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# THE UNSOLVED FRACTURE[1]

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BEFORE this body of surgeons, bound by clinical ties, the selection of a talk on fractures should cover a practical subject which might suddenly be of interest to any one of us. The unsolved fracture is chosen for discussion because it is the major peripheral fracture of our skeleton; and because for more than a century its treatment and the results have been a matter of controversy and inquiry among surgeons; and because, although the results obtained today show improvement, they are not at all comparable to those of other fractures. The progress in the investigation of fracture of the neck of the femur has been along many lines which can merely be mentioned here without discussion of their details. The collection of studies and statistics gradually increases in our surgical literature, reports for the most part being based on observations and research in anatomy, physiology, pathology, roentgenology and treatment, including end-results. Appended to this paper is a list of recent articles.

One hundred years ago the difficulties in treatment of this fracture, which was recognized as of major importance and had already invoked years of study, were discussed by Sir Astley Cooper in his work on "Dislocations and Fractures of the Joints." He said in part: "In the examinations which I have made of transverse fractures of the cervix femoris, entirely within the capsular ligament, I have only met with one in which a bony union had taken place or which did not admit of a motion of one bone upon the other. . . . I believe the reason that fractures of the neck of the thigh bone do not unite is that the ligamentous sheath and periosteum of the neck of the bone are torn through, that the bones are consequently drawn asunder by the muscles, and that there is a want of nourishment of the head of the bone, but I can readily believe, if a fracture should happen without the reflected ligament being torn, that as the nutrition would continue, the bone might unite, but the character of the accident would differ; the nature of the injury could scarcely be discerned, and the patient's bones would unite with little attention on the part of the surgeon."

In 1834, there were claimed to exist 19 specimens of healed fracture of the neck of the femur in the various museums of the whole of Europe, including the 3 of Malgaigne at the DuPuytren museum and Tilanus' 3 at the Hospital of St. Peter at Amsterdam. Hamilton was inclined to doubt the authenticity of some of these specimens and believed that many of them were the results of old rachitic or other deformities. Some of these doubts were later sustained by Basset and aired in his monograph. It was further stated by Hamilton before 1880 that the number of specimens to be found in American museums was probably as great as all those in Europe and he advised that treatment "ought to be directed to the retention of the bone in place, by suitable mechanical means for a length of time sufficient to insure bony union, or for so long a time as the condition of the patient will warrant." He employed a long side splint with extension of 10 pounds applied by adhesive tape to prevent eversion of the limb, but failed to employ any abduction.

Anatomical study of the neck of the femur has been directed along the lines of the architecture of the lamellar construction of the head and neck in relation to the trochanteric portion of the bone in weight bearing axis to obtain a more or less diagrammatic viewpoint of how the angulated neck carried the superimposed body and yet permitted freedom of motions in the hip joint. The internal arrangement of the bone is found to conform to the requirements of these two purposes and to fit in with the general supporting trabecular scheme of the pelvis as carried up to the spine. Another most important point has been an acceptance of the idea that the blood supply of the head and neck comes from 3 sources: (1) through the ligamentum teres, the arteries

[1] Fracture Oration, presented before the Clinical Congress of the American College of Surgeons, Boston, October 15–19, 1934

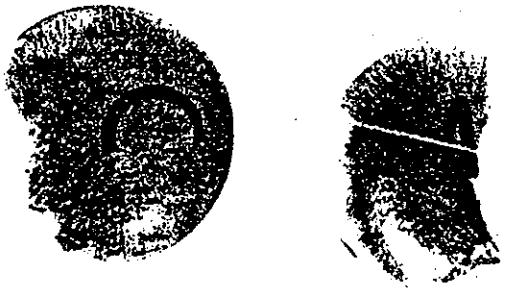


Fig. 1. Head removed November 14, 1931, 13 months after fracture with non-union. The dark areas show bone of original density as of the time of accident, now aseptically necrotic. The lighter areas represent efforts at bone replacement and revascularization. The cartilaginous rim seems quite intact without pleating. On the neck surface is found bone absorption and wearing away of osseous structure. The finer details and microscopic findings have been given in other articles.

Fig. 2. A postmortem specimen removed 4 months after fracture treated in the conventional manner. Impaction and apposition of fragments was evidently obtained with slight rotation of the head, but very little evidence in the gross specimen of any mal-position. The main portion of the head seems alive, with some lighter areas around the rim, as of bone replacement, but no true bony union has occurred and no effort at new bone formation has started from the trochanteric fragment. The angulation of the trabecular lines at the fracture plane and the loss of density in the trochanteric portion of the bone are apparent. The specimen does not show definite bone replacement as starting from the vessels entering via the fovea which may have been occluded or of minor caliber, yet the head is not dead *en masse*. No weight bearing had ever been permitted so that factor of pressure is eliminated. Note the intact cartilage. Non-union to a live head.

of which are shown by Chandler and Kreuscher to be present in nearly all individuals; (2) the periosteal vessels; and (3) capsular branches of the anterior and posterior cervical arteries. We have also come to believe that there is some extension of blood vessels through the epiphyseal plane into the head from the superior nutrient artery.

