INTRACAPSULAR PROXIMAL FEMORAL FRACTURES

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There is a wicked inclination in most people to suppose an old man decayed in his intellects. If a young or middle-aged man, when leaving a company, does not recollect where he laid his hat, it is nothing; but if the same inattention is discovered in an old man, people will shrug up their shoulders, and say, "His memory is going"

Boswell, Life of Johnson, vol iv, p 181 1783

Old age is the most unexpected of all the things that happen to a man.

Trotsky, Diary in Exile, 1935

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Finally I would like to thank the patients at the Leicester Royal Infirmary who consented to enter into the various clinical trials. I came to know many of them very well as they continued to attend the review clinics, and I thank them for their willingness to participate.

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1. Introduction.

1.1 Introduction

Fractures of the proximal femur are an increasing problem and present a continuing challenge for Orthopaedic Surgeons.

Each year at least 46,000 people sustain a fracture of the proximal femur in England and Wales and at any one time twenty percent of orthopaedic beds are occupied by such patients. The in-patient cost to the health service was estimated to be £160 million per year in 1987 (Wallace 1987), such costs will be higher now and do not take into account the costs to the community of the increased demand for community based services.

The chance that a man will sustain a fracture of the proximal femur before reaching 85 is 5% and for a woman is 12% (Gallagher 1980, Jensen 1980(b), Hedlund 1987). The number of elderly people is increasing throughout the Western world, and coupled with this there is an increase in the number who sustain hip fractures (Alffram 1964, Rockwood 1990). A study from Oxford indicated a doubling of the annual fracture rate in the period between 1954-58 and 1983 (Boyce 1985). If this trend continues, and allowing for the increase in the elderly section of the population, there will be 117,000 proximal femoral fractures in the year 2016 in England and Wales.

The aetiology of proximal femoral fractures is multifactorial and includes osteoporosis, an increased risk of falling and disordered neuromuscular reflexes. Although there has been much research into identifying risk factors for proximal femoral fractures no single factor has been conclusively identified. Even if a cause for these fractures could be found and appropriate treatment instituted it is unlikely that any reduction in fracture rates would occur rapidly.

Outcome from these fractures has been almost universally reported as poor with a 30 day mortality of 6% (Jensen 1984) and 3 month mortality of nearly 19% (Foubister 1989). Only 64% of patients return to their own homes and 24% manage to walk without a stick or frame after fracture.

Although the original mental and physical state of the patient may have an important influence on outcome (Evans 1979(a), Evans 1980) an important additional factor is the treatment they receive in the hands of orthopaedic surgeons.

These frail and elderly patients are a vulnerable group who require optimal treatment in order for a good result to be achieved. Unfortunately although there have been a large number of publications on the treatment of these fractures most are retrospective, have small numbers and inadequate follow-up. In addition almost all the published randomised prospective studies have not taken into account important determinants of outcome such as mental function.

The humanitarian, medical, social and economic implications of these fractures require us to treat those affected by methods that have been shown, in a scientific way, to produce acceptable outcomes.

1.2 Anatomy of the hip

1.2.1 Osteology

The hip joint is a ball and socket joint comprising the head of the femur and the acetabulum (Fig 1.1).

The socket of the hip joint is a cup shaped concavity formed at the confluence of the three components of the bony pelvis, the ilium, the ischium and the pubis. The ilium forms the antero-superior two fifths of the acetabulum, the ischium the floor and the postero-inferior two fifths and the pubis the antero-superior one fifth. The acetabulum is approximately hemispherical in shape. There is a deficiency inferior to the rim of the acetabulum called the acetabular notch. The cavity of the acetabulum consists of two areas, the central acetabular fossa, which is non-articular and the crescentic lunate surface that articulates with the head of the femur. The acetabulum faces antero-inferiorly.

The proximal femur consists of the head, the neck and greater and lesser trochanters. The head of the femur is more than half a sphere directed upwards medially and slightly forwards. The smoothness of the head is broken just below and behind its centre by a small roughened pit, the fovea, into which the ligamentum teres is attached. The head of the femur lies entirely within the capsule of the hip joint.

The neck of the femur is a cylinder approximately five cm in length connecting the head with the shaft of the femur at an angle of approximately 130 degrees. The neck of the femur does not lie in the same plane as the shaft but is, most usually, anteverted as it moves from distal to proximal. Thus the transverse axis of the head makes an angle with the transverse axis of the distal femoral condyles. This angle varies from twenty degrees of retroversion to thirty eight degrees of anteversion. The anterior half of the neck is entirely intracapsular but only the proximal half of the posterior surface of the neck lies within the capsule.

The greater trochanter is a large supero-lateral projection of bone at the junction of the neck with the shaft.

The lesser trochanter is a conical eminence that projects medially from the shaft.

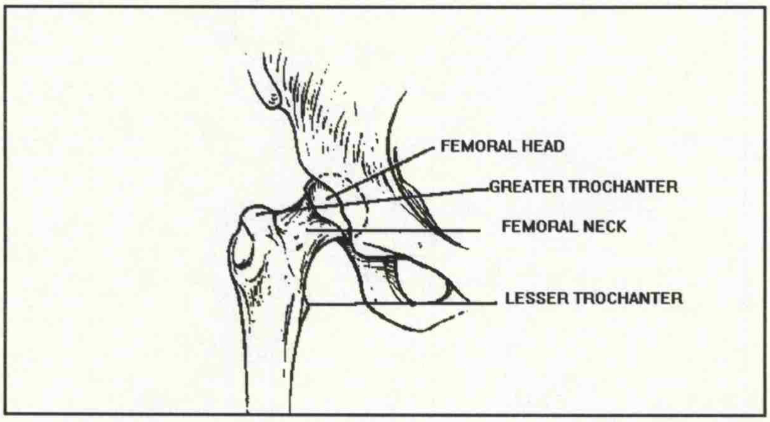
The intertrochanteric line joins the greater and lesser trochanters anteriorly and marks the junction of the anterior neck with the shaft.

The trochanteric crest joins the trochanters posteriorly and is the junction of the posterior neck with the shaft.

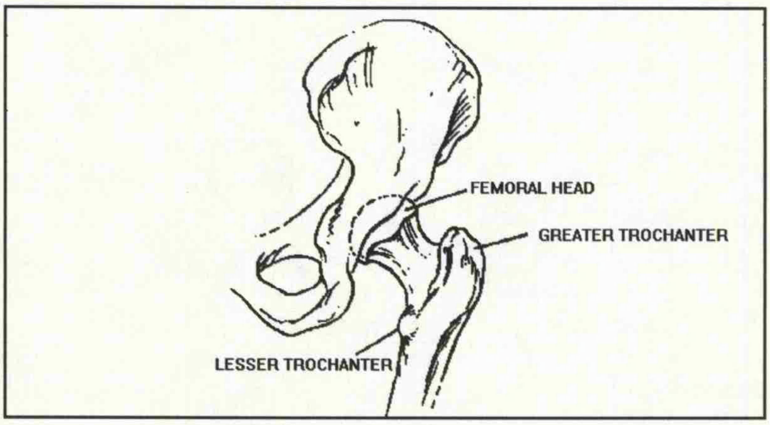
The internal structure of the proximal femur consists of trabecular bone invested by thin cortical bone. The arrangement of the proximal trabeculae are characteristic and were first described by Ward in 1838. These can be seen in both sagittal sections of the proximal femur and on radiographs The trabeculae are arranged in four groups (Fig 1.2). The principal compressive group fan out from the calcar femorale to the superior aspect of the head and correspond to the principal direction of force through the femoral head during weight bearing (Garden 1961). The secondary compressive group fan out from the calcar to the lateral shaft and greater trochanter. The principal tensile group pass from the fovea to the lateral femoral neck and then become the secondary tensile group as they pass from the neck to the femoral shaft. With bone loss, such as occurs with osteoporosis, one or more of these groups may become less apparent (Singh 1970).

Between the intersection of these trabecula groups lies an area of bone called Wards triangle where the trabeculae are much less closely arranged. It is along the lines of the principal compressive trabeculae and through Wards' triangle that the majority of intracapsular proximal femoral fractures occur (Klenerman 1970) (Fig 1.3).

Fig 1.1 The bony anatomy of the hip joint.



Anterior bony anatomy of the hip joint.



Posterior bony anatomy of the hip joint.

Fig 1.2 The appearance of the trabeculae of the proximal femur.

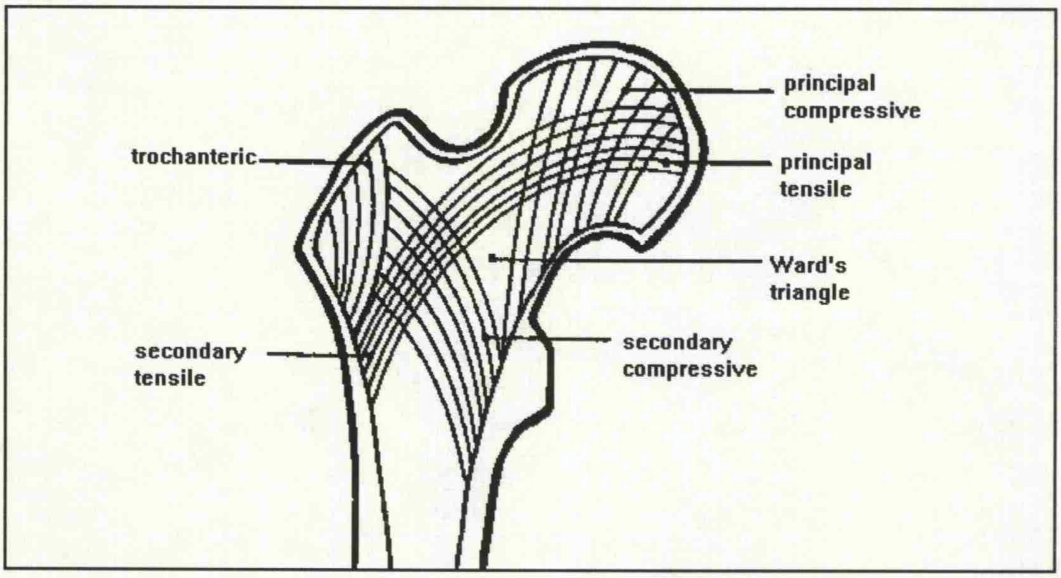
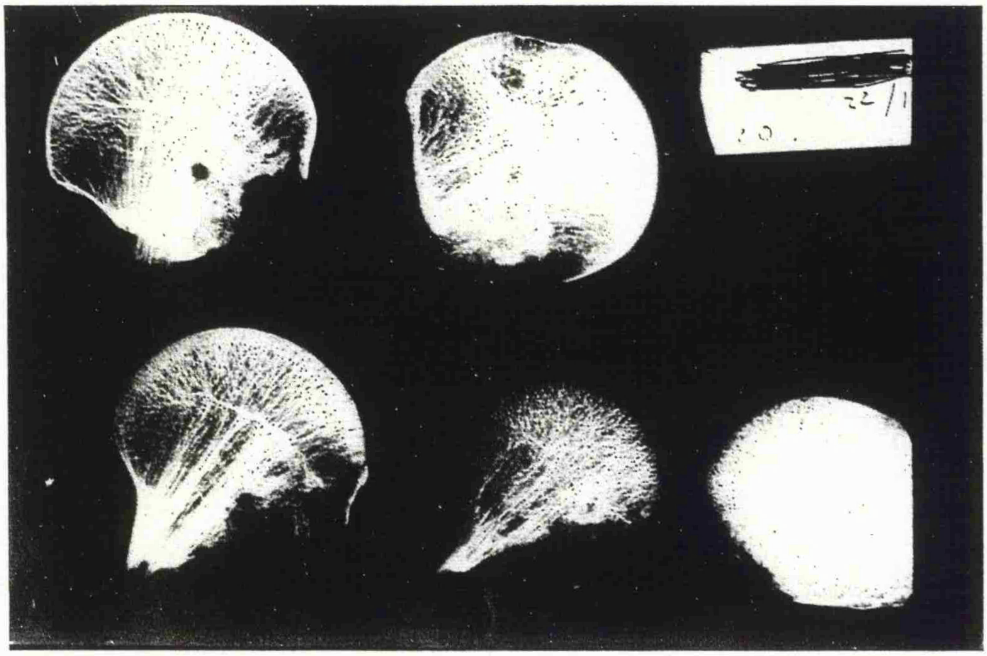


Fig 1.3 Slab radiograph of sagittal slices of a femoral head following fracture showing the common pattern of the fracture line in intracapsular proximal femoral fractures.



1.2.2 Arthrology.

The hip joint is a multiaxial spheroidal cotyloid joint. The head of the femur is covered by articular cartilage apart from the fovea. The lunate surface of the acetabulum is clothed by cartilage, the fossa has no cartilage but has a synovial covered fibro-fatty pad. The acetabulum is ringed by the fibrocartilaginous acetabular labrum.

The fibrous capsule is attached from the acetabular labrum to the femoral neck as detailed previously.

The iliofemoral, pubofemoral and ischiofemoral ligaments are all thickenings of the capsule. (Fig 1.4 - 1.5)

The ligamentum teres lies within the hip joint and is attached to the fovea with its base arising from the acetabular notch.

Fig 1.4 The anterior capsular thickenings (ligaments) of the hip joint.

