The appliance was inserted in a manner as consistent with ordinary operating room technique as possible. In a few cases when an attempt was made to place the nail along the calcar the bone was slightly split. The Charnley screw pulled out of two femoral heads as the tension of the nut was being increased, the heads were slightly rotated and the screw reinserted and was found to hold well. Roentgenograms were taken in two projections. The bone was then placed in the test vice with the shaft of the femur held in a vertical position. At times the plate of the fixation appliance was held in the test vice, this had no effect on the final breaking strength of the osteosynthesis. Force was applied until the system was seen to disrupt by a fracture of the inferior cortex or a slipping of the head on the neck of at least a few millimeters. At times roentgenograms were taken while the specimen was under pressure to study the bending taking place in the nail or screw. All specimens were roentgenographed after removal from the test vice. The appliance was removed and the head and neck of the femurs cut into sections perpendicular to the axis of the neck and roentgenographed. Figs. 2 and 3. Table I.

Of the nine specimens tested with Charnley screws eight showed fractures in the inferior cortical area after disruption of the osteosynthesis. The average breakdown force was 165 Kg. (100–260 Kg.). From the sections of the head and neck it was evident that no head was cut by the screw. Measurements were taken of the angle that the screw made with the plate after breakdown; it was found to be about three degrees less than the original angle of 120 degrees. In addition to this



*Figs. 2 a-b.*

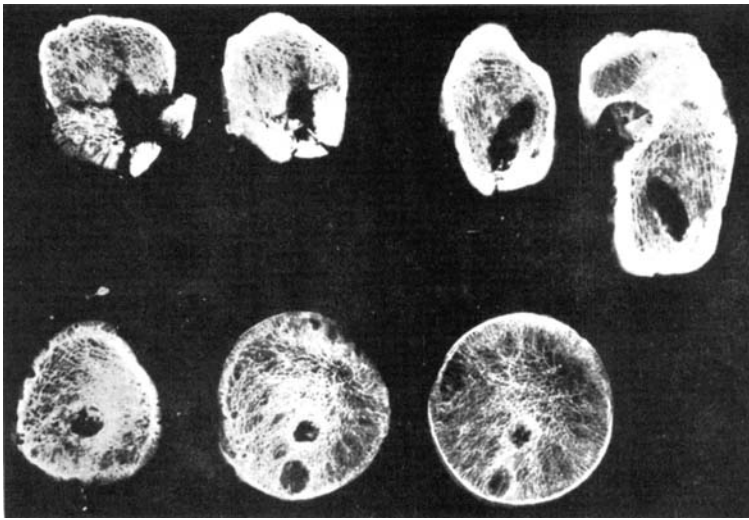
*Fig. 2 a.* Fractured femoral neck with Charnley screw inserted.

*Fig. 2 b.* After application of vertical force to point of breakdown. Note impingement of screw on inferior cortex and resultant fracture.

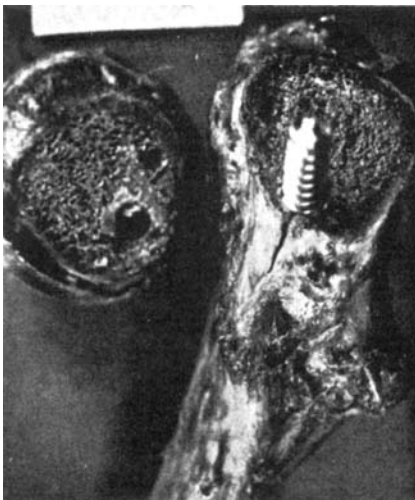
permanent deformation some appliances were observed to bend under pressure and then return to nearly a normal angle after the pressure was removed. This temporary bending or elastic deformation could be seen with pressures as low as 50 Kg. The inferior cortical fractures were due to the screw-plate bending under pressure and allowing the screw to rest on the cortex where it produced a fracture.

In the specimen that did not show a cortical fracture the head had slipped down on the neck 5 millimeters as the screw-plate bent and this was considered a breakdown of the osteosynthesis. With further pressure it was felt that the screw would then rest on the inferior cortex and produce a fracture. After the breakdown of the osteosynthesis many of the screws could be tightened one turn or the screw was seen to be extruded one turn.

Seven specimens were used for the nail tests. In three of the tests inferior cortical fractures were produced on insertion of the nail and after application of pressure the cortex was seen to split further. One test was stopped when the head had slipped on the neck five millimeters.