Physiological investigation has been directed toward the changes in this part of the bone during adolescence and senility and their relation to bone repair after fracture. Study of sections of the femur confirming old observations demonstrate that in senility the canal openings in the bone enlarge in diameter especially in the neck where the cortical shell of bone is the thinnest, but contrary to previous understanding according to Radasch, the

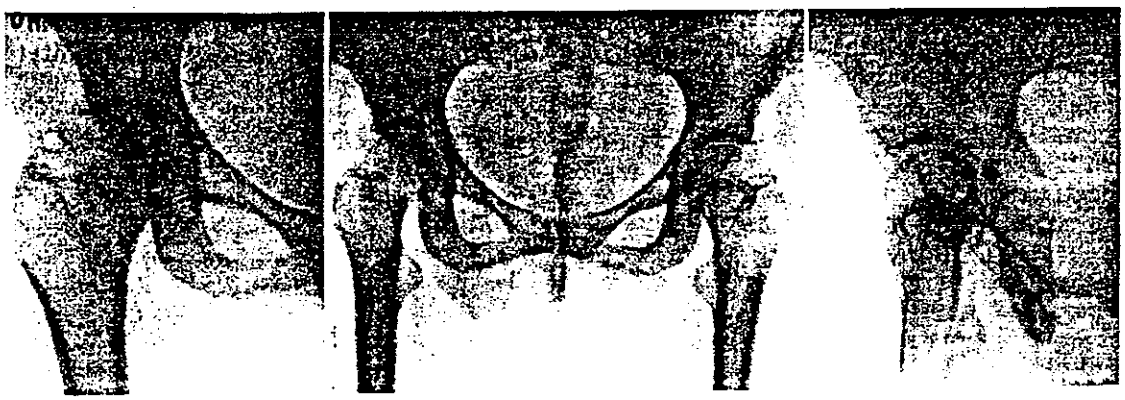
Fig. 3. Left figure, reduced fracture of neck in a large, heavy woman, 73 years old, in the conventional position and plaster dressing, May 2, 1932. The head appears viable. Right figure, same hip May 17, 1933. The patient had 18 weeks in plaster, then wore a walking caliper for 7 months. The head still seems viable and the union at the neck holding. She was continued on the caliper 3 additional months and now has satisfactory functional use of the joint with no further bony changes. Union to a live head.

amount of organic material in the bone slightly increases in ages from 60 to 90 years. The average adult has 39 to 40 per cent of organic material in his femur, whereas in advanced age, a proportion as high as 42 per cent is maintained. The cause of fragility in old bones cannot then be ascribed to their loss of organic material with resulting change in the elasticity required for resistance to stress, but must lie in the change in porosity and thinning of the bony wall, which overbalances any gain of organic material. Although repair by callus after fracture will be attempted in this senile bone, the effort must represent a distortion of ordinary healing, inasmuch as the regressive changes incidental to age still go on and two conflicting processes are at work.

No accepted evidence has been offered of the exact physiological nature of the changes affecting the epiphyseal area before the occurrence of separation of the epiphysis in adolescents to prove that it is directly based on local or constitutional disease. Many instances occur in fat youths, but no definite relationship between thyroid, hypophysis, or other endocrine disturbance accounts for all cases. Some have shown pre-separation changes, betrayed by a luckily made X-ray examination; or symptoms of slight pain or lameness have existed prior to separation. Mild trauma or muscular action can be traced in the final cause of nearly every one.

Fig. 4. Hip of a young man 8 years after traumatic epiphyseal separation at the neck of the femur, replaced accurately, immobilized 16 weeks, and supported with a walking caliper 10 months. He had grown 8 inches in height following the separation, with 1¼ inches shortening in the injured leg; very good final painless function; range of motion in joint restricted about 50 per cent. The head has broken down with flattening and abundant new bone has formed in the neck. Union to a head undergoing late aseptic necrosis with deformity and joint changes involving the acetabular surface.

A glimpse at the reported investigations of local pathology betrays the great interest in this phase of the fracture. Most important have been the findings in the hips of patients on whom operation was performed and the relatively scant postmortem material obtainable. The amount of tear in the capsule of the joint—rarely complete,—the character of the fracture plane, and especially its reduction and the rapid loss of bone substance in unimmobilized or reduced cases has been watched.



a. b. c.