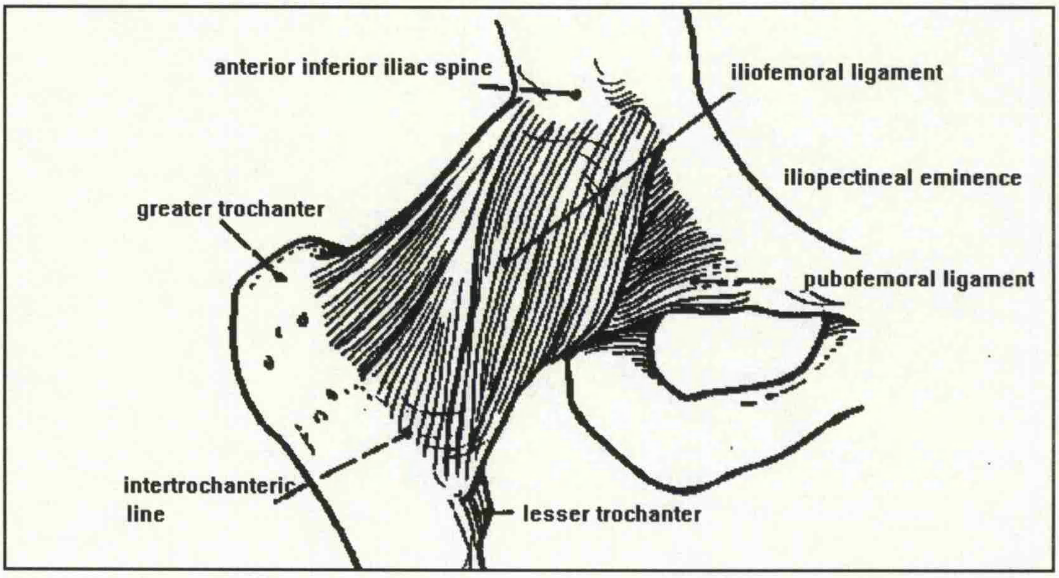
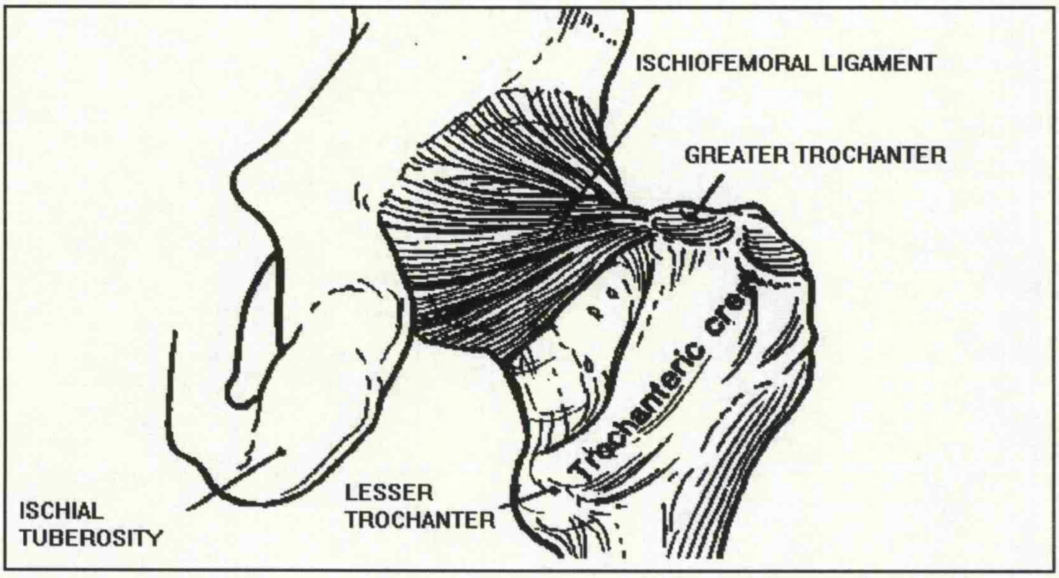


Fig 1.5 The posterior capsular thickenings (ligaments) of the hip joint.



1.2.3 Myology.

The principal movements of the hip joint are flexion, extension, abduction, adduction, internal and external rotation.

Flexion is produced principally by psoas major and iliacus. Sartorius, rectus femoris and pectineus also assist. Extension is produced by gluteus maximus and the hamstrings. Gluteus medius and minimus produce abduction. Adduction is produced by the three adductors (longus, brevis and magnus) and gracilis.

Internal rotation is produced by psoas, tensor fascia lata and the anterior fibres of gluteus minimus and medius and external rotation by the obturators, gemmelli and piriformis.

1.2.4 Angiology.

The blood supply to the proximal femur is derived from three arterial groups (Crock 1980).

1) The extracapsular arterial ring

2) Ascending cervical branches of the extracapsular ring

3) The arteries of the ligamentum teres.

The extracapsular ring lies at the base of the femoral neck. It is formed posteriorly by a branch of the medial femoral circumflex artery, anteriorly by branches of the lateral femoral circumflex artery and minor branches from the superior and inferior gluteal arteries. From this extracapsular ring arise the ascending cervical vessels. These vessels, after passing through the capsule anteriorly at the intertrochanteric line and posteriorly through orbicular fibres, pass upwards under synovial reflections and fibrous prolongations of the capsule to form a subsynovial anastomosis at the junction of the bony part of the neck and articular surface of the head.

These arteries arising from the extracapsular ring can be divided into lateral epiphyseal and the superior and inferior metaphyseal vessels (Trueta 1953).

The most important blood supply comes from the lateral epiphyseal vessels. These lie intimately related and bound down to the postero-superior aspect of the femoral neck and thus may be easily damaged in intracapsular fractures of the proximal femur. They have been demonstrated, by injection techniques, to supply two thirds of the femoral head and significantly this is the most important weight bearing portion, the supero-lateral segment (Sevitt 1965).

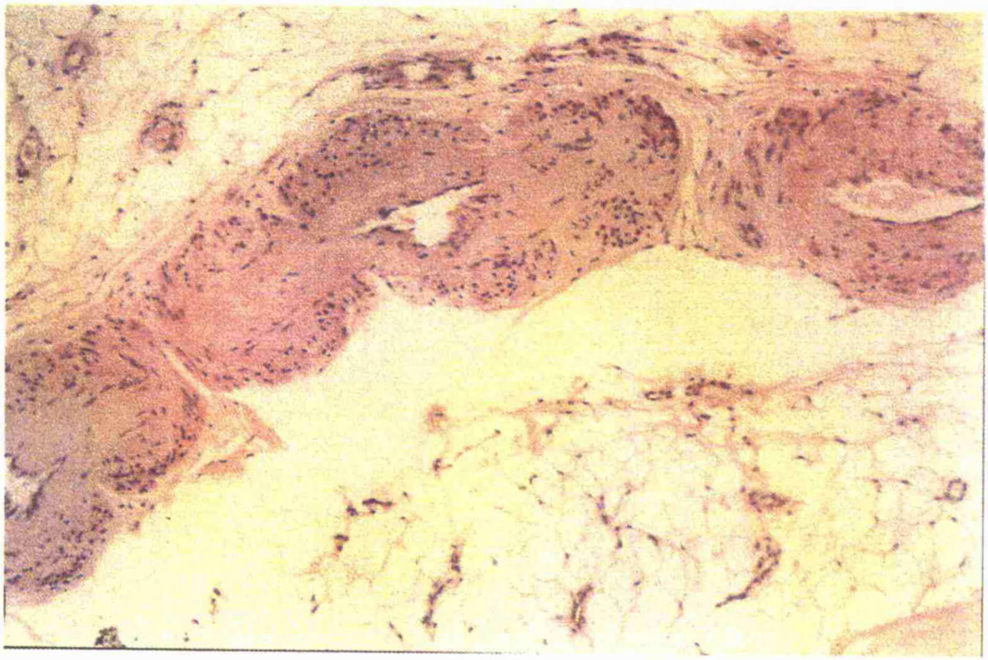
The superior metaphyseal vessels enter the superior aspect of the neck lateral to the articular rim. The inferior metaphyseal vessels enter the neck inferiorly close to the margin of the articular surface and supply the infero-medial portion of the femoral head.

The medial epiphyseal artery is the artery of the ligamentum teres (fig 1.6). This artery is variable in presence and may be insufficient on its own to maintain viability of the femoral head following damage to other vessels. It supplies a variable wedge of bone adjacent to the fovea (Catto 1965).

Venous drainage (Phillips 1966) is via lumino capsular veins, tortuous medullary sinusoids, which drain mainly into the obturator and femoral veins. There is said to be no venous drainage via the ligamentum teres.

The blood supply of the proximal femur is summarised in figures 1.7 and 1.8.

Fig 1.6 Histological section of the ligamentum teres showing presence of patent vessels.



magnification x 10

Fig 1.7 The arterial supply of the anterior aspect of the proximal femur.

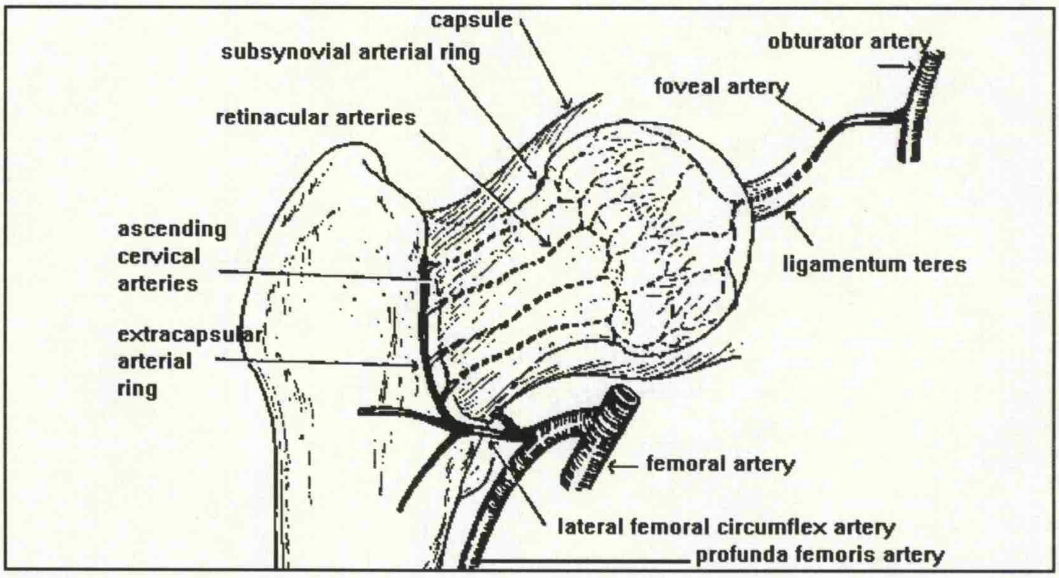
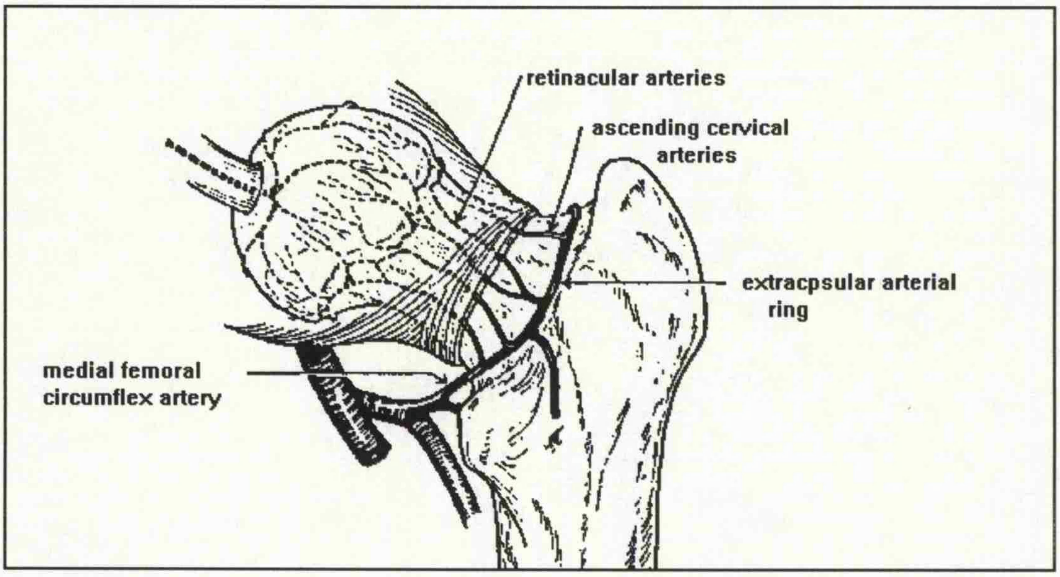


Fig 1.8 The arterial supply of the posterior aspect of the proximal femur.



1.3 The aetiology of proximal femoral fractures.

1.3.1 Bone Quality.

1.3.1.1 Osteoporosis.

"Osteoporosis is a disease characterised by low bone mass, microarchitectural deterioration of bone tissue leading to enhanced bone fragility and a consequent increase in fracture risk." This definition of osteoporosis was produced at the consensus conference on osteoporosis in 1990 (Osteoporosis 1991), and although the initial part of the definition is satisfactory doubt must be cast over the increased fracture risk, most particularly with regard to proximal femoral fractures. Both proximal femoral fractures and osteoporosis are more common in the elderly although a direct causal relationship has yet to be proven (Riggs 1986, Compston 1987, Hedlund 1987, Jarnlo 1989).