c



d



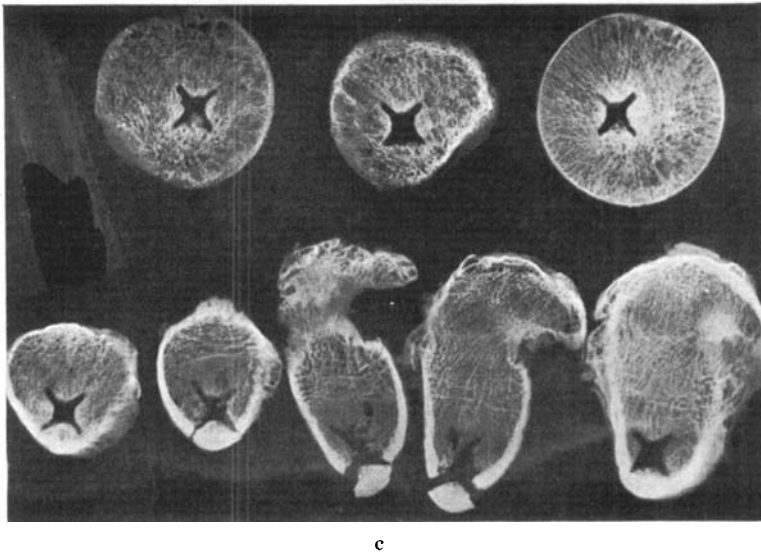
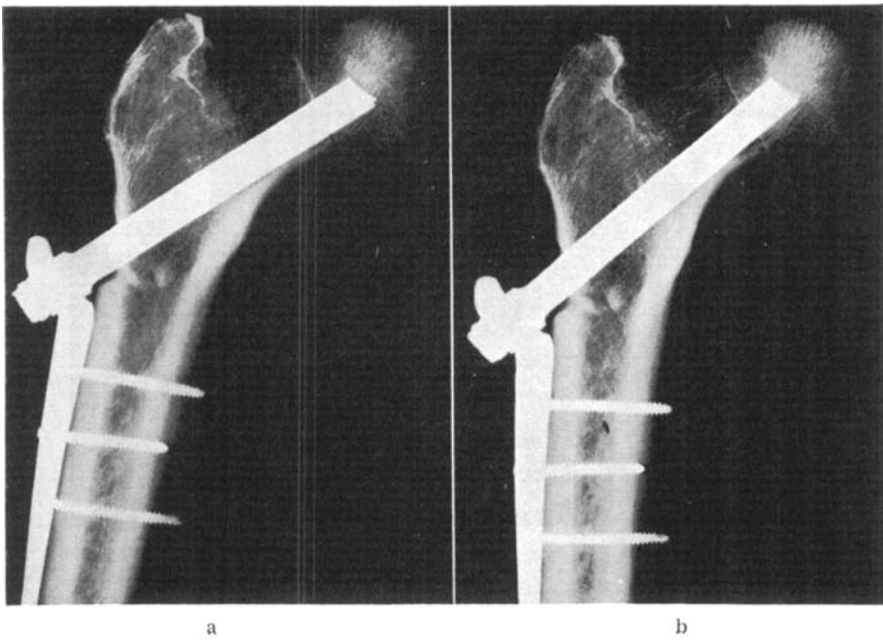
e

*Figs. 2 c-e.*

*Fig. 2 c.* Cross section of head and neck. The screw has not cut through the head. The inferior cortex of the neck has been fractured.

*Fig. 2 d.* The round hole in the head shows that the screw has not cut through. Note crack in inferior cortex below screw.

*Fig. 2 e.* Note crack in lower portion of neck.



*Figs. 3 a-c.*

*Fig. 3 a.* Fractured femoral neck with McLaughlin nail-plate.

*Fig. 3 b.* After vertical force.

*Fig. 3 c.* Cross section of head and neck. Note fracture of inferior cortex of neck.



d

*Fig. 3 d.*

Specimen with massive inferior cortical fracture.

In the other three tests cortical fractures were produced. The average breakdown force was 200 Kg. (50–360 Kg.). The same mechanism was present in the nail-plate tests as was found in the screw-plate tests. That is, the nail-plate was bent either at the junction of the nail with the plate or along the course of the nail. The bending was both of an elastic and permanent nature. Permanent deformations of about five degrees were seen in the nail-plates after breakdown. After breakdown the heads were still firmly on the nails and had to be hammered off. No head was cut by a nail.

The screws holding the plate to the shaft of the femur were found to be firmly attached at the end of the test and were not pulled out in any test.

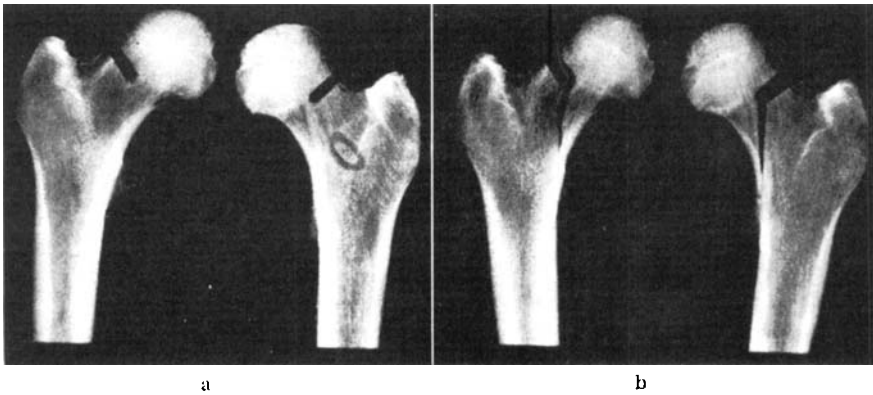
#### *Strength of the Neck.*

In order to determine the strength of the inferior cortical area of the neck, a section of the superior part of the neck was removed and cancellous tissue gently curetted from the interior of the neck down to the level of the medial trabecular system. The specimen was then placed in the test vice with the shaft held vertically. Force was applied until the neck fractured. The average fracture force was 135 Kg. (75–220 Kg.). If the group be divided by six the average breakdown force for males was