Fig. 5. a, Impacted fracture of left neck before reduction in a heavy woman 55 years old. Manipulative reduction 5 days later, on February 11, 1933. She had walked on the fracture several days and had considerable pain. Head seems viable and somewhat rotated. b, Same, both hips May 18, 1933, after conventional 18 weeks in plaster. Head appears viable and firmly united. One year later walks very well, slight pain but no change in roentgenological findings. c, Lateral view this hip June 26, 1933. There appears to be every evidence of fair position of the head and bony union to a live head. Had been walking on caliper more than a month.

Fig. 6. Heavy male, 40 years old, 6 months after an attempted fixation of neck fracture. The trochanteric portion of the bone was pushed up by weight bearing on an unrecognized fracture and lay completely posterior to the head. Operation for bone graft into the head was planned and started. Difficulties in freeing the trochanteric fragment and hæmorrhage led to shock and abandonment of operation when only a side-to-side contact had been obtained. This film represents the condition 2 months after removal from plaster and after weight bearing in a walking caliper. He has no pain, a fair range of motion, and no change in position. Apparently a union by lateral contact only, without proper apposition to a viable head.

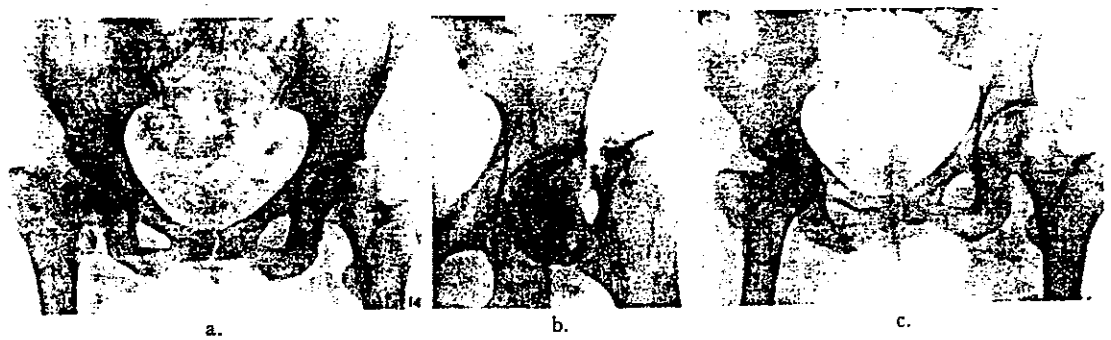
The principal points of interest have been in the behavior of the head of the bone after fracture, the changes developing in it or its covering cartilage resulting in interference with blood supply, aseptic necrosis, revascularization and substitution for dead bone by newly formed bone. Studies have also been made of resulting changes in cartilage of the head of the femur and the acetabulum, involving slowly progressing loss or deformity of cartilage over areas of dead bone, with replacement by bone from the subchondral areas, or complete collapse depending on the length of time or the amount of unwise weight bearing permitted after fracture. Observation of patients over long periods of time coupled with roentgenological investigation has advanced our ideas of prognosis and treatment and supplemented the information gained in other branches of the study. The fate of the head separated from the neck, or attached to it in proper approximation can be followed and foretold largely by its complete or partial change of density as compared to neighboring bone. This information, however, still leaves something to be learned about the fracture. One cannot say in the early weeks after fracture, even in an average adult or adolescent to say nothing of a senile person, whether the head in a given case will die and yet unite to the neck, or live and unite and later break down to flatten and slowly disintegrate, after hope had been advanced of a perfect restoration. It is this great uncertainty of the fate of the head and its subsequent mechanical changes which hold this fracture in the unsolved class.

From the studies of Santos, Phemister, myself, and others, it is known that 4 general results are to be obtained—a dead head with no union, or a real union (which is rare), a live head with no union, or a non-union (which is far from uncommon). In his recent report Phemister states that he has seen 49 patients at varying periods after fracture, following different methods of treatment, of whom 17 had heads which were alive, 8 with union, 9 with non-union. There were 32 cases of complete or partial necrosis of the head with union present in 4 and non-union in 28.

Pleat formation and other cartilage changes incidental to disease as described by Freund are not found after fracture, but replacement of cartilage and finally pannus formation with adherence of the head fragment in the acetabulum are seen. True ankylosis of the hip joint has been found after a healing of the neck of the femur.

Roentgenological investigation has covered a study both of the patient's bone *in situ* and of the specimens removed, coupled with the summary of the pathology and histology present. The most recent X-ray advance has also done much from the popular standpoint to influence treatment.

Every surgeon should know, however, that not only the amount of union between head and neck can be shown on the X-ray film, but that even more important information can be conveyed. The film must show both hip joints and the adjoining parts of the pelvis. The amount of regional atrophy about the fracture, a natural sequence of the injury and loss of activity, the changes in the head showing by retained original density or by mottling whether the head is entirely or partly dead or is undergoing bony replacement, along with changes in configuration indicating flattening or collapse or cartilage changes may all be read from one film. The future of the fracture from the standpoint of union to live or dead



a. b. c.