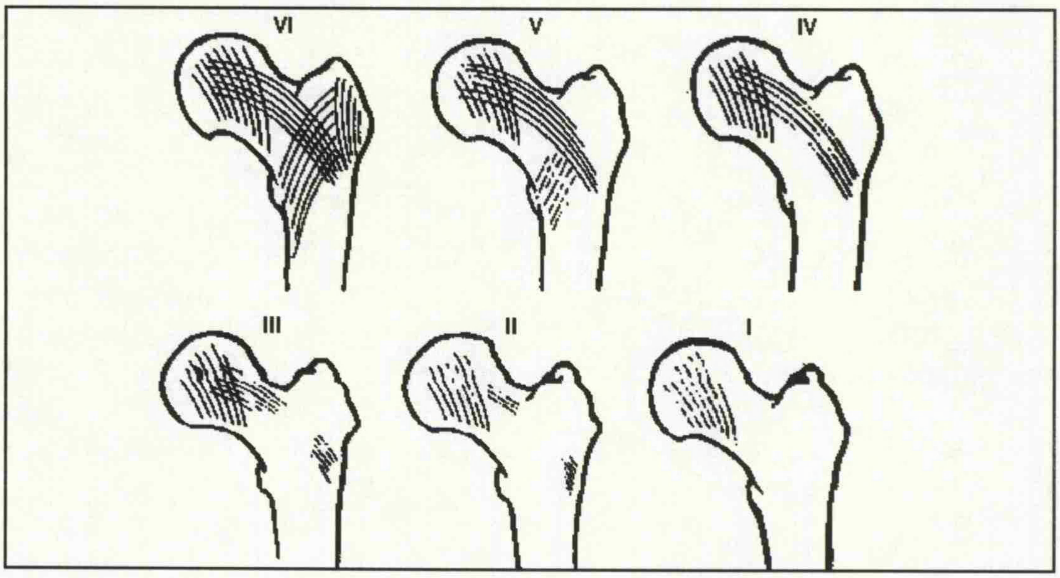
Examination of post mortem specimens of the midcervical area of the femoral neck in subjects without fracture or other coexistent disease has shown decrease in bone area with increasing age (Komatsu 1988).

It has also been suggested that this bone loss can be correlated with the radiographic appearances of an ordinary antero-posterior radiograph of the hip (Singh 1970). The Singh classification is divided into 6 grades, Grade VI being normal and grade I severe bone loss (fig 1.9). The correlation, apart from at the extreme grades, between the Singh index and bone mass is poor and the inter and intraobserver error when classifying these grades is also significant (Smith 1989).

Although it is tempting to make the correlation between bone loss and fracture of the hip there is contradictory evidence in the literature. A longitudinal study of elderly women in Jerusalem showed an increased incidence of osteoporosis in those women sustaining a fractures (38%) as compared to the incidence of osteoporosis in the normal population (11.5%) (Makin 1987). However of those sustaining a fracture 34% had borderline osteoporosis and 28% no evidence of osteoporosis. Aitkin showed no such difference between osteoporosis in a fracture population of 200 patients and a control group (Aitkin 1984).

Although the proximal femur which is weakened by involutional osteoporosis has a lower threshold for fracture (Burstein 1976), not all people who sustain a proximal femoral fracture have osteoporosis nor do all patients with osteoporosis suffer a fracture. Other additional factors must therefore be operating to create the fracture.

Fig 1.9 The Singh index.



1.3.1.2 Osteomalacia.

Vitamin D deficiency, secondary to poor dietary intake and leading to osteomalacia has been postulated as a significant factor contributing to proximal femoral fracture. (Chalmers 1967, Jenkins 1973, Aaron 1974). Direct examination of femoral heads following fracture (Wicks 1982) and of iliac crest biopsies (Wilton 1987) has failed to confirm an increased incidence of osteomalacia in fracture patients compared with that in the normal population.

1.3.2 Biomechanical factors.

Biomechanical studies have shown that forces as low as 256 kg can produce fractures of the femur (Compere 1942(b)) and that the energy absorbing capacity of the proximal femur is 60Kg/cm (Frankel 1974). During normal walking, analysed by force plate reaction (Paul 1966), there is a cyclical load taken through the hip joint with two peaks. The first peak is at heel strike and the second just before toe off (fig 1.10). The mean force was calculated as 3.39 times body weight and peak force was 4.46 times body weight. These results have been corroborated by other workers (Crowninshield 1978) with results of 2.5 times body weight at heel strike and 3 - 4 times body weight just before toe off.

Thus considerable forces pass through the hip joint and it is only because of dissipation of forces by normal muscular and ligamentous reaction that the femur does not spontaneously fracture during normal walking. In the elderly patient with impaired neuromuscular responses and osteoporosis the proximal femur may have a lower energy absorbing capacity to failure.

Microfractures have been demonstrated in the bone (Freeman 1974) of the femoral neck in elderly subjects and it is suggested that these microfractures may progress to a complete fracture. Although stress fractures of the femoral neck do occur (Devas 1965) the most common precipitating incident in a complete fracture of the femoral neck is trauma, such as a fall.

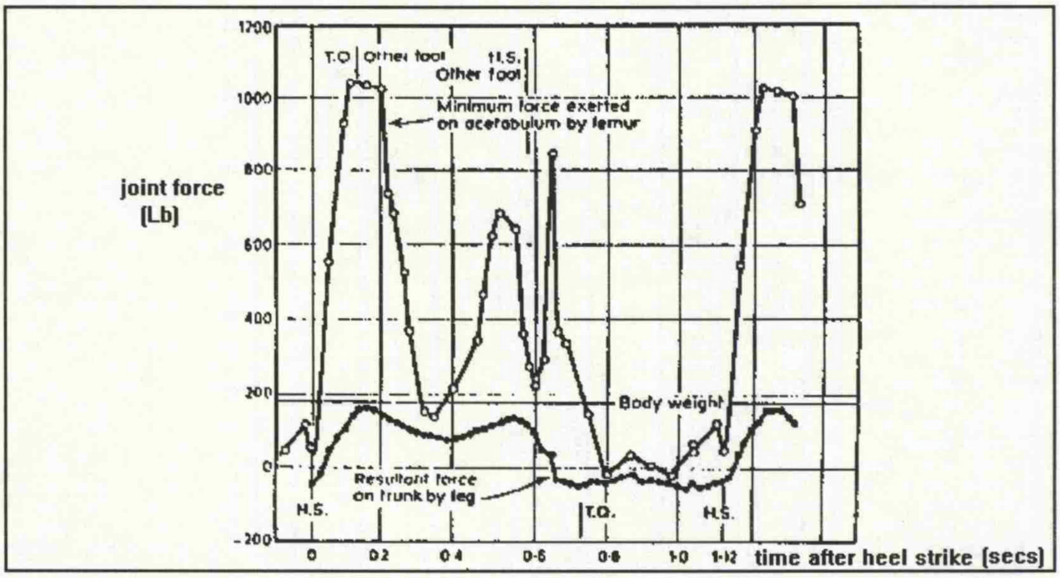
Elderly people are more subject to falls because of poor balance (Jarnlo 1990), and a fall in an average sized woman will produce a force of 4,000 Kg cm. This exceeds the energy absorbing capacity of the upper femur and it is only by the dissipation of energy produced by muscular contraction that a fracture is prevented following a fall. In the elderly these protective mechanisms may not act quickly enough to prevent fracture.

It has also been suggested that a fall onto the greater trochanter may produce a fracture by direct transmission of force (Kocher 1896).

However the situation may be adversely influenced by the muscles acting around the hip joint. The forces acting around the femoral neck can be resolved into two components, a line of force perpendicular to the femoral neck which acts as a bending component and a line of force along the axis of the femoral neck which acts as a compressive force (Fig 1.11). The typical fracture pattern of an intracapsular fracture can be produced in cadaveric femora by increasing the compressive component in relation to the bending component (Hirsch 1960). Thus the muscle action of the abductors, producing axial compression, at the time of injury may have a significant influence on fracture production (Frankel 1960). A further factor that may be involved in the production of intracapsular fractures is a combination of an external rotation force with a strong abductor force tensioning the anterior femoral neck and compressing the posterior femoral neck which pivots on the posterior acetabular margin producing comminution of the posterior femoral neck (Kocher 1896).

Action of the muscles alone around the femoral neck is sufficient to produce an intracapsular fracture, such as is encountered after strong muscle contraction following an epileptic fit or an electric shock (Morrey 1977, Taylor 1985).

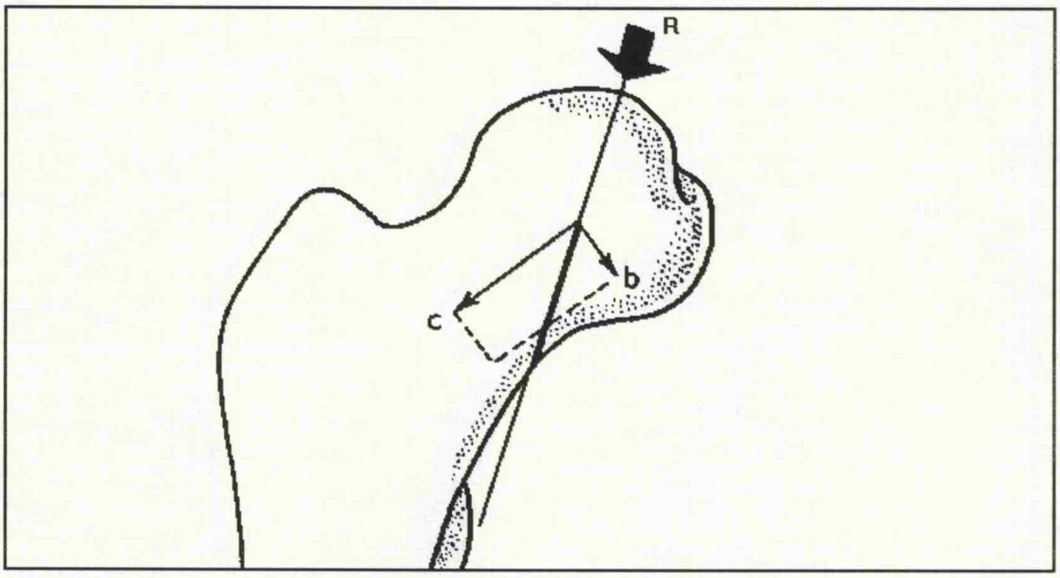
Fig 1.10 Diagram of loads passing through the hip during walking.



T.O. = toe off

H.S. = heel strike

Fig 1.11 Forces acting through the neck of the femur.



R (the resultant force through the femoral head) can be resolved into a compressive component (c) in the axial line of the femoral neck and a bending component (b) perpendicular to it.

1.4 Classification of fractures of the proximal femur.

Fractures of the proximal femur may be classified into intracapsular and extracapsular fractures.

1.4.1 Extracapsular fractures.

These are fractures that occur in the proximal femur distal to the insertion of the fibrous capsule. The division into intracapsular and extracapsular fractures is an important and practically useful one because of the difference in prognosis of fracture union. Extracapsular fractures occur through an area of cancellous bone with a good blood supply and therefore they usually progress to union. The blood supply to the head of the femur is not affected and therefore the femoral head is not at risk of developing avascular necrosis. Intracapsular fractures, occurring within the hip joint capsule, may damage the blood vessels supplying the proximal fragment and therefore, increase the risk of non-union and avascular necrosis of the femoral head.

This thesis is concerned with intracapsular proximal femoral fractures and therefore extracapsular fractures will not be discussed further.

1.4.2 Intracapsular fractures.

The difference in prognosis between these fractures that occur within the capsule of the hip joint and extracapsular fractures was first recognised by Sir Astley

Cooper (Cooper 1823). Because of the variable damage to the blood supply to the proximal fragment the sequelae of this fracture are often non-union and avascular necrosis. Classification of these fractures has been attempted to enable a prognosis to be made with regard to fracture pattern.

The classification of Pauwels is based on the angle of inclination of the fracture line with respect to the horizontal (Pauwels 1935). The classification divides intracapsular fractures into three types, the fracture line becoming more vertical with higher grade (fig 1.12). The classification is based on the post reduction appearance.

Type 1	A fracture thirty degrees from the horizontal
Type II	A fracture fifty degrees from the horizontal
Type III	A fracture seventy degrees from the horizontal

Type III fractures were supposed to have an increased incidence of non-union because of the greater shearing forces across the fracture line (Pauwels 1935). The value of this classification has been called into doubt for several reasons. There does not appear to be a difference between non - union and avascular necrosis rates between types II and III, with 12% non-union and 33% avascular necrosis rates in type II as compared to 8% non-union and 30% avascular necrosis rates in type III (Boyd 1964). This work has been verified by other authors (Cassebaum 1963, Ohman 1969), although Hulth stated that avascularity may be more important and that avascularity coupled with a steep fracture angle produced a very poor prognosis (Hulth 1961).

The classification of the fracture is based on the radiographic appearance of the fracture on an antero-posterior projection and may not represent the angle of the fracture line itself. Because of the spiral nature of the femoral neck rotation of the distal fragment varies the apparent obliquity of the fracture angle (Garden 1974). Linton showed that by altering either the position of the x-ray source or of the limb the apparent inclination of the femoral neck could be altered and therefore altering the classification type of the fracture (Linton 1944).

The classification of Garden is the most widely used classification. It is based on the displacement of the head of the femur as seen on antero-posterior radiographs of the hip prior to reduction of the fracture (Garden 1961(a)).

The Garden classification is divided into four stages (Fig 1.13 - 1.18).

Stage 1 — An incomplete or impacted fracture. The medial cortical trabeculae of the neck are intact

Stage 2 — Complete but undisplaced fracture. The alignments of the head,neck and acetabulum are undisturbed. These are extremely rare fractures.

Stage 3 — A complete but only partially displaced fracture.

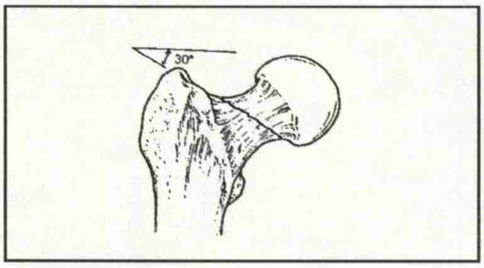
Stage 4 — A complete fracture with total displacement of the fracture fragments.