TABLE I  
*Experimental Determination of Breakdown Forces Using a Charnley Screw and McLaughlin Nail-Plate.*

Specimen	Vital data	Breakdown force		Fixation apparatus angle		Remarks
		Charnley Screw	McLaughlin nail-plate	Original	After breakdown	
1 Rt	75 yr. old F. Bedridden 6 weeks .... Arteriosclerotic C. V. Disease	100 kg		120°	117°	Cortical crack, screw loose 2 turns
2 Rt	78 yr. old F. .... Acute pyelonephritis	110 kg		120°	120°	Cortical crack, screw extruded 1 turn
Lt			290 kg	145°		5 mm slip. At 200 kg cortical crack Nail bent to 130°
3 Rt	74 yr. old F. Bedridden 1 week .... Paraganglioma retroperitonealis	245 kg		120°	117°	Cortical crack, screw extruded 1 turn
Lt			290 kg	130°	125°	Cortical crack
4 Rt	77 yr. old M. Bedridden 1 week .... Coronary occlusion	190 kg		120°		Cortical crack
Lt			360 kg	230°	125°	Cortical crack
5 Rt	68 yr. old F. .... Uremia	120 kg		120°	117°	0.5 cm slip
Lt			205 kg	135°	133°	Cortical crack
6 Rt	70 yr. old F. .... Thyrotoxicosis	260 kg		120°	116°	Cortical crack
7 Rt	74 yr. old F. Bedridden 2½ months Arteriosclerotic C. V. Disease	175 kg		120°		Cortical crack, screw extruded 1 turn
Lt			165 kg	120°	115°	Slight cortical crack on nail insertion
8 Rt	77 yr. old M. Bedridden 4 days .... Pulmonary embolus	175 kg		120°		Cortical crack, screw extruded 1 turn
Lt			230 kg	120°	115°	Slight cortical crack on nail insertion
9 Rt	69 yr. old M. .... Fx skull	140 kg		120°		Cortical crack, screw extruded 1 turn
Lt			120 kg	115°	112°	Cortical crack on nail insertion

Average: 163 ± 13.6 kg      200 ± 30 kg



*Figs. 4 a-b.*

*Fig. 4 a.* Roentgenogram of femoral neck with portion of superior cortex removed and cancellous bone curretted.

*Fig. 4 b.* Fracture in inferior cortical area following vertical loading.

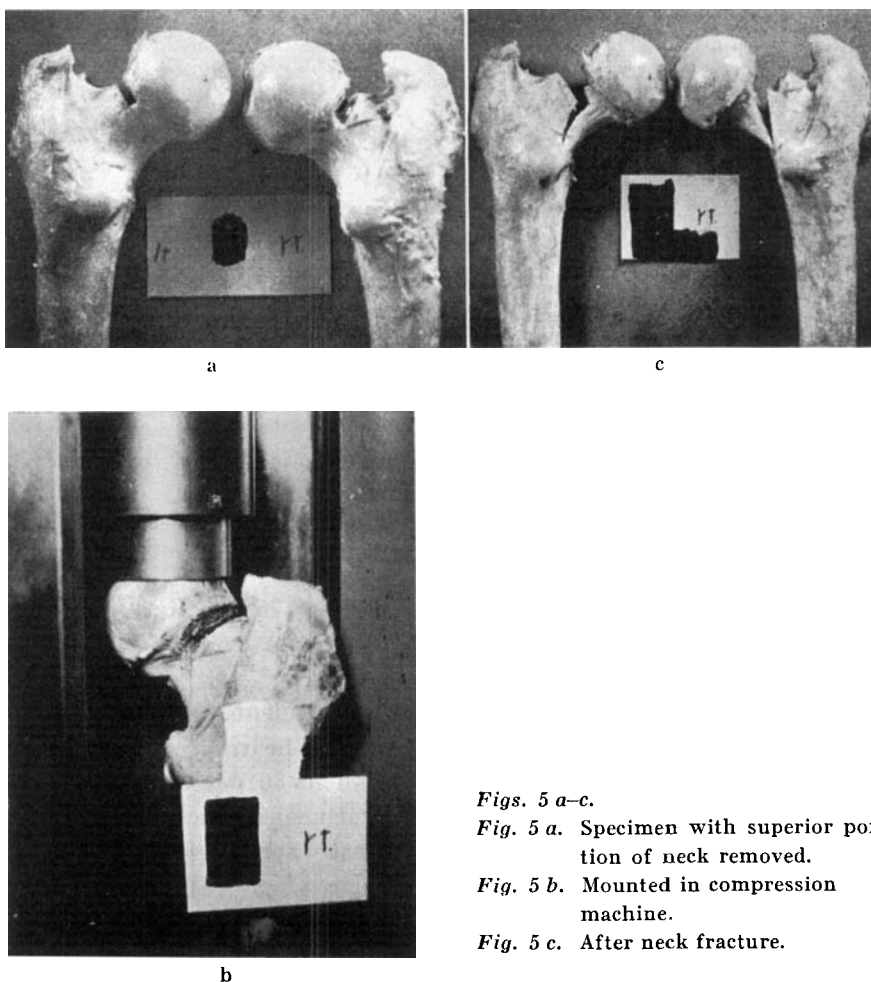
170 Kg. (95–220 Kg.) and for females 100 Kg. (75–145 Kg.). However, the female group was slightly older than the male group. Figs. 4 and 5, Table II.