Fig. 7. a, A 57 year old woman with fracture of neck of the femur in a limb the site of an old infantile paralysis. Manipulative reduction attempted 3 weeks after accident followed by the conventional period in plaster. Only fair apposition was obtained. b, Same hip 8 months later. After removal from plaster, had been walking in caliper with very little weight bearing. Non-union to dead head betrayed by the relative densities of the bone fragments. c, Same patient after a Whitman reconstruction operation had been performed. A fair functional result was obtained in this patient considering the defect in the leg from a former paralysis.

head, or a hopeless outlook which might be bettered by operative procedure of fixation or reconstruction, can be thus exposed in a series of films taken at intervals after treatment is started.

Rigorous analysis of films and results obtained by reduction or operations and careful clinical examination after months of supposed perfect reduction lead to the development of roentgenological technique for lateral views of the head and neck of the bone. The surprising result was that there had been as high a percentage of functional use and slight disability as had been found in the average case because glaring deficiencies in angulation or approximation of bony surfaces were exposed. However, union was found in some instances in which complete or perfect approximation had not obtained—a condition known to exist in many fractures throughout the body.

An understanding of my title lies in a review of the care of this fracture, the mechanical treatment of which was put on a rational basis by Royal Whitman 45 years ago. His suggestions have only slowly been adopted by the surgical world, more rapidly in Germany than in France and England. In the United States every effort has been made to teach the basic points in the last generation, but there is still woeful lack of application of the principles laid down by him. Traction on the leg, inversion followed by abduction, are not universally used, partly because of lack of interest among many men handling these fractures and partly because these same men, including many surgeons who receive patients with this fracture, do not know how to apply a comfortable, lasting, and serviceable plaste rdressing with the patient in the position of reduction. There is no excuse for this lack of treatment ability since, through Hawley's ingenuity, we have been given the fracture table. For that matter, a proper plaster-of-Paris dressing may be applied by use of a simple padded perineal post on the edge of a table with the patient lying on an inverted bowl as was done 30 years ago.

Failing, on account of some of the points mentioned in preceding paragraphs or for other unknown reasons, to get union in a satisfactory percentage of instances, surgeons turned to operative attempts to force the fracture to heal or to remove the head as advised by Sir Robert Jones. In 1902, Murphy began nailing on the heads of femora. Delbet perfected his screw and hip guide a few years later and there has followed a series of different operative attempts, some with, some without, opening the hip joint, all aiming at close and exact lasting approximation of head onto neck. Ivory and bone transplants into the head via the trochanters, nails, special screws, the Smith-Petersen flanged nail, and lately nails or screws applied along guide wires inserted through the trochanteric portion of the bone under fluoroscopic guidance—devised by Sven Johannson, Jerusalem, and others—are all being tried. Hillebrand has reported