Garden suggested that increase in stage indicated a worsening of the prognosis, particulary in a stage 4 fracture where the rotation of the head implies complete disruption of any ligamentous attachments between the head and neck and consequently a disruption of a significant proportion of the blood vessels supplying the head.

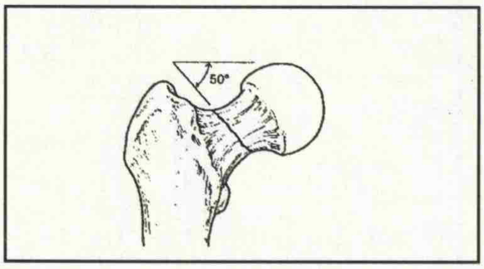
A large multicentre study of hip fractures seemed to confirm Gardens views with higher stages having a worse prognosis (Barnes 1976). However in this large study although the prognosis did deteriorate between stages 3 and 4 there was not a large difference between the prognosis between those two groups and similarly between stages 1 and 2. In addition the classification relies on the appearance of the trabeculae in the femoral head. With increasing osteoporosis these trabeculae become less apparent making identification of the stage of the fracture difficult. In an intraobserver error study of the Garden classification of the radiographs of 100 intracapsular fractures three consultant Orthopaedic Surgeons, 2 consultant radiologists, 1 radiology trainee and 2 orthopaedic trainees agreed on Garden stage in only 22% of cases (Frandsen 1988). However disagreement between whether a fracture was displaced or undisplaced was much less. In recent literature the classification of intracapsular fractures has been simplified into displaced (Garden stages III and IV) and undisplaced/impacted (Garden stages I and II) fractures because problems of union and avascular necrosis are much more common in displaced than undisplaced fractures (Rehnberg 1989(a), Sernbo 1990, Herngren 1992).

To this simple classification should be added an additional classification, that of pathological fractures because of the different treatment needs of these fractures (Grundy 1970, Lane 1980).

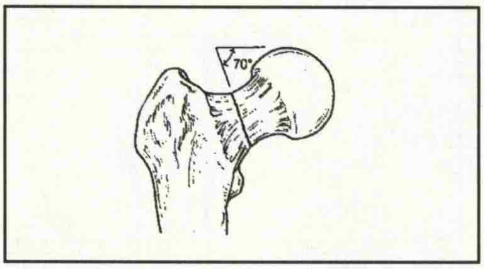
Fig 1.12 The classification of Pauwels.



Type I



Type II



Type III

Fig 1.13 Garden stage I and II fractures (undisplaced).

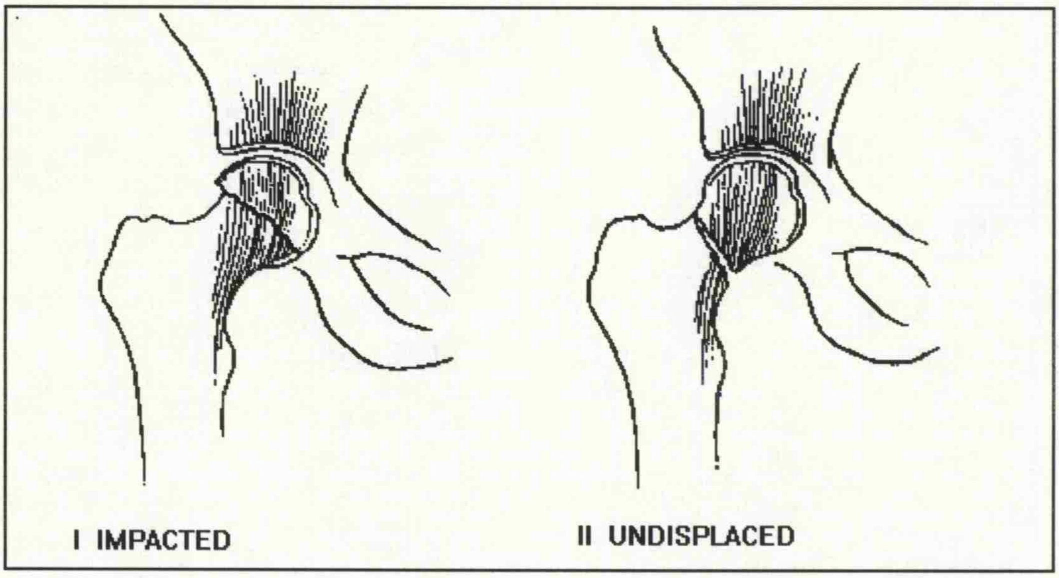


Fig 1.14 Garden stage III and IV fractures (displaced).

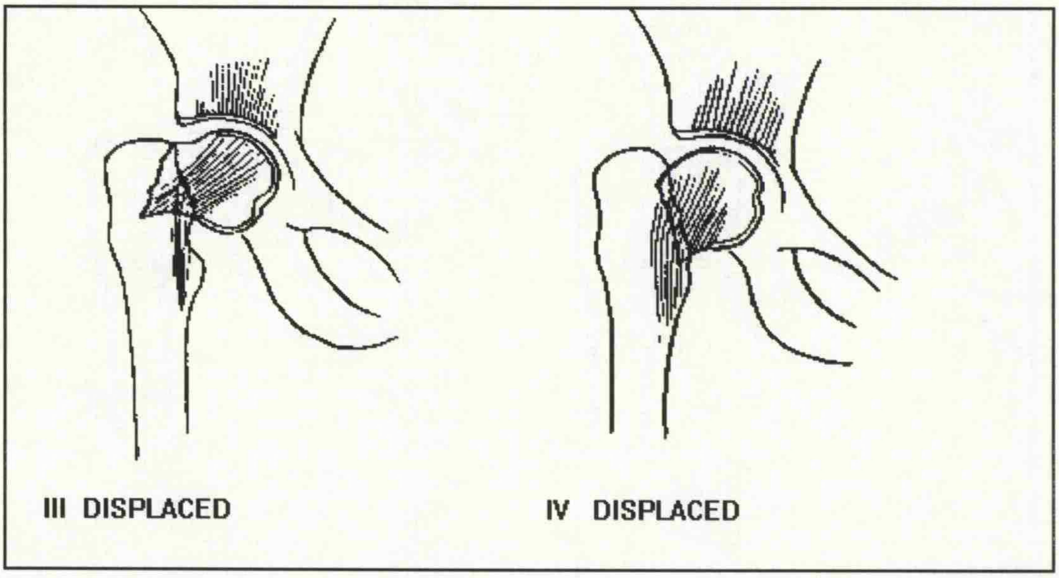


Fig 1.15 An antero-posterior radiograph of a Garden Stage I fracture showing the bony trabeculae of the inferior portion of the femoral neck intact.

Fig 1.16 An antero-posterior radiograph of a Garden Stage II fracture showing the trabeculae of the femoral neck and head remaining in line.

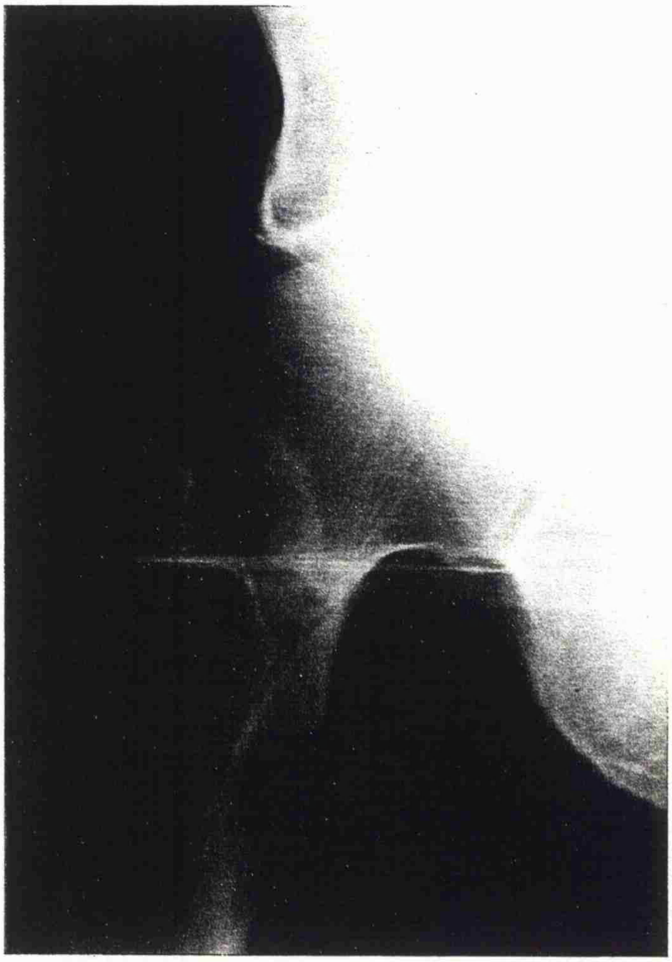


Fig 1.17 An antero-posterior radiograph of a Garden Stage III fracture showing rotation of the femoral head.

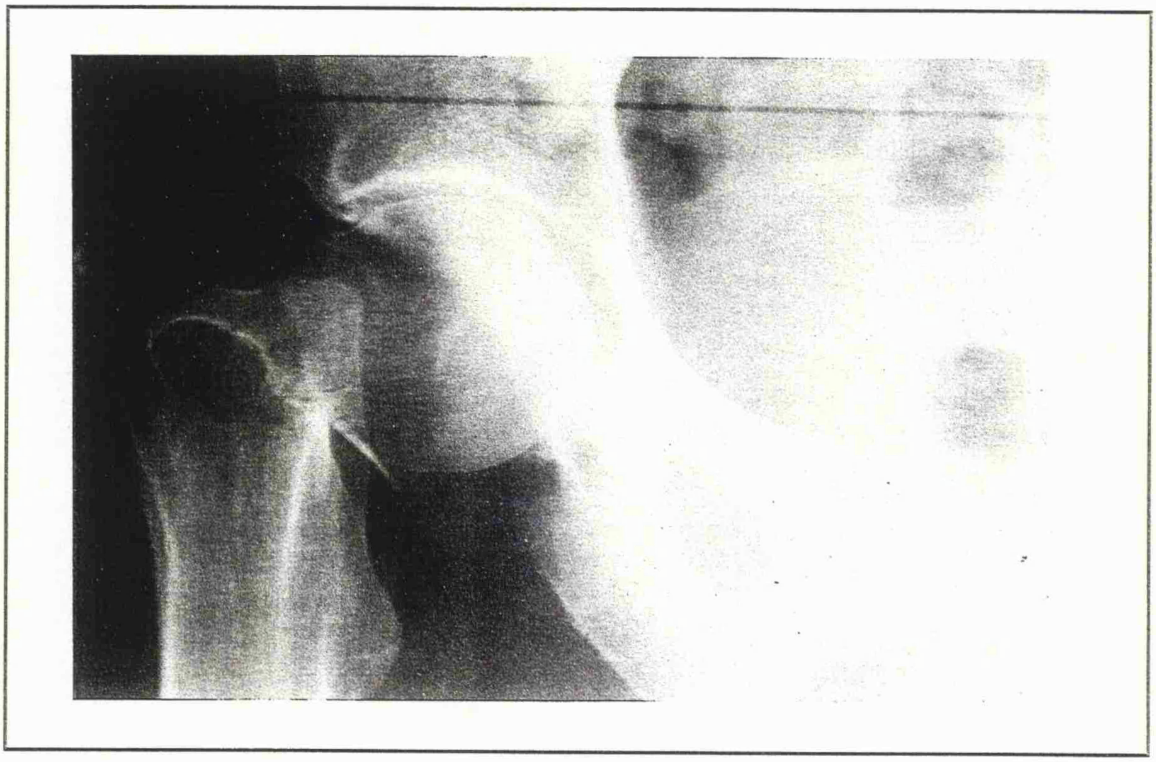
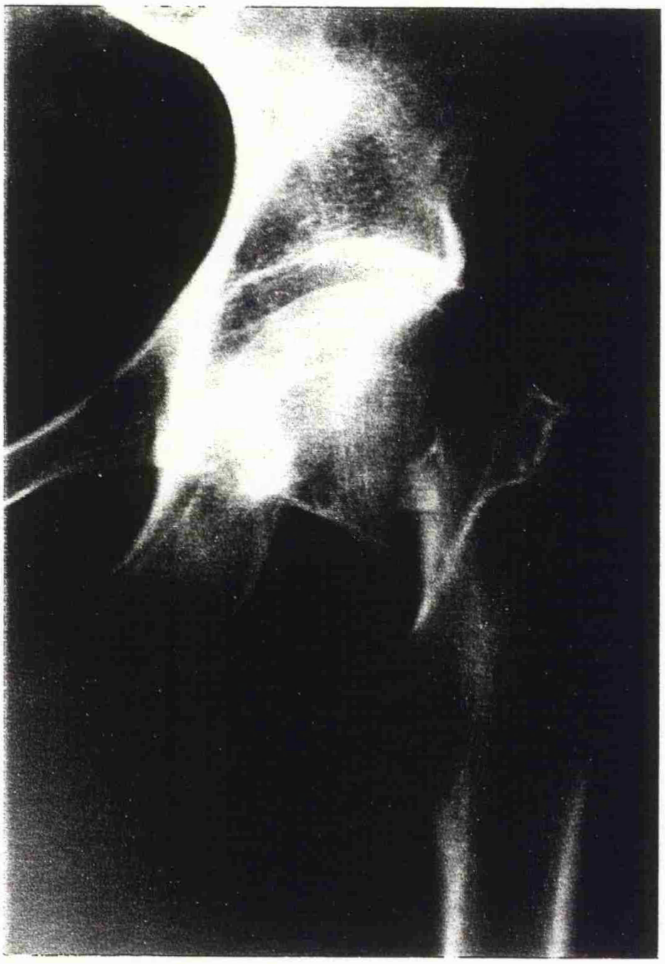


Fig 1.18 An antero-posterior radiograph of a Garden Stage IV fracture showing the femoral head rotated back into the anatomical position.