Hirsch and Brodetti performed similar experiments on femoral necks using vertical force and found that the weight-bearing capacity of the inferior cortex of the femoral neck was 40 to 50 per cent of normal weight bearing capacity. They used femoral necks which had a breakdown threshold above 400 Kg. and were mostly specimens from sources under 40 years of age.

The breakdown force for the intact femoral necks in the group over 60 years of age was found to average 510 Kg. (325–870 Kg.) by Hirsch and Brodetti. Half of the femoral necks in this elderly group broke below 400 Kg. For the femurs in the below 400 Kg. group the inferior cortex should support about 160 to 200 Kg. This calculation is supported by the figure of 135 Kg. found in the present study.

Compere, Wallace, and Lee found the average breaking strength of the femoral neck to be 750 Kg. (255.8–1,251.9 Kg.) in a group which included all ages and both sexes. Kolodny in similar experiments found the breaking strength to be 445–500 Kg. in women and 545–590 Kg. in men, both groups being middle-aged.

A rough appreciation of the weight-bearing strength of the inferior cortical area for the elderly age group, in which femoral neck fractures commonly occur, can be derived from these experiments if the figure of



*Figs. 5 a-c.*

*Fig. 5 a.* Specimen with superior portion of neck removed.

*Fig. 5 b.* Mounted in compression machine.

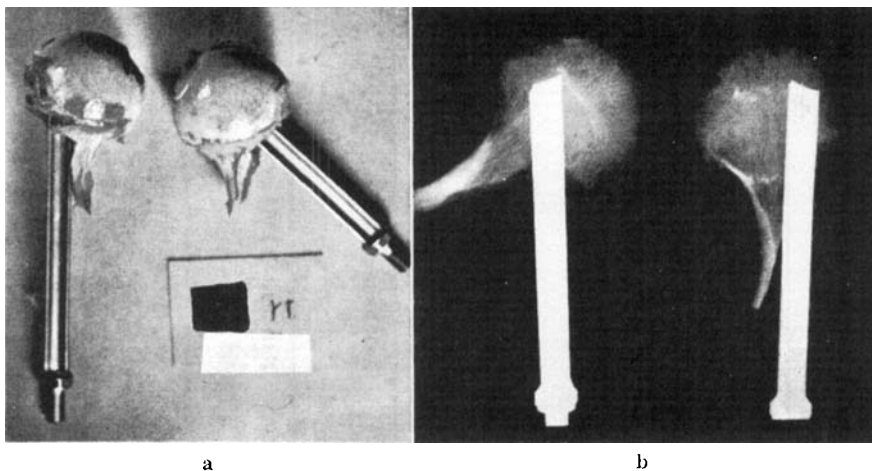
*Fig. 5 c.* After neck fracture.

500 Kg. is used as the breaking strength of the femoral neck when exposed to vertically directed force. With the average of 135 Kg. found in this experiment the inferior cortical area supplies about 30 per cent of the strength of the neck and probably varies from 25-50 per cent depending on the specimen.

It can be seen from these experiments that in making an internal fixation of a femoral neck fracture, if the inferior cortical area of the neck is depended upon for support of the nail, not more than about 30 to 40 per cent of the normal breaking strength of the intact femur will be produced.

TABLE II  
*Determination of the Strength of the Inferior Cortex of the Femoral Neck, and the Cancellous Bone of the Femoral Head.*

Specimen	Vital data	Breaking force			Comment
		Inferior cortex	High nail	Head Low nail	
10 Lt	78 yr. old F. ....	75 kg	400 kg		Nail broke at 400 kg
11 Rt	65 yr. old M. Bedridden 1 month .... Carcinoma of lung	95 kg		200 kg	
Lt		100 kg	400 kg		
12 Rt	70 yr. old F. Bedridden 3 weeks ..... Coronary occlusion	105 kg	210 kg		Nail slipped in vise, two loadings
Lt		75 kg		90 kg	
13 Rt	66 yr. old F. Bedridden 1 month .... Ileus + circulatory failure	105 kg	180 kg		Nail bent at 150 kg
Lt		145 kg		105 kg	
14 Rt	68 yr. old M. Bedridden 2 months .... Gastric carcinoma	185 kg		200 kg	Nail bent at 240 kg
Lt		220 kg	300 kg		
15 Rt	63 yr. old M. Bedridden 11 months ... Bronchopneumonia	200 kg		125 kg	Nail broke at 240 kg
Lt		175 kg	240 kg		
		Average: 135 ± 13.8 kg	288 ± 30 kg	144 ± 21.5 kg	



Figs. 6 a-b.