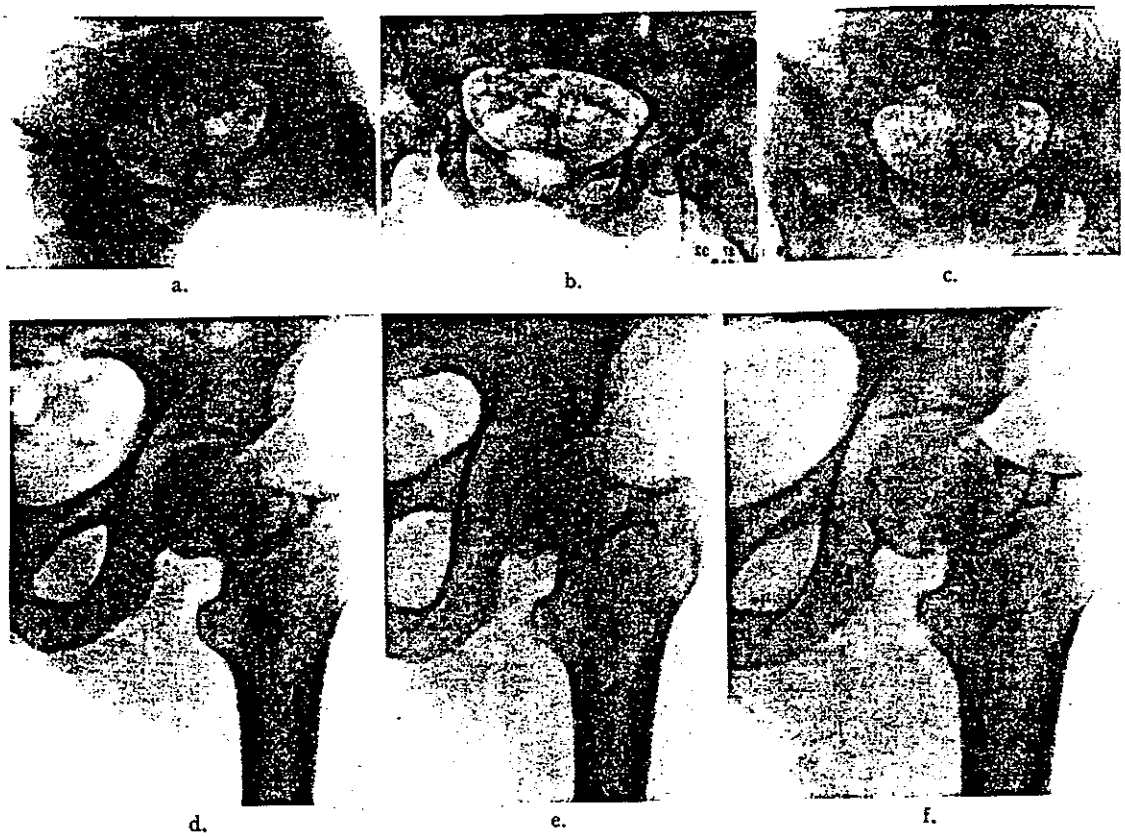


Fig. 8. a, Fracture of neck in a 35 year old woman. Seen, reduced, and put in plaster within 2 hours after accident, December 10, 1931. b, Same patient, both hips in plaster December 27, 1931. Replacement, apposition, angle of neck, all seem good. c, Same hips April 11, 1932, just out of immobilization. Apparently good union to live head. d, Same fractured hip June 6, 1932. Union good and head viable but neck seems to bend a trifle. Has never borne any unsupported weight, worn caliper constantly. e, Same hip September 1, 1932. Evidence of bone absorption upper edge of neck. Head outline good, union persists. f, Same hip November 1, 1932. Head mottled a little as if bony replacement were going on in it. Neck a little depressed with evidence of absorption spots upper edge. g, (See opposite page.) Same patient, both hips, December 1, 1932. Has constantly worn caliper and not returned to work. Head fragment definitely depressed and denser than that of other femur. Outline slightly oval.

favorably on the Hotz-Richard method of nailing through neck of the femur into the head and on into the pelvis. For delayed union Hey-Groves advises taking the head out and bolting it on by a bone peg before reinsertion in the hip joint, violating one of the sacred sources of blood supply to the head via the ligamentum teres.

Manipulative reduction with subsequent plaster-of-Paris dressing has held the most adherents and has shown, in statistical review of well handled series of cases by such men as Stern, Henderson, Campbell, and others, good results in from 60 to 70 per cent of the cases. Cotton has amplified manipulative reduction by artificial impaction to drive the fracture surfaces together with a hammer, striking on the trochanteric area in the axis of the neck after approximation of fractured surfaces. In spite of these methods of treatment, the percentage of unions with retention of live heads in patients surviving, taking all ages into consideration, does not satisfy. Darrach and Stimson, in a series of their cases found by checking with lateral roentgenograms a high percentage of inaccurate appositions which they feel may explain an unsatisfactory percentage of bony unions heretofore obtained.

Union to a live or dead head does not always follow the quite exact approximation which

g. h. i.

j. k.

Fig. 8, *continued*. h, Same hips March 1, 1933. Increasing depression of head and neck, with mottling; union still present. i, Same hips September 1, 1933. Head has increasing density and is flattened. Union persists. Caliper removed as patient refuses to wear it longer. Cannot work and walks with limp but has no pain. j, Same hips December 4, 1933. Neck flattened down to a right angle. Considerable restriction of motion in hip joint with definite shortening of leg. k, Same hips September 17, 1934, with further progression in neck and head flattening, fragmentation of head, increased density and dead head. Union still seems present. Pain and disability continue; patient persuaded to resume caliper again. Were changes in head due solely to vascular failure or to pressure reaction? The early prognosis of the fracture this patient suffered had been good, that is, as of union to a live head, but the life history of the fracture in 3 years has proved to be just the reverse.