1.5 Diagnosis of intracapsular proximal femoral fracture.

1.5.1 Clinical presentation.

Elderly patients with intracapsular fractures present most frequently with pain in the hip and difficulty in weight bearing on the affected limb. With displaced fractures the patient is usually incapable of weight bearing and the affected limb lies externally rotated and shortened. There is usually pain on movement of the hip.

The diagnosis can easily be confirmed by an antero-posterior radiograph of the hip. Patients with undisplaced or impacted fractures may present with more subtle symptoms and signs. Often they are able to weight bear on the limb but with pain. Careful clinical examination usually reveals some pain on movement of the hip and the range of movement may be limited.

The young patient presents usually after significant trauma and other injuries may be present. A rare but important combination is a fracture of the femoral shaft and ipsilateral intracapsular hip fracture, an association which is frequently overlooked because attention is directed to the femoral shaft fracture (Friedman 1986, Swiontkowski 1987, Wu 1991).

1.5.2 Radiology and Examination.

The displaced fracture is easily seen on a standard antero-posterior radiograph of the hip. A lateral view of the affected hip should also be obtained (Maninger

1992).

The appearance of an undisplaced or impacted fracture is often less apparent to inexperienced eyes, and may lead to such patients being diagnosed as not having a fracture. The fracture may become obvious later when it displaces after the patient has been allowed to weight bear (Bentley 1968).

Some authors have suggested that patients may present with a normal initial radiograph but later progress to a definite fracture (Eastwood 1987). Studies of hospital in-patients with suspected fracture have demonstrated that 43 of an initial 693 patients with suspected hip fractures had normal initial radiographs. Of these 43, 13 subsequently developed a radiographically apparent fracture (Fairclough 1987). These findings have led some authors to conclude that patients with hip pain following trauma should have bone scintigraphy (Fairclough 1987). However other conditions, such as osteoarthritis may give rise to positive bone scans. In Faircloughs series nearly 30% of patients with painful hips and normal radiographs developed what the authors describe as positive radiographic findings, 12 of those thirteen had fractures around the proximal femur and of these only 5 subsequently displaced, 2 completely and 3 minimally. It may be that the initial radiographs in these series were of such poor quality such that a fracture could not be seen.

No study has specifically investigated the problem of a cohort of elderly patients who have had trauma, a painful hip and normal radiograph and then to follow-up these patients to see how many subsequently developed a fracture. This is important because of the costs, both socially and financially, involved in admission and extensive investigation in these patients.

Stress fractures occur through overuse in a normal healthy individual without bone disease. Initial radiographs in these individuals may have an initial normal appearance, or a small linear crack may be seen and/or a periosteal reaction superiorly or inferiorly. If the initial radiograph is normal and stress fracture is suspected bone scanning or MRI will confirm the diagnosis of fracture (Deutsch 1989).

1.6 The treatment of undisplaced intracapsular proximal femoral fractures.

Undisplaced or impacted fractures in the elderly patient and stress fractures in the young can be treated by operative or conservative means.

Conservative treatment usually involves a period of bed rest until the hip is comfortable and then a period of non or partial weight bearing for up to three months until the fracture is united (Crawfurd 1960). A period of non or partial weight bearing is probably an unrealistic treatment strategy for the elderly patient. Raaymakers followed a regime of partial weight bearing for 8 weeks for undisplaced fracture, he however found that only 42% of his patients followed this advice (Raaymakers 1991). The danger of conservative treatment is displacement of the fracture and the rate of occurrence of displacement is about 15% (Bentley 1968, Raaymakers 1991). Disimpaction of the fracture requires surgery, and this may not affect prognosis if the fracture is treated by internal fixation. There is little evidence in the literature that fixation following displacement increases the avascular necrosis rate. Only two series discuss the late avascular necrosis rate following fixation of disimpacted fractures. Jonasch found avascular necrosis in two of 13 patients, and Crawford in 1 out of four (Jonasch 1969, Crawford 1960). These studies used implants that would now be considered outmoded. If the disimpaction is treated by a hemiarthroplasty the problem of late avascular necrosis does not arise, however a prosthesis may not be considered optimal treatment in a younger patient.

Operative treatment of these fractures prevents disimpaction and allows earlier weight bearing, but may confer different risks because of the surgery. Bentley compared the results of conservatively and operatively treated groups, and found that the end result was excellent or good in 96% of operatively treated patients but only 79% in those treated conservatively (Bentley 1968). The one poor result in the operatively treated group was reported to be due to distraction of the fracture when a Smith Peterson nail was inserted. This should not occur with more modern implants which rely upon compression. The incidence of avascular necrosis, based on radiological appearance, does not appear to be higher following operative treatment with 5 out of 43 conservatively treated patients developing avascular necrosis and 2 out of 23 developing it following operation (Bentley 1968). The conservatively treated group excludes the three treated by prosthetic replacement following displacement. In addition one of the fractures that displaced during conservative treatment and subsequently was treated by fixation did not unite. The excellent results of operative treatment for impacted fractures have been verified by other workers (Skinner 1986, Stromqvist 1987, Wihlborg 1990) using more modern implants. Although no randomised prospective trial has compared operative and conservative treatments operative treatment prevents redisplacement, does not seem to increase the avascular necrosis rate and does not require a period of partial weight bearing which may be an unrealistic goal in the elderly, therefore the balance of published opinion seems to favour a strategy of early internal fixation of undisplaced fractures.

1.7 Conservative treatment of displaced intracapsular fractures

Displaced intracapsular proximal femoral fractures treated by conservative means do not usually unite. This fact was recognised over 150 years ago (Cooper 1823). Cooper believed that since bony union was never going to occur the appropriate way to treat these fractures was with bed rest until the limb became comfortable and then allow mobilisation. Following this type of treatment the fracture developed a fibrous union and weight bearing on the limb was possible, however the patient had a permanent limp. During the last century surgeons attempted to achieve union by traction (Hamilton 1880) and reduction of the fracture (Whitman 1920). These methods of treatment produced high rates of non-union and avascular necrosis. With improvements in internal fixation devices attempts to obtain union by conservative treatment were abandoned.

A few recent publications have suggested that the complication rate in the elderly and demented patient is so high that they are best treated conservatively (Lyon 1977, Lyon 1984).

In the study by Lyon (1984) a comparison was made between operatively treated and conservatively treated fractures, although this was done in a non-randomised way. Twelve patients were treated by neglect of the fracture but with intensive medical care of the patient and 14 were treated operatively. The authors reported no early deaths, no major complications and all patients developed a pain free hip when treated conservatively. In the operatively treated group there was a 43% major complication rate. The authors concluded that the most humane treatment for the patient and the most economically suitable method for society was that minimally ambulant demented patients should be treated conservatively in their own place of residence.

With proper facilities and suitable surgical skills there is no doubt that the majority of intracapsular proximal femoral fractures should be treated operatively. However with increasing age and decreasing mental function the results of internal fixation and of survival of the patient deteriorate (Ions 1987). However poor outcome in relation to survival and mobility must be balanced against the complications of conservative treatment. Winter (Winter 1987) reported the results of treating four patients with proximal femoral fractures conservatively. Three of the four cases reported moved from minimal ambulation to a bed to chair existence and the fourth patient died one month after the fracture still in pain. Although Winter's series is very small it does raise questions concerning the appropriateness of conservative treatment in this group of patients. If a patient in this vulnerable and frail group is to be treated conservatively the result should be no worse than operative treatment and the treatment should give the patient optimal life quality for whatever life remains. There has been no randomised prospective trial comparing the results of operative versus conservative treatment in the management of displaced intracapsular proximal femoral fractures to allow these important considerations to be taken into account.

1.8 The treatment of displaced intracapsular proximal femoral fractures by reduction and internal fixation.

1.8.1 The timing of internal fixation.

Two factors must be considered when considering the timing of internal fixation. Firstly, the effect of timing on mortality and general complications and, secondly, the effect on the specific complications of internal fixation of intracapsular proximal femoral fractures. These are avascular necrosis of the femoral head and non-union of the fracture.

There is conflicting evidence in the literature on the effect of early fixation of proximal femoral fractures on general complications and mortality. Some published studies show that early fixation reduces mortality and morbidity (Fitts 1959, Kenzora 1984, Villar 1986) whereas others conclude that delay between fracture and operation has no effect on these factors (Davis 1988, Dolk 1990, Parker 1992(a)). Of these studies only one is prospective (Davis 1988) and none is randomised. Therefore care must be taken when analyzing results because studies that have shown increased mortality with delays to surgery (Villar 1986) have not taken into account important factors that delay surgery such as general health, mental function and the resources of the individual hospital, which may, in themselves have a profound influence on outcome (Evans 1979(b), Evans 1980).

The other factor that has to be taken into account when treating intracapsular proximal femoral fractures is the effect of delay on the incidence of non-union and avascular necrosis. A large multicentre study (Barnes 1976) could find no difference in rates of failure if operation was delayed by up to one week. However a more recent retrospective non-randomised study compared failure rates between those having early internal fixation (<6hrs) and those patients having later fixation (Maninger 1989). Those patients who had early operation had non-union rates of 1.5% at one year and late segmental collapse secondary to avascular necrosis of 10.5%, compared to 11.1% non-union and 40% late segmental collapse when fixation occurred greater than 6 hours after injury. The age distribution was similar between the two groups. Although this study must be viewed with caution because of the fact that it was retrospective and non-randomised, 6 hours is probably a critical time for irreversible osteocyte ischaemia. It can therefore be postulated that before fixation either the displacement of the fracture , causing kinking of the blood vessels (Woodhouse 1964) or intracapsular haematoma, producing a tamponade effect, (Stromqvist 1985) may cause diminished blood flow which is improved by relief of these two factors. However there would be great practical difficulties in operating on these fractures within 6 hours of fracture in all cases and therefore until a properly organised randomly controlled trial provides the answer it seems prudent to operate on these fractures as soon as possible after fracture.

1.8.2 Reduction of intracapsular proximal femoral fractures.

Accuracy of reduction is probably the key to success in the treatment of displaced intracapsular proximal femoral fractures. (Garden 1961(b), Barnes 1976).

Inadequate reduction results in an increased incidence of non-union and avascular necrosis as shown in a large multicentre study (Barnes 1976).

Accuracy of reduction can only be gauged on plain radiographs, both antero-posterior and lateral, obtained at the time of surgery.

Appearances suggesting malreduction are extreme tilting of the head in any direction, wedging, narrowing or widening of the hip joint space, undue prominence of the fovea, loss of near circular outline of the hip joint space, and disturbance of Shentons line (Garden 1971).

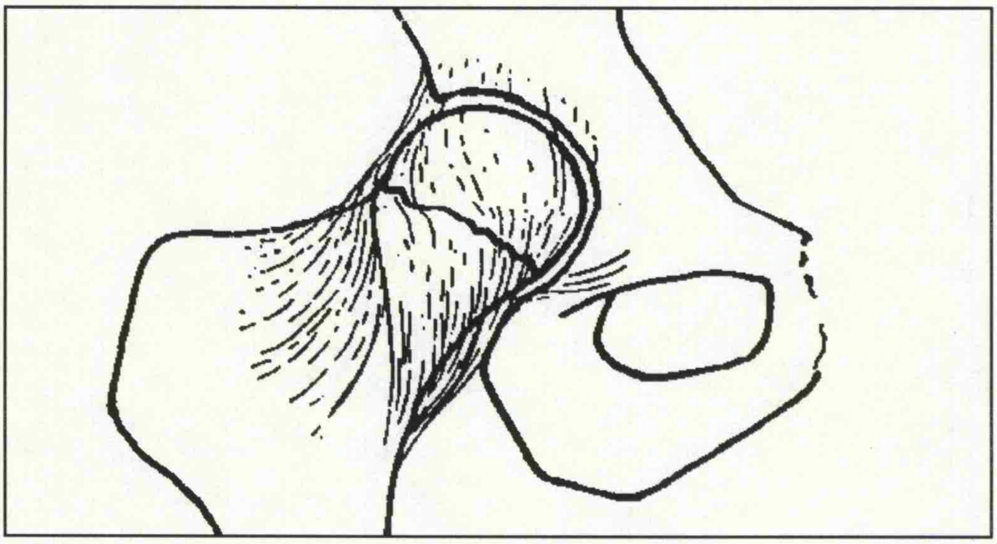
More accurate ways of assessing reduction have been suggested. Garden suggested an alignment index to estimate accuracy of reduction (Garden 1971). The normal angle between the medial head trabeculae and the medial cortex of the femoral shaft on anteroposterior radiographs is 160 degrees and in the lateral view the central axis of the femoral head and the central axis of the femoral neck lie in the same line (Fig 12). This gives an alignment index of 160/180. He found that if the angle was greater than 185 or less than 155 on the anterior radiograph 100% of fractures developed late segmental collapse. He considered an alignment angle in the range of 155-180 in either the antero-posterior or the lateral view to be acceptable.

Closed reduction of the fracture is the most commonly employed mode of reduction. The ease of reduction depends on whether ligamentous attachments remain between the head fragment and the neck. If no ligamentous attachments exist the head lies free in the acetabulum attached only by the ligamentum teres. The aim of reduction is to bring the neck round to meet the head because movement of the neck, when there are no capsular attachments, will not influence the head position. When there are ligamentous attachments remaining between the head and the neck, movements of the neck influence movements of the head. The spiral nature of the fibres of the posterior joint capsule increases stability of the reduction when the hip is internally rotated and extended, the so called "close packed" position (Fig 1.19).