*Fig. 6 a.* On the right a horizontal "high" nail. On the left a "low" oblique nail.  
*Fig. 6 b.* On the right a "low" nail. Note its position on the inferior cortex of the neck still attached to the head and its course parallel to the trabeculae. On the left side the nail is horizontal. The nail crosses the trabeculae at an angle of 60 degrees.

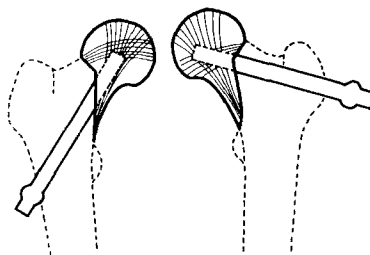
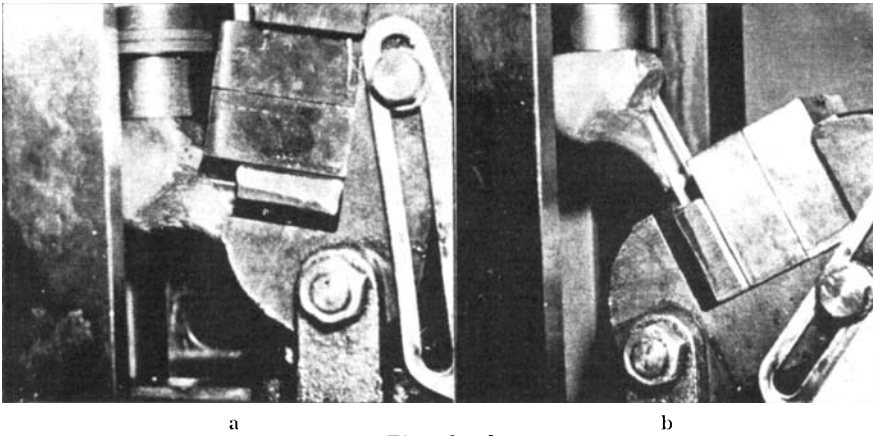


Fig. 7.

Orientation of the nail, femoral head and neck.—The heavily drawn sections of the head and neck are the parts used in the experiment.—The dotted line indicates the discarded portions of neck and shaft.—The trabecular system is indicated in a diagrammatic manner.—On the left a low orientation of the nail.—On the right a high orientation.

### *Strength of the Head.*

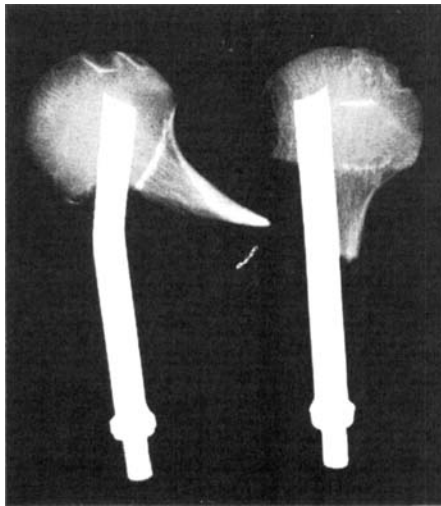
Femoral heads were taken from the femurs used in the previous experiment. A nail was introduced into the head. Two different orientations of the head and nail were used. Figs. 6, 7. In one head the nail was placed nearly parallel to the medial trabecular system, a low nail. In the head from the opposite side the nail was placed in an almost



*Figs. 8 a-b.*

*Fig. 8 a.* Femoral head with "high" nail mounted to simulate the normal anatomical position of the head.

*Fig. 8 b.* Femoral head with "low" nail mounted in anatomical position.



*Fig. 9.*

On the right a "low" nail which has moved towards the cortical shell.—The nail on the left had bent before it started to cut through the trabeculae.

horizontal direction, a high nail. The nail was then placed in the test vice in such a fashion that the head was oriented as if the shaft were vertical. Fig. 8. Pressure was then applied until the head was seen to move on the nail. In many cases the nail bent first, more so in the high

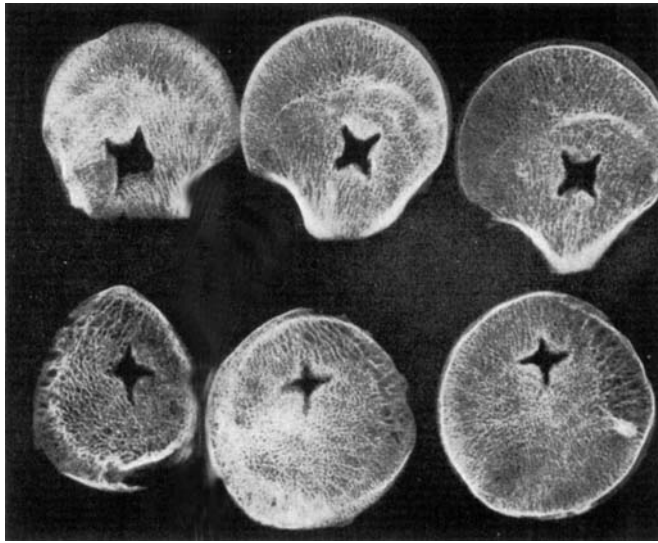


Fig. 10.

Cross sections of the femoral heads after application of force.—Above, the nail hole enlarged due to the horizontal nail cutting through. Below, the nail hole has not enlarged as the nail has cut through along its longitudinal axis.