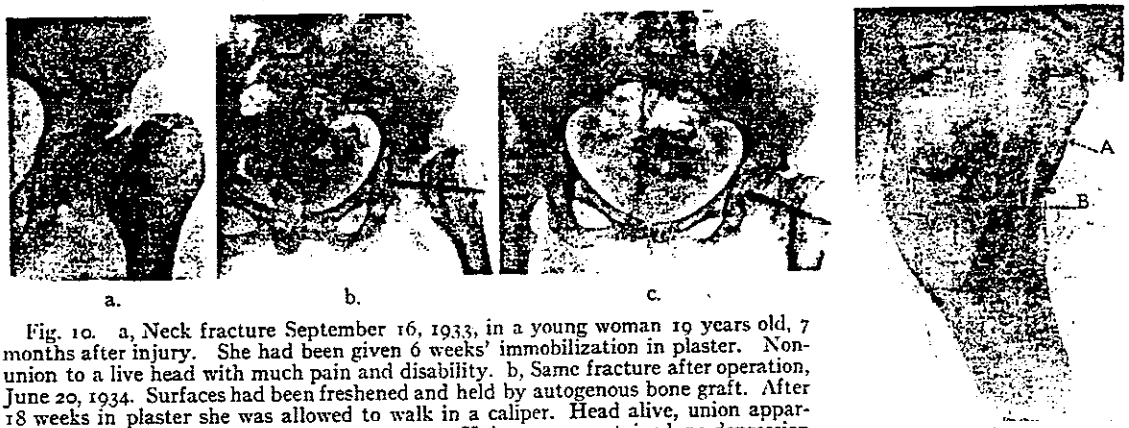
must be aimed at in every case, whether obtained by manipulative, artificially impacted or operative means. When the head gives warning that it is to die, becoming aseptically necrotic in part or completely, one cannot wonder at failure of union, no matter how exact is reposition. In some individuals the trauma of fracture, the loss of or even temporary interference with blood supply add weight to the destructive processes already set up in senile bone, upsetting its physiological equilibrium and leading to its necrosis with subsequent absorption when the patient survives. It would be expected that these factors would not affect the proper healing of adolescent bones which are still in bone-building health with senile changes not expected. Yet some instances of this fracture in relatively young individuals lead to dead head and nonunion; in the adolescent, death and degeneration of the head—in appearance strikingly similar to Legg-Perthes' disease—may come on months after an apparent bony healing of epiphyseal separation. These changes have occurred when apposition of fracture surfaces has been most satisfactory; they are evidently either an expression of further progress of the unknown pathological changes present in the epiphysis before the separation, possibly leading to changes comparable to those of senility, or of too early functional use of the newly healed bone.

Weight bearing or pressure which exists on the head of the bone from the very moment of reduction, or continues on the active process of attempted bone healing, is the one factor which seems understandable as leading to delayed non-union, aseptic necrosis of the head, and deformity of the hip with joint changes. If we concede that it is largely pressure which causes absorption of the neck after untreated fracture, a similar pressure may act untowardly after reduction with Whitman's method by too early display of force against the capital portion of the bone as yet unable to withstand it, on account of internal vascular changes. It

a.

Fig. 9. a, Recent fracture of neck, July 19, 1928, in a 53 year old woman. This occurred during an attack of sleeping sickness; exact date was concealed by attendants as she may have been allowed to fall out of bed. Head appeared viable compared to the other femur. b, Same hip, December 5, 1928. Operative reduction was performed, the edges of the two fragments cut back with a chisel, and surfaces fitted together in exact apposition under the eye. Eighteen weeks in plaster followed, then walking in a caliper. c, Same hip, February 3, 1929. Head appears viable and union firm. Joint space seems narrowed but function very good. d, Same hip, January 9, 1932, at least 3½ years after fracture. Solid unyielding union to live head. If a bone transplant, screw, or device other than simple replacement after freshening had been employed, credit for final union and live head might have been given the internal splint. This case makes one doubt the necessity and possibly the value of any mechanical internal fixation.

b. c. d.




a. b. c. d.

Fig. 10. a, Neck fracture September 16, 1933, in a young woman 19 years old, 7 months after injury. She had been given 6 weeks' immobilization in plaster. Nonunion to a live head with much pain and disability. b, Same fracture after operation, June 20, 1934. Surfaces had been freshened and held by autogenous bone graft. After 18 weeks in plaster she was allowed to walk in a caliper. Head alive, union apparently promised. c, Same neck, August 24, 1934. Union seems sustained, no depression of neck, head viable, bony trabeculæ developing across fracture plane. Still wearing caliper. Prognosis very good. d, Lateral view of the preceding figure same date, August 24, 1934. *A* indicates healed fracture plane and *B* the imbedded transplant.