Various methods of reduction have been proposed but none clearly stands out as the method of choice. The published methods of reduction were summarised by Bruekmann (Bruekmann 1988) ,but no comparison was made between the different methods of reduction and accuracy of that reduction.

Most of the manoeuvres are performed on the fracture table and the majority were devised before the advent of image intensification.

Fig 1.19 The Close Packed position



The following methods of reduction have been described.

1) Whitman Manoeuvre

The reduction is performed on a traction table. The affected limb is flexed and then, with traction applied along the longitudinal axis of the leg, is fully extended and abducted and brought to meet the unaffected side. (Whitman 1920)

2) Leadbetter manoeuvre

The fractured limb is flexed to 90 degrees at the hip. Traction is applied along the axis of the thigh and combined with adduction. The affected leg is then circumducted into abduction with the leg in internal rotation. The heel palm test is applied once the leg is brought down to the level of the unaffected leg. If the fracture is reduced when the heel is placed on the palm of the hand it slowly rotates into external rotation, if the fracture is not reduced the foot rapidly springs into external rotation. (Leadbetter 1938)

3) Bozsan manoeuvre

The Bozsan technique relies on maximal internal rotation and lateral traction of the affected limb. (Bozsan 1934)

4) King manoeuvre

Longitudinal traction is combined with posterior pressure on the upper thigh and internal rotation of the leg. (King 1939)

5) Smith manoeuvre

The thigh is abducted and externally rotated. In full abduction the leg is internally rotated and then adducted (Smith 1953).

6) McElvenny manoeuvre

The affected leg is internally rotated and 16-45 Kg of traction applied to medially displace the shaft. With the leg abducted pressure is applied downwards and medially over the greater trochanter. The leg is then adducted into neutral and traction released. (McElvenny 1945)

7) Wellmerling technique

Traction is applied on the affected leg so that it is 0.64cm longer than the unaffected. Pressure is applied proximally over the thigh near the groin and distally under the thigh near the popliteal fossa. The leg is internally rotated and traction released. (Wellmerling 1944)

Although all these methods have been published as techniques to reduce intracapsular proximal femoral fractures there has been no comparative study of different methods. Reduction of these fractures requires precision and it is mandatory to have both image intensification and plain radiographs. It is worth noting that the majority of described techniques for reduction where used prior to the introduction of image intensification, which allows precise evaluation of reduction as a dynamic phenomenon. The patient should be placed on the traction table and the fracture reduced with the minimum of force to prevent further damage to the blood supply (Garden 1971).

1.8.3 Internal fixation with single nails.

A four flanged nail for fixation of intracapsular fractures was introduced by Hey Groves (1916) and Smith-Petersen described a trifin nail in 1937 (Smith-Petersen 1937) (Fig 1.20 - 1.21). The advantage of these devices was that they were easy to insert over a pre placed guide wire and the operation could be performed as a percutaneous technique. Although some control over rotation was conferred by the finned nature of the nail the stability depended on contact of the fracture fragments. A solution to the problem was to drive the nail through the head and into the acetabulum (Jarry 1964). This conferred increased stability but the result was lack of hip movement. The other disadvantage of single nails was the tendency to disimpact or distract the fracture fragments as the nail was driven across the fracture (Bentley 1968).

When compared with other devices in a large multicentre series of hip fractures single nails were associated with non-union in 55% of cases at one year and performed the worst of all fixation devices (Barnes 1976).

The fixation of displaced intracapsular fractures with a single nail should be of historical interest only.

Fig 1.20 The principle of three point fixation with a single nail.

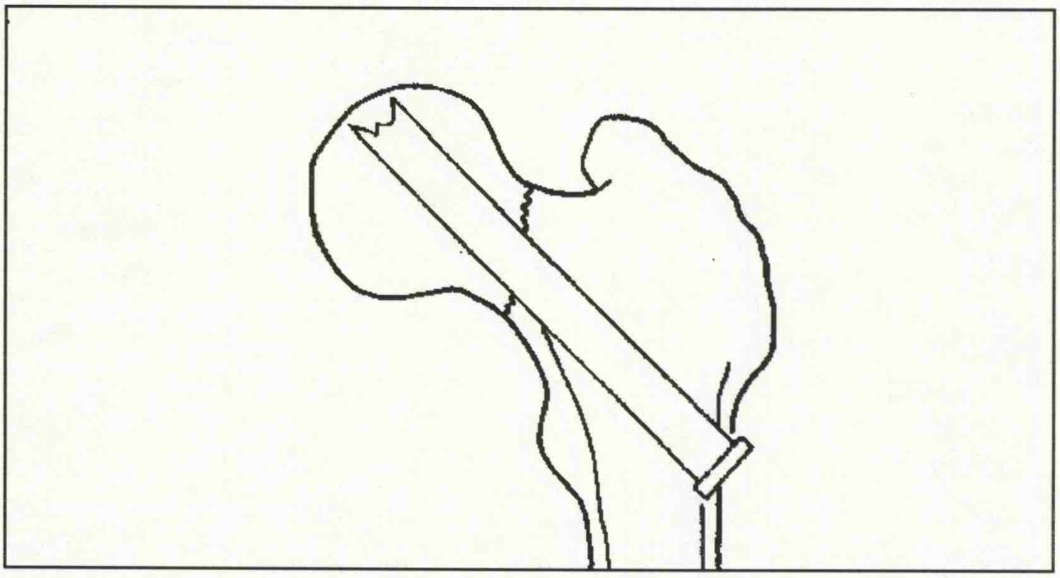
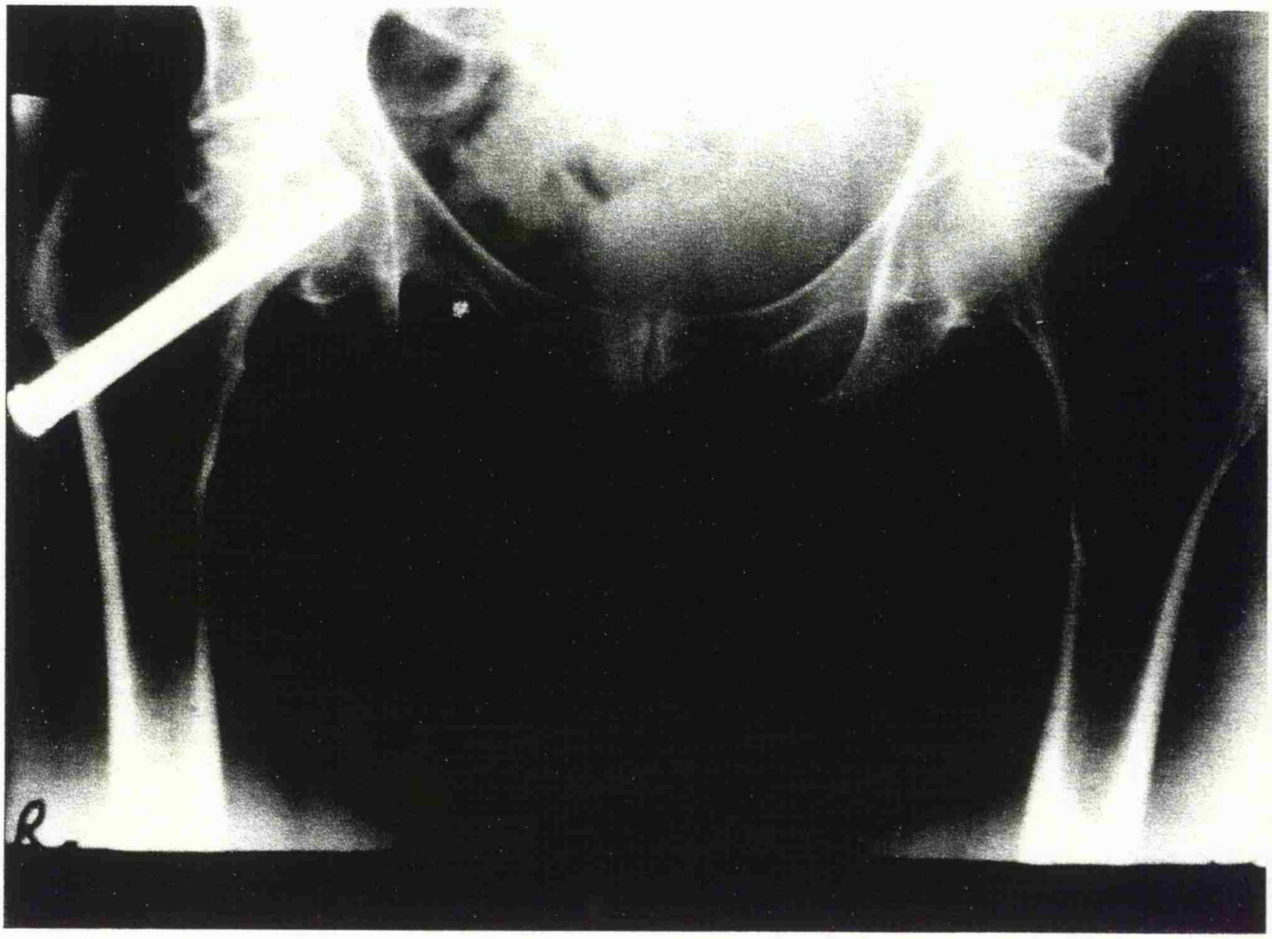


Fig 1.21 An antero-posterior radiograph of an intracapsular fracture internally fixed with a single nail.



1.8.4 internal fixation with multiple pins.

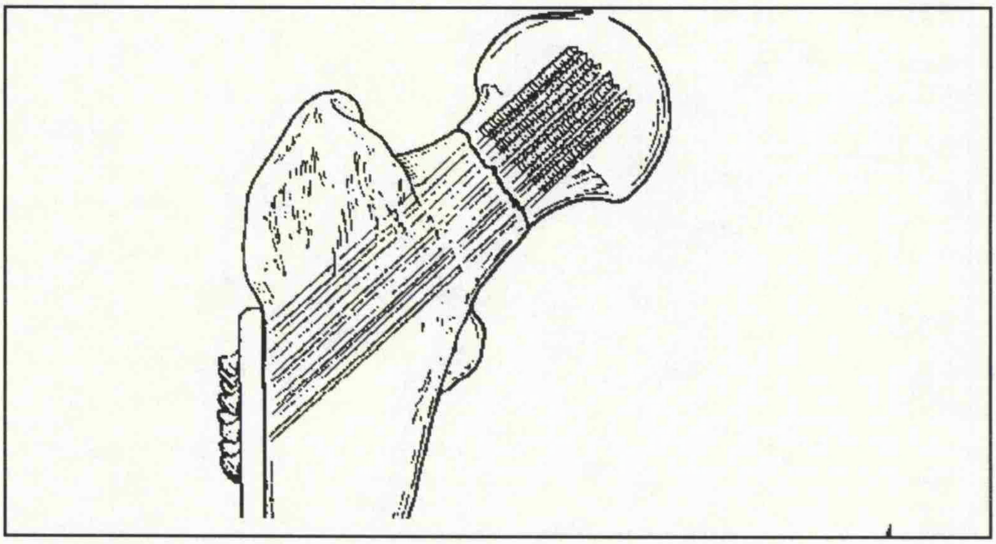
The simplest method of internal fixation of intracapsular proximal femoral fractures is with multiple pins, and this was one of the first methods used (Langenbech 1850). The pins that have been most commonly used are the Moore, Knowles or Deyelre (Fig 1.22).

Moores or Knowles pins may be inserted percutaneously under local anaesthetic. Peripheral placement of the pins in the femoral head is recommended in the shape of either a parallelogram with four pins (Moore 1937) or a triangle with three pins (Arnold 1974). Convergence of the pins is associated with higher rates of failure of fixation (Moore 1935). To improve fixation in osteoporotic bone it is recommended that the pins are placed in subchondral bone (Arnold 1974).

Because of the difficulty in obtaining good lateral support for multiple pins (Green 1960) a side plate with an increased number of pins was recommended (Deyerle 1959). Deyerle stressed the importance of a slight valgus over reduction on the anteroposterior view, placement of at least nine pins and "good hammer percussion impaction" (Deyerle 1980) (Fig 1.23). Although his own results were good with a 1.8% non-union and 9% avascular necrosis rate (Deyerle 1980) the technique itself is a difficult one and other authors have not produced such good results , with failure rates of up to 50% for combined avascular necrosis and non-union at one year (Baker 1978, Chapman 1975).

Fig 1.22 An antero-posterior radiograph of a fracture fixed with multiple pins.