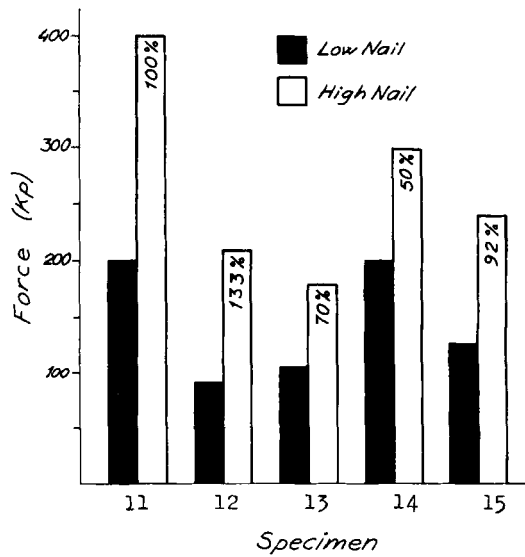


Fig. 11.

The effect of the position of the nail on the femoral head's ability to resist cutting through.

nailings. Fig. 9. The heads were removed from the nails, sectioned, and Roentgenographs taken. Figs. 10 and 11. Data are found in Table II. The high nails started to cut at 145 Kg. (90-200 Kg.).

Hardinge, using a punch to determine the strength of the cancellous femoral head found that the holding force was greatest along a tract between the medial end of the inferior cortex of the neck and the middle of the superior surface of the head. For the center of the head the holding strength was 3.4 Kg/mm<sup>2</sup> and for the peripheral portions of the head it was on an average of 2.3 Kg/mm<sup>2</sup>. Rauber reported the shearing strength of cancellous bone to be 0.6 Kg/mm<sup>2</sup> when the shearing force was acting in a direction perpendicular to the direction of the trabeculae and only 0.2 Kg/mm<sup>2</sup> when the force was acting parallel to the bone. This may explain why the head with the horizontal nail can withstand greater forces than the low nail in which the shearing force is more parallel to the trabeculae. In the horizontal nailings the force is able to act on a greater surface area and the per unit stress is less. The low nail tends to be in the portion of the head where the trabeculae are weaker. The low nail, with its sharper leading edge cuts the bone easier than the horizontal nail.

#### *Strength of the Fixation Devices.*

The metallic appliances under two types of deformation when force is placed on them; a plastic, or permanent deformation, and an elastic deformation. If the total load is small the main part of the deformation is elastic. If the load exceeds the yield limit the plastic deformation is no longer small and progressively increases with load.

Martz has determined the vertical force necessary to produce permanent deformations in various types of nail-plates. The Moore and Jewett devices tolerated 49 Kg. The Neufeld, Thorntorn, and Pugh nails withstood forces between 80 and 95 Kg. The Blount blade plate (130 degrees) was able to withstand 172 Kg.

Foster has recently performed static loading tests and calculated the strength of various types of nail-plates in terms of the bending moment causing breakage or gross permanent deformation. The bending moment causing failure for the McLaughlin nail-plate was found to be about 500 Kgcm. and to compare favorably with various other types of nail-plates.

Although the acting moment varies in the author's experiments as to the angle and length of nail or screw, it is obvious that loads as low

as 50 Kg. cause deformations big enough to affect the bone. The bending moment on the nail-plate junction resulting from the application of 50 Kg. to a 10 cm. McLaughlin nail at an angle of 140° is 322 Kgc. The calculated bending moment for the Charnley screw of 120° and 10 cm. length is 434 Kgc.

TABLE III  
*Deformations Produced by Vertical Loading of the Charnley Screw  
and the Nail-Plate.*

	Force	Angle	Comment
Charnley screw-plate	0	120°	
	50 kg	115°	
	100 kg	110°	
	115 kg	110°	
	0	110°	Permanent deformation 10°
McLaughlin nail-plate	0	140°	
	50 kg	135°	
	100 kg	134°	
	150 kg	132°	
	200 kg	130°	
	0	135°	Permanent deformation 5°

The Charnley screw was tested and found to undergo a permanent deformation of 10 degrees with 115 Kg. of force applied to the end of the screw in a vertical direction. During similar experiments with the four-flanged nail permanent deformation occurred from 125–170 Kg. depending on the angle of the nail-plate. Table III lists the deformation produced with increased loadings.

#### DISCUSSION

A summary of some of the more recent studies on the strength of femoral neck fracture fixation is given below in Table IV.

In Harmon, Baker, and Reno's study the femur is positioned with the shaft held at an angle of 50 degrees so that force is applied in a direction almost parallel to the axis of the neck. The fracture line seems to be perpendicular to the applied force and under compressive and not shearing and bending forces.

The force acting on the femoral head when the body weight is supported on one limb has been stated by Inman to be from 2.4–2.6 times

the body weight based on electromyographic studies and geometrical analysis. Pauwels and Backman have both calculated from geometrical analysis the forces acting on the femoral head on walking and find it to be in the vicinity of 4 of 5 times the body weight. It must be borne in mind that this force is not acting in a purely vertical fashion but acts in a direction that is parallel to the medial trabecular system. Pauwels and Inman calculate, however, that with an antalgic gait due to hip disease the weight is borne more vertically on the head of the femur. It must be emphasized again that these figures have been derived from calculations of the lever arm arrangement between the body weight, the head of the femur and the line of pull of the abductor muscles. No one to date has actually been able to measure the direction and amount of the forces acting on the femoral head in a living subject.