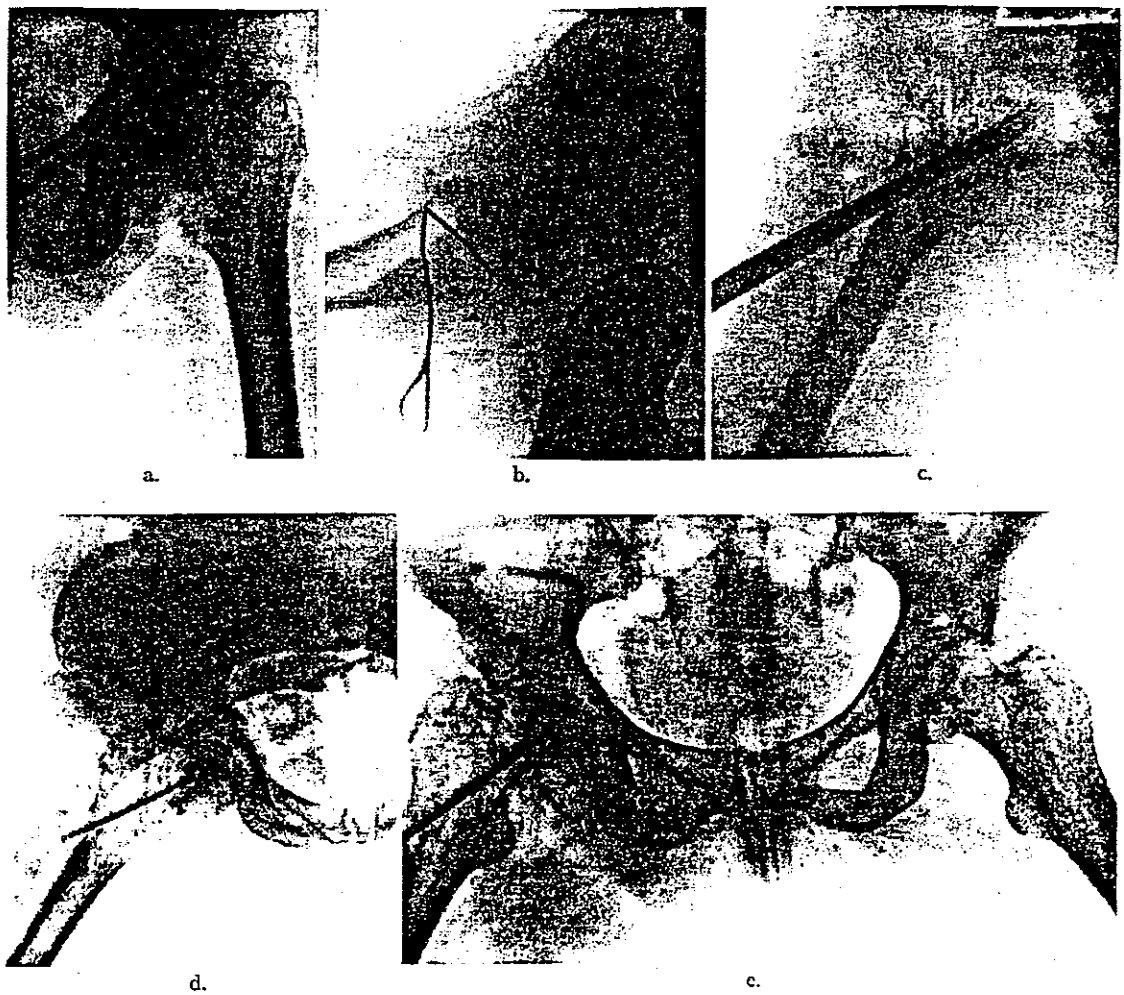
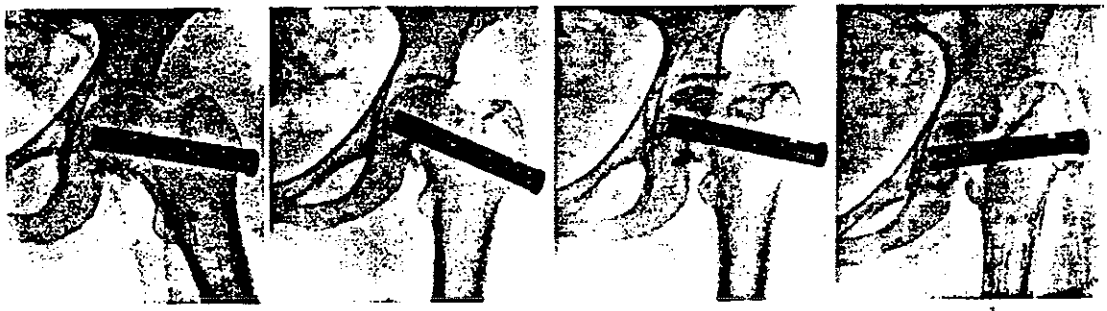