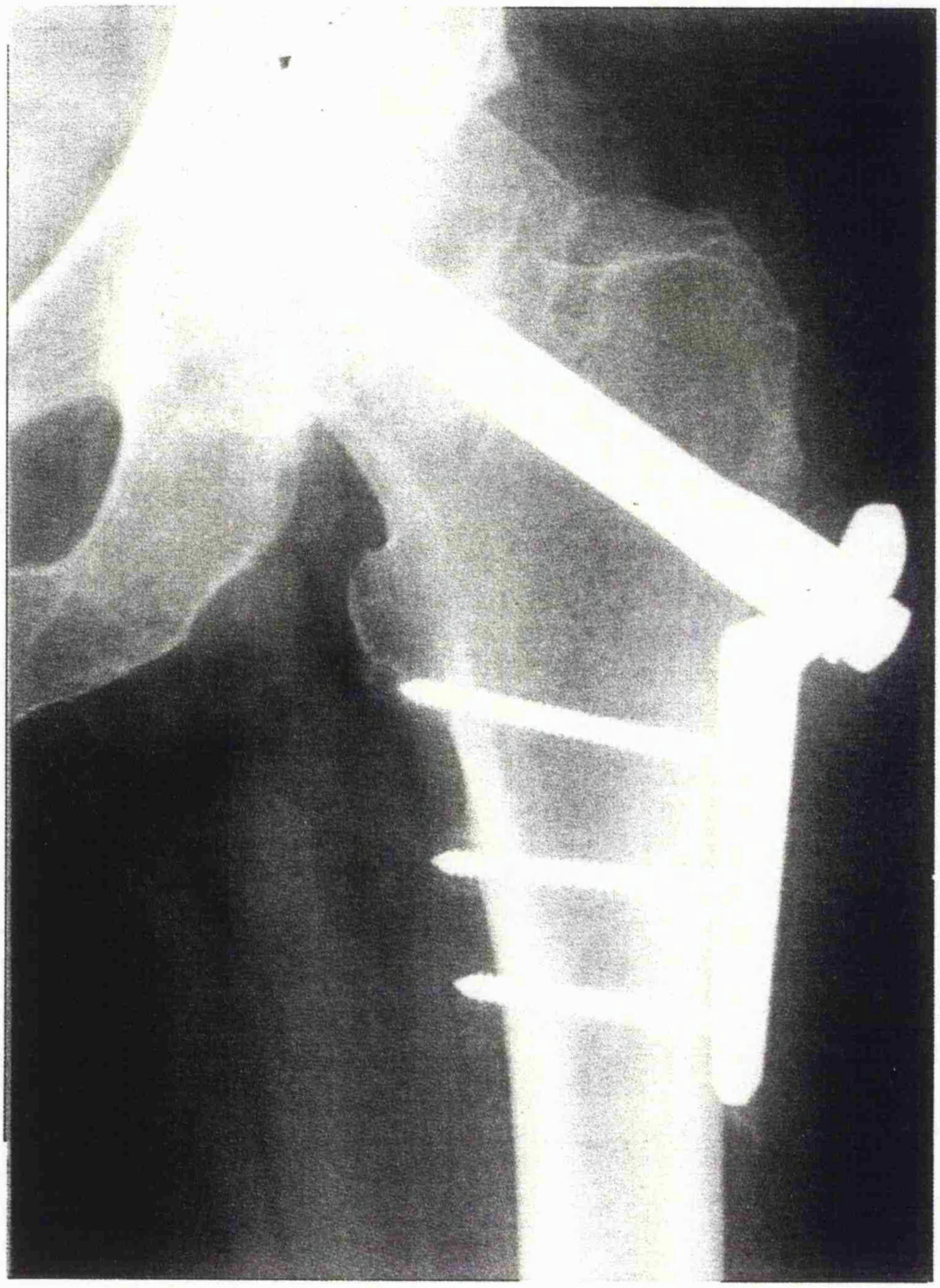
Fig 1.23 The device of Deyerle showing the addition of a side plate to multiple pins used for fixation.



1.8.5 Internal fixation with nail plates.

To overcome the problems of lack of lateral support and in the hope of improving rotational stability plates were added to single nails. These may either be a separate plate which is attached to the nail by a bolt, such as the McLaughlin nail plate, or fixed angle devices where the nail and plate form an integral unit, such as the Jewett nail plate (Jewett 1941) (Fig 1.24). Although union rates were higher than when compared to single nails (Frangakis 1966), these devices still produced combined complication rates (for both avascular necrosis and non-union) of around 50% (Svennigsen 1984). The problem of distraction of the fracture during implant insertion remained with these devices with the added complication that as the fracture collapsed the nail did not back out of the head but rather protruded through into the hip joint itself and damaged the acetabulum .

Fig 1.24 An antero-posterior radiograph showing a nail plate used for fixation of an intracapsular fracture.



1.8.6 Internal fixation with sliding screw plates.

In comparison to a triflanged nail a large threaded screw provides stronger fixation (Brodetti 1961), because the flat surface of the screw provides a larger area per unit force.

Thus to improve the fixation and retain the advantages of controlled compression that was allowed with a sliding nail plate a sliding screw plate was introduced (Schumpelik 1955).

With this device non-union rates of approximately 25% have been reported (Skinner 1986, Skinner 1989).

A potential disadvantage of the sliding screw plate system is the potential of the screw to rotate the head fragment during insertion, this is apparent both clinically (Rau 1982) and experimentally (Mills 1989). This rotational malalignment may cause compression of the retinacular vessels or allow incongruity between the head and the acetabulum and thus the early development of degenerative disease within the hip (Garden 1974). To prevent this rotation during insertion of the screw, supplementary guide wires can be used to hold the head fragment in position. Other authors have recommended use of a supplementary screw or pin to be used in addition to the large screw (Quinby 1986). This supplementary screw must lie exactly parallel to the main screw otherwise the sliding properties of the device will be lost, causing jamming (Fig 1.25).

Another potential cause of jamming is insufficient engagement of the shank of the screw in the barrel of the plate (Kyle 1980).

If, despite all these efforts rotational malalignment does occur this can be corrected at the time of surgery by using the screw in the head to gently derotate the head fragment and thus restore reduction (Muirehead 1989). However the head fragment must not be rotated to obtain a reduction if one cannot be achieved by other means because of the risk of twisting the vessels supplying the femoral head and thereby obstructing flow (Madsen 1987).

To provide compression at the time of surgery and confer additional stability to the fracture a compression screw can be used. This is inserted into the barrel of the plate and engages in a thread in the shank of the large screw (Fig 1.26). Care must be exercised in using the additional screw in osteoporotic bone because of the risk of rotating the screw in the head and stripping the thread in the bone (Frandsen 1983, Husby 1989).

The use of sliding screw plates requires care and, in some reports of the use of this device, the operating surgeon may not have been aware of all the important technical factors that can influence outcome thus producing unacceptable failure rates (Christie 1988). The careful use of the sliding screw plate care has produced much lower failure rates of approximately 20% (Skinner 1986) (Fig 1.27).

Fig 1.25 An antero-posterior radiograph of an intracapsular fracture fixed with a sliding screw and plate with a supplementary screw showing non-parallel placement of the supplementary screw.

Fig 1.26 The use of a compression screw to provide additional compression at the time of surgery.

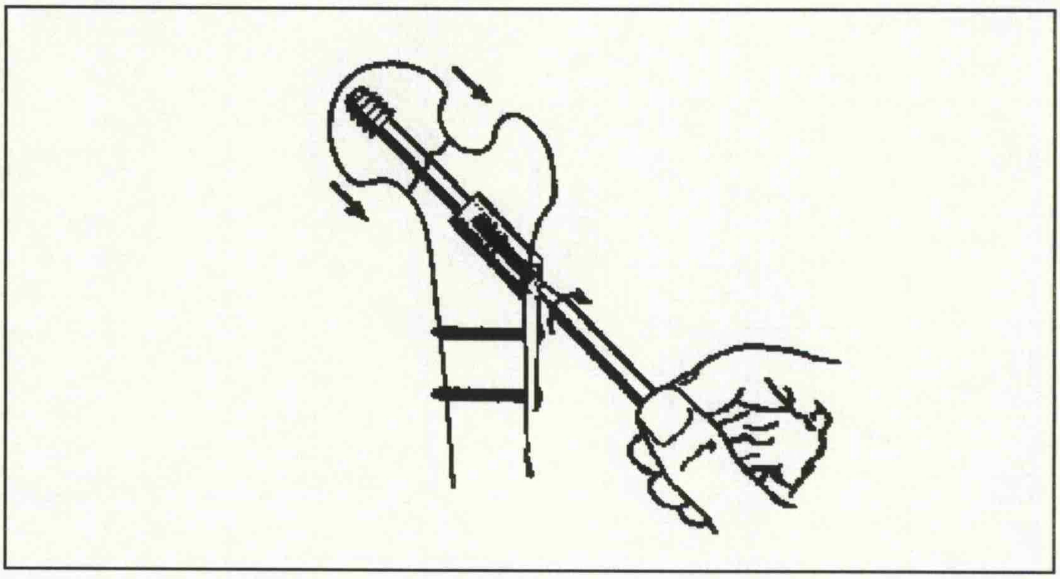
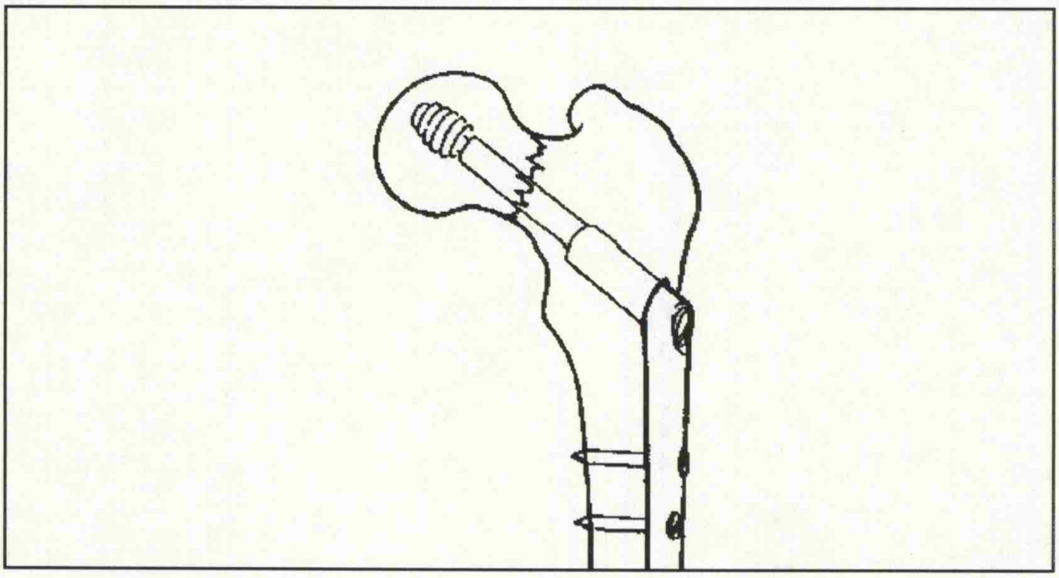


Fig 1.27 The sliding hip screw (Ambi hip screw).



1.8.7 Internal fixation with multiple screws.

Garden devised a crossed screw system (Garden 1961(b)). The two screws are inserted one inferiorly resting on the calcar and one superiorly crossing the inferior screw (Fig 1.28). These crossed screws form a rigid double lever system with a common fulcrum at the fracture site and lateral fixation to the femoral cortex which theoretically equilibrates the forces acting on the head.

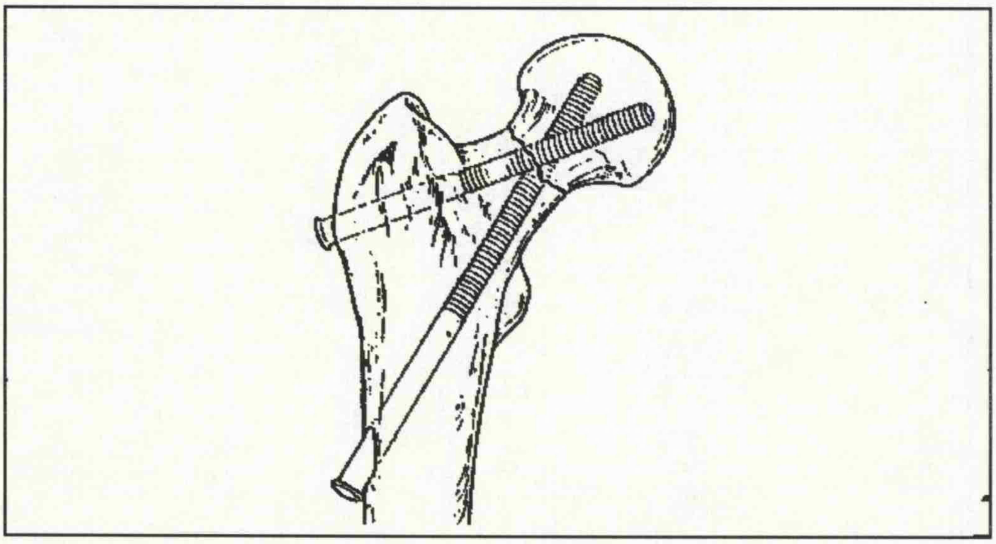
Cross screw fixation does not allow the screws to back out as the fracture site collapses, however if the screws are placed parallel this can occur. A retrospective comparison between crossed and parallel placement of Garden screws has shown a lower rate of non-union and avascular necrosis at two years post injury compared with parallel placement of the screws (Parker 1991).

In vitro biomechanical testing has shown a triangular parallel pin configuration to be the strongest with one screw inferiorly and two superiorly (Schwartz 1981, Mizrah 1980).

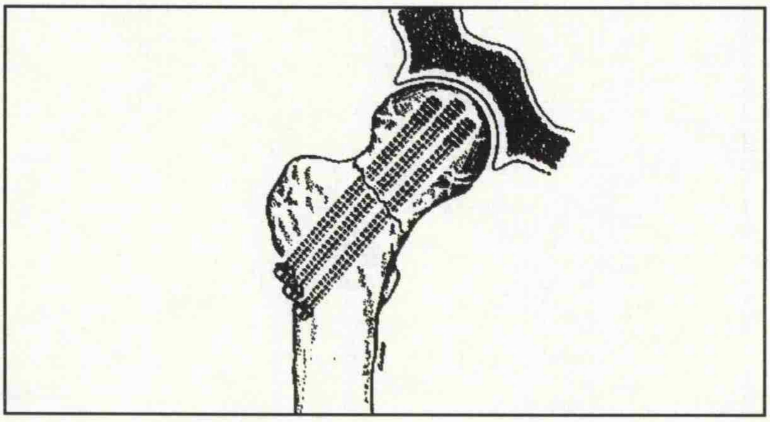
Results with parallel cancellous screw fixation have shown encouraging results (Wood 1991, Kuokkanen 1991). However a worrying complication reported with multiple screws is subtrochanteric fractures through the lower screw site (Andrew 1984, Neuman 1990).