TABLE IV  
*The Experimental Breakdown Strength of Various Osteosyntheses.*

Author	Fixation device	Breaking force
Compere, Wallace & Lee	Smith-Petersen nail	157.8 kg
	Three Steinman pins	168.7 kg
	Three Compere wires	206.4 kg
Harmon, Baker & Reno	Smith-Petersen nail	362 kg
	Lorenzo screw	340 kg
	Lipman bolt	318 kg
	Two Vitallium screws	227 kg
	Five Compere wires	164 kg
Martz	Smith-Petersen nail	159 kg
Frankel	McLaughlin nail-plate	200 ± 30 kg
	Charnley screw-plate	163 ± 14.0 kg

If these studies are accepted a hypothesis can be drawn that for a 60 Kg. elderly man, the force exerted on the head of the femur would be about 300 Kg. when he walks. From the results of experimental fracturing of the neck of the femur Backman has concluded that the safety factor is on the order of five; that is, five times the force present on weight-bearing is necessary to fracture the neck when the force acts in a direction parallel to the medial trabecular system. The forces necessary to fracture a femur when the force has been applied in a vertical direction have been found to be less.

According to Martz, any nail or screw subjected to repeated stress should be twice as strong as the breaking strength of the appliance when

subjected to a single loading. Furthermore, if the factors of corrosion fatigue are taken into account the safety factor must be much higher. For a safety factor of two, the metallic appliance should be able to tolerate five times the body weight before bending if standing on one limb is allowed, and at least 10 times the body weight for walking. For a sixty Kg. man this would be at least 300 and 600 Kg. respectively.

It is possible from the data observed in this experiment to calculate the relative strengths of the various components of the osteosynthesis without knowing exactly the magnitude and direction of the forces acting on the hip joint normally as all the experiments were conducted with the same direction of force, i.e. parallel to the shaft of the femur.

As far as the initial strength of the osteosynthesis is concerned the limiting factor seems to be the head of the femur as it can stand the most force of the osseous elements in the head and neck. This is particularly so if the nail is introduced in a horizontal direction. The inferior cortex of the neck is the next strongest element in the system and can stand the nail pressing against it until the force exceeds 135 Kg. The nails and screws tested so far have proven to be the weak links. When force is put on the head of the femur it is transferred to the nail or screw. The nail or screw gives some support initially but at forces of about 50 Kg. they start to bend both along the course of the nail or screw and at the junction of the nail or screw with the plate. This bend allows the nail or screw to come into contact with the inferior cortical area of the neck. The inferior cortical area begins to carry the force and succeeds in doing so until it fractures. If the nail and screw plates were absolutely stiff under these conditions, force would be transmitted to the shaft of the femur bypassing the inferior cortex as a weight bearing element. From these observations it is seen that the inferior cortex is the limiting factor in this series of experiments. It can be postulated from the experiments on the isolated head that if a powerful nail-plate were used the strength of the trabeculae of the head would be the limiting factor as they have been found capable of carrying up to 400 Kg. of force before the nail starts to cut through.

From the data observed in this experiment calculation may be made of the per cent of normal strength the osteosynthesis appliance provides. If the figure of 500 Kg. is taken as the average force necessary to break the neck of the femur when loaded vertically, the Charnley screw produces 30 per cent of normal strength and the McLaughlin four-flanged vitallium nail plate provides about 40 per cent. This is the same percentage that the inferior cortical area of the neck provides and makes

the strength of the inferior cortex the determining factor with these appliances.

Compere, Wallace, and Lee give figures for the average fracture force for the femoral head and for the average breakdown force for the osteosynthesis thus allowing calculations to be made of the per cent of the normal strength the osteosynthesis provides. For the Smith-Petersen nail it is 23 per cent, for the Steinman pins 21 per cent and for threaded wires it is 27 per cent.

A word might be added about the mechanism of breakdown of screws and nails without sidebars. In addition to a possible bending in the nail as a cause for breakdown, the distal end of the nail is held by a thin cortical shell at or below the greater trochanter and movement of the nail with reference to the long axis of the femur may take place decreasing the angle between the nail and shaft. Even the nail-plate bends at its junction. Similar mechanisms have been discussed by Dickson, Putti, and Eaton.

The nail-plate and screw-plate tested in this experiment do not approach the ideal strength suggested by Martz. It is the author's belief that to take full advantage of the strengths and weaknesses of the proximal end of the femur, within the limits of current knowledge, a nail-plate or screw-plate should be constructed of such design and material that after a fracture is fixed the force borne on the head of the femur would be transmitted to the nail and the nail would transmit the force to the side bar without appreciable bending movement, the side bar would transmit the force to the shaft of the femur via strong bone screws.

#### SUMMARY

1. An analysis of the initial strength of internal fixation of the neck of the femur has been performed using specimens in the elderly age group.