Fig. 11. a, Fracture of neck 5 months old in a heavy woman of 49 years, May 12, 1934. She refused offers to be put in plaster with reduction in January, 1934. Non-union, pain, never been out of bed. Viability of head questionable. b, On operating table May 25, 1934. Through a small anterior incision hip joint opened, fracture site exposed and freshened, reduction and abduction. End of a small flexible probe introduced between fracture surfaces as guide to drill for hole to carry transplant. c, Same date as preceding, still on Hawley table. Using probe as guide, the drill has been inserted below the greater trochanter and advanced across the fracture plane, striking the probe, to enter the head fragment which can be seen and felt to move impaled on the end of the drill. d, Same date after operation, encased in plaster of Paris. Bone transplant taken from the tibial cortex (which seems very thin here, probably on account of the preceding 5 months in bed) has been thrust into the head along the drill tract. Position satisfactory. e, September 25, 1934. Just out of plaster after 18 weeks. Position same as at operation, head a little mottled, union seems started at least, as there is evidence of callus at fracture plane. Was this all due to the implantation of the bone? Will the head retain vitality or will it go on to a complete replacement, and for how many months or years must weight bearing be guarded?

is also possible that too early or too great pressure, as from unguarded weight bearing in walking, interferes with the long period of time required for the return of the bony lamellæ to their full maturity—a time varying with different individuals—and leads to a reversal of the healing process and an absorption with necrosis of the bone. Some of these changes are irreplaceable either by time or method of treatment, including greatly prolonged freedom from weight bearing, but not from active motion, which is no doubt beneficial.

Fig. 12. Left, 2 years after fixation of recent neck fracture in an elderly woman, patient of Dr. Hugh McKenna. Union to a live head seems present. Right, 4 years later. Union has held, head has broken down and flattened. Cartilage collapsed, bone transplant still unabsorbed, but welded to rest of femur. Did transplant cause original union? Did it interfere with circulation in the head, coming from the ligamentum teres? Did the head die and fragment on account of weight bearing after several years?



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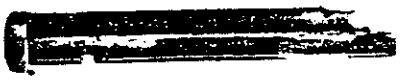

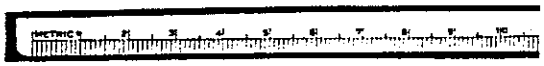

e.

Fig. 13. a, Repair of fracture of neck in a woman 53 years old, by means of the Smith-Petersen nail. The fracture occurred August 21, 1932; nail was inserted August 24, 1932. From the service of Dr. Phemister at the University of Chicago Clinics. b, Same patient. This film taken when plaster was removed on October 26, 1932. Apposition, angle of neck and penetration of nail all very good. Head appears slightly denser than surrounding bone with well-rounded outline and not spotty. Prognosis good. c, Same hip February 17, 1933. Patient had never worn a caliper but had used crutches and not borne full weight. Much pain. The head appears aseptically necrotic in upper portion; some effort at bone replacement in the lower half which is of less density. Union, however, has not been obtained. The trochanteric portion of the bone has slipped up, the neck is depressed and the nail, strange to say, shows evidence of absorption in a notch-like area near its head and a little roughening at its extremity. It maintains its long axis but one wonders whether or not the head of the femur may not have rotated on it. This is nearly 6 months after operation. d, The same hip May 2, 1934. Further dead head and absorption of neck. Increased absorption of the nail, elevation of the trochanter, non-union to a dead head. e, Nail removed from patient. Its absorption and partial disappearance affect its stability as a fixation agent to a certain extent. If the circulation in the head has been so poor that death of it resulted, was change in nail caused solely by mechanical stress, or by action of cells or chemical agents in blood serum? Lowering of blood supply after fracture in the head in living human may not be so great as we suspect.

The average percentage of union is probably higher than it was 100 years ago, but in comparison to practically all others this fracture remains unsolved. Our organization might advantageously provide for a corps study of this lagging fracture. Such a study should lead to the adoption of a more or less orthodox line of care for the recent fracture, consisting of gentle reduction by traction, inversion and adjustment of the trochanteric portion of the femur to fit its displacement, followed by abduction to the degree indicated in the pre-reductive roentgenogram as necessary to restore the angle of the neck and coaptation of fractured surfaces. This reduction would be maintained by immobilization in plaster of Paris. Such a method would be practiced by most surgeons. A few might prefer to treat their patients by operation very soon after fracture, employing selected methods in an attempt to minimize the period of immobilization and to avoid feared complications. All methods should be subject to proper X-ray control for position and progress of healing. The convalescent period must be guarded by adequate support of the fracture plane not only during the healing and re-forming of the bone of the neck but also during the first months after release from immobilization when weight bearing is begun. At the present time there is no guarantee of 100 per cent cure. The secondary changes in hip joint and femoral head still occur, caused, possibly, by vascular deficiencies or other unknown factors following even in the face of most satisfactory replacement and apposition by any method in vogue, with a supposedly proper period of immobilization and freedom from weight bearing. Apparently they are immediate results of the fracture or its treatment, but they seem uncontrollable by present methods of care. The fracture is still unsolved.

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