2. The various components of the osteosynthesis system have been isolated and the average breaking strength on exposure to a vertical load determined.

The breakdown force for a medial fracture fixed with a Charnley apparatus averages 165 Kg. (100-260 Kg.). The breakdown force of the femurs fixed with the McLaughlin nail-plate was 200 Kg. (50-360 Kg.).

The inferior cortical area of the femoral neck can support about 135 Kg. (75-220 Kg.).

The Charnley screw plate starts to bend with 50 Kg. of force and undergoes permanent deformation at 115 Kg.

The McLaughlin nail-plate starts to bend with forces of the magnitude of 50 Kg. and deforms permanently at forces between 125 and 175 Kg.

The cancellous tissue of the femoral head will resist the nail cutting through until 290 Kg. (180–400 Kg.) are applied with the nail nearly horizontal, or until 145 Kg. (90–200 Kg.) are applied with an oblique nail.

3. The head of the femur is the strongest element isolated in the proximal end of the femur as far as supporting osteosynthesis material is concerned. The nail and screw-plates tested were the weakest elements and deformed under relatively low forces. The cortex of the femoral shaft is a strong part of the system.

It is postulated that the ideal nail should be strong enough to receive the force from the femoral head and transmit it to the shaft of the femur without undergoing deformation and resting on the inferior cortex.

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The author wishes to thank Prof. C. Hirsch for his helpful suggestions and criticism.

#### RESUME

1. Une analyse de la force initiale de la fixation interne du col du fémur a été pratiquée en se basant sur les spécimens du groupe des malades âgés.

2. Les différents facteurs du système de l'ostéosynthèse ont été isolés et la force moyenne de rupture a été déterminée en exposant à une charge verticale.

La force de rupture d'une fracture médiale fixée par un appareil Charnley s'est établie en moyenne à 165 kg (100–260 kg), la force de rupture du fémur fixé par la plaque cloutée McLaughlin était de 200 kg (50–360 kg).

La surface cartilagineuse inférieure du col du fémur peut supporter environ 135 kg (75–220 kg).

La plaque vissée Charnley commence par se courber à 50 kg de force et subit une déformation permanente à 115 kg.

La plaque cloutée McLaughlin commence à se courber à des forces d'une magnitude de 50 kg et se déforme d'une manière permanente à des forces entre 125 et 175 kg.

Le tissu cartilagineux de la tête fémorale résiste à la perforation du clou jusqu'à ce qu'une charge de 290 kg (180–400 kg) soit appliquée

avec le clou presque horizontal ou jusqu'à 145 kg (90–200 kg) appliquée avec un clou oblique.

3. La tête du fémur est l'élément le plus fort isolé dans l'extrémité proximale du fémur en ce qui concerne le matériau supportant l'ostéosynthèse. Les plaques cloutées et vissées mises à l'épreuve sont les éléments les plus faibles et se déforment sous des forces relativement faibles. Le cortex du corps fémoral est une partie forte du système.

Il est établi que le clou idéal doit être assez fort pour recevoir la force de la tête fémorale et la transmettre au corps fémoral sans subir de déformation et sans reposer sur le cortex inférieur.

#### ZUSAMMENFASSUNG

1. Ein Analyse der ursprünglichen Stärke der inneren Fixation des Femurhalses wurde ausgeführt indem man Proben von älteren Patienten verwendete.

2. Die verschiedenen Komponenten des osteosynthetischen Systems wurden isoliert und die durchschnittliche Bruchstärke bei vertikaler Belastung wurde bestimmt.

Die durchschnittliche Kraft, welche nötig war um einen medialen, mittels Charnleys Apparat fixierten Bruch niederzubrechen betrug 165 Kg (100–260 Kg). Die Kraft, benötigt zur Niederbrechung eines mittels McLaughlins Nagelplatte fixierten Femurs, war 200 Kg (50–360 Kg).

Die untere Corticalis des Femurhalses kann ungefähr 135 Kg (75–220 Kg) abstützen.

Charnleys Schraubenplatte beginnt sich bei einer Kraftanwendung von 50 Kg zu beugen und wird bei 115 Kg dauernd deformiert.

McLaughlins Nagelplatte beginnt sich bei einer Kraftanwendung von 50 Kg zu beugen und wird bei Kräften zwischen 125–175 Kg dauernd deformiert.

Das Markgewebe des Schenkelkopfes widersteht dem Durchschneiden des Nagels bis zur Anwendung von 290 Kg (180–400 Kg) bei nahezu horizontalem Nagel oder bis zur Anwendung von 145 Kg (90–200 Kg) bei schrägem Nagel.

3. Der Schenkelkopf ist im Zusammenhang mit dem unterstützenden Osteosynthesematerial das stärkste Element im proximalen Femurende. Der Nagel und die Schraubenplatten waren die schwächsten Bestandteile und wurden bei verhältnismässig schwachen Kräften deformiert. Die Corticalis des Femurhalses ist ein widerstandsfähiger Teil des Systemes.

Die Forderung für einen idealen Nagel würde daher sein, dass er stark genug ist um die Kraft vom Schenkelhals auf den Schenkelkopf zu übermitteln ohne Deformierung zu erleiden und auf der unteren Corticalis zu ruhen.

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