To improve parallel placement of lag screws several cannulated systems have become available (Wood 1991) (Fig 1.29).

Fig 1.28 Cross screw fixation using Garden screws.



<u>Fig 1.29 Cannulated screw system (Richards).</u>



1.8.8 Internal fixation with hook pins.

Hook pin fixation was devised by Hansen (Stromqvist 1992). The system consists of two parallel pins with hooks at the end which are extended when the pins are in place. A comparison between hook pins and the Rydell nail (a four flanged nail) showed the results with hook pin fixation to be superior in one series (Stromqvist 1984), however another series has shown no difference in results (Sernbo 1990). Two year results show 25% avascular necrosis and failure rates for all fractures (Stromqvist 1987). However these results are not significantly better than those achieved with multiple cannulated screws (Wood 1991) or Sliding Screw plates (Skinner 1986, Hegge 1989) and this method of fixation has not gained wide popularity in the United Kingdom.

1.8.9 Internal fixation with a prong plate.

Recently a description has appeared in the literature of a prong plate for the fixation of displaced proximal femoral fractures.(Yamano 1989) The device consists of a side plate and two prongs 40 mm in diameter at a 60 degree angle to the plate. Implantation of the device requires an open reduction, the fracture is reduced and following this the prongs introduced into the femoral head and the side plate is secured to the greater trochanter.

The only report of this device in the English literature is of a very small series of 32 patients whose mean age was only 48.5 yrs (Yamano 1989). The rate of non-union was 9.3% and the avascular necrosis rate was 13.8%. These results from a single centre with a device designed by the author are not surprising considering the relative youth of his series. It is unlikely that this device, particularly because of the need for open reduction, confers any advantage over other means of fixation.

1.9 Treatment of displaced intracapsular fractures by prosthetic replacement

1.9.1 Treatment of displaced intracapsular fractures by Hemiarthroplasty

The first recorded use of a hemiarthroplasty to treat intracapsular proximal femoral fractures was by Hey-Groves in the 1920's, using an ivory endoprosthesis (Hey-Groves 1927).

In the 1950's reports started to appear in the literature of unipolar endoprostheses being used in the treatment of displaced intracapsular fractures.

The use of a clear acrylic prosthesis was reported to give satisfactory results in the treatment of intracapsular proximal femoral fractures in 70% of cases (Judet 1950), however the anchorage of this innovative prosthesis was by a very short stem and high rates of loosening were reported (Fig 1.30)

The two most commonly used unipolar endoprostheses in common use are the Thompson and the Moore (Fig 1.31 and Fig 1.32)

The Moore endoprosthesis was originally used to replace the proximal femur in a case of giant cell tumour (Moore 1943). Subsequently it became widely accepted in the treatment of displaced intracapsular proximal femoral fractures in the elderly.

The Moore endoprosthesis is a straight stemmed prosthesis with fenestrations which theoretically allow the ingrowth of bone into the prosthesis. The prosthesis was designed to be calcar bearing and the neck of the femur to be sectioned 1/2 - 3/4 inch above the calcar.

Reports of the use of Moore endoprostheses have been disappointing in long term follow-up with 42% of patients experiencing hip or thigh pain (Pun 1988) and only 47% of patients being able to move about independently five years after fracture when treated with a Moores endoprosthesis as compared to 82% of non fracture controls (Jalovaara 1991).

The Thompson's endoprosthesis was used initially for the treatment of non-unions resulting from displaced intracapsular proximal femoral fractures. The stem is banana shaped and it was originally designed to be used without cement, although more recently surgeons have used it with cement (Gingras 1980).

Results with the Thompson prosthesis have been as disappointing as the Moore with reports of up to 50% poor results (Hunter 1980).

Fig 1.30 The Judet prosthesis.

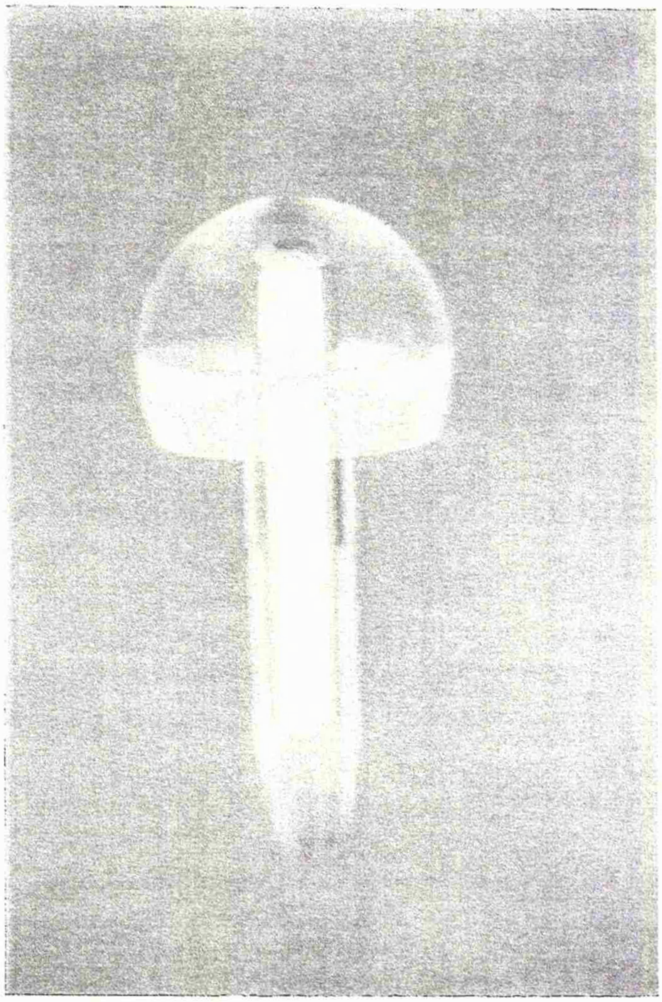


Fig 1.31 The Moore prosthesis.

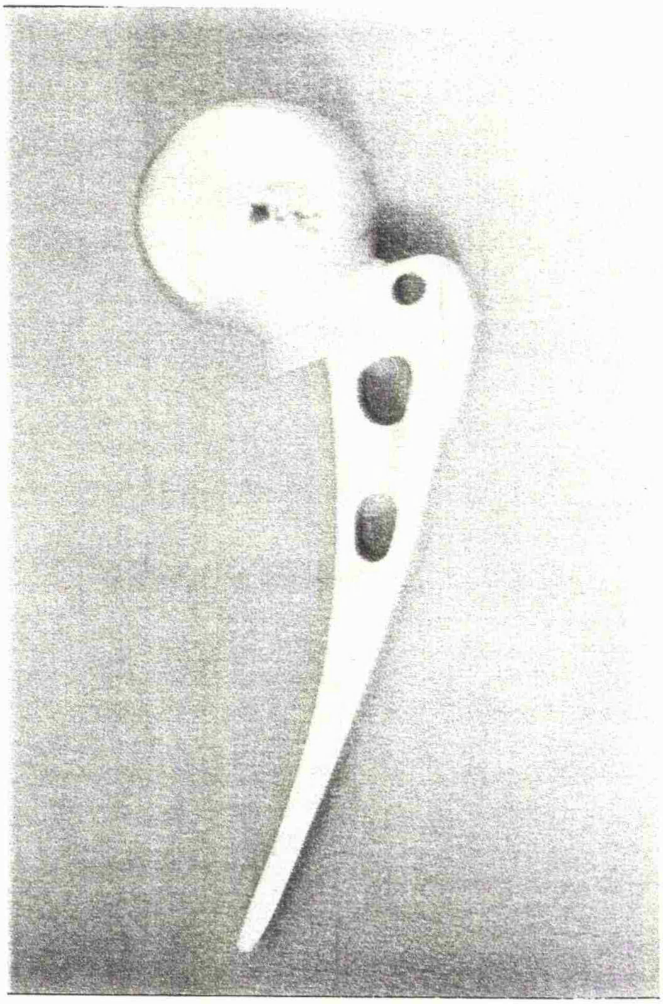
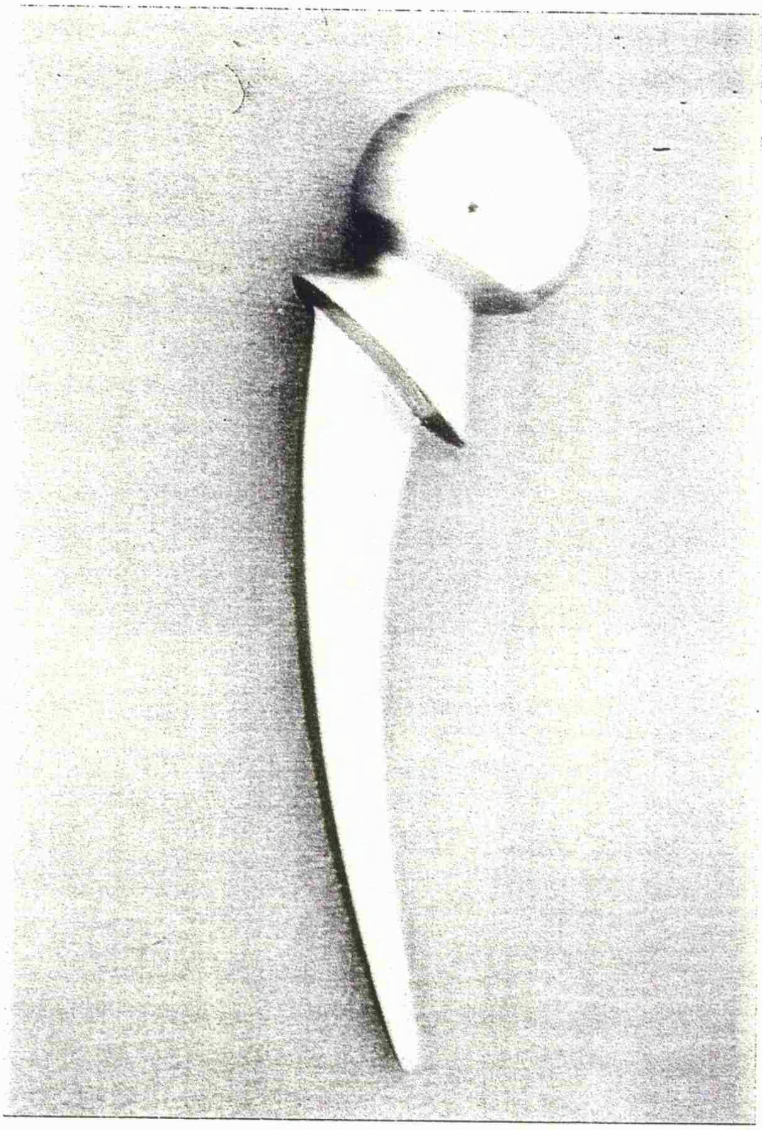


Fig 1.32 The Thompson prosthesis.



1.9.2 Treatment of displaced intracapsular fractures by biarticular replacement.

Because of the problems of acetabular wear with simple endoprostheses, biarticular prostheses were developed in an attempt to counteract this problem. The biarticular prosthesis consists of a metal head which articulates with a cup. The cup has a further articular surface to articulate with the acetabulum. This has the theoretical advantage of distributing loads and forces more normally and thereby reducing wear on both the articular cartilage of the acetabulum and the implant.

The Monk endoprosthesis was introduced in 1970 and the Bateman bipolar prosthesis was introduced in 1974 (Bateman 1974) (Fig 1.33). The original Monk prosthesis was a "soft top" (Fig 1.34) with the outer acetabular cup of polyethylene was replaced with a "hard top" in 1976 because of osteolysis around the acetabular cup due to polyethylene debris (Hansen 1977, Webb 1980). In this type the polyethylene cup is covered with a cap of stainless steel (Fig 1.35). Since the introduction of bipolar prostheses there have been reports published on the Batemean, Monk, Hastings and Christianson.

A review of 307 Hastings prostheses implanted for between 1-9 years showed 95% with no pain and 69% walking unaided or with 1 stick (Wetherall 1990). However although purported to be a ten year review the authors had very small numbers reviewed after 3 years. Acetabular erosion was 5.5% at one year.

A unique complication of biarticular prostheses is interprosthetic dislocation. The rate of interprosthetic dislocation when reported varies between 0.4 - 1 % (Bochner 1988, Wetherall 1990). Interprosthetic dislocation, although representing a small proportion of complications is an serious event, always requires open reduction of the dislocation.

The theoretical reduction of wear with the biarticular prosthesis is consequent on two factors, movement between the femoral component and the polyethylene liner of the socket and of the probable shock absorbing effect of the polyethylene between the head and the acetabulum. Whether this interprosthetic movement occurs in vivo has been questioned. Mess (Mess 1990) studied 14 patients at a mean interval of 2.6 years post surgery with a Bateman bipolar endoprosthesis. They carried out a radiological evaluation of component motion in weight bearing and non-weight bearing positions. In all movements of the hip extraprosthetic movement accounted for 50% and intraprosthetic for 50% of total movement when non-weight bearing, with weight bearing the ratio between inner and outer movement was a ratio of 3:1.

Bochner et al (1988) found less prosthetic movement but the study was only six months following surgery.

Less exact studies using fluoroscopy have shown no intraprosthetic movement (Phillips 1987).

It is possible that reduction of movement occurs early after implantation of the prosthesis (Verberne 1983).

It seems from the result of several studies that intraprosthetic movement, if it occurs at all, accounts for only a small proportion of total prosthetic movement and the supposed reduction of acetabular wear, which has not been confirmed in any randomised prospective study, may be related to the shock absorbing effect of the polyethylene liner.

Although authors have attempted to retrospectively compare the results of biarticular replacements with unipolar there have been no randomised prospective trials comparing one with the other

Fig 1.33 The Bateman bipolar prosthesis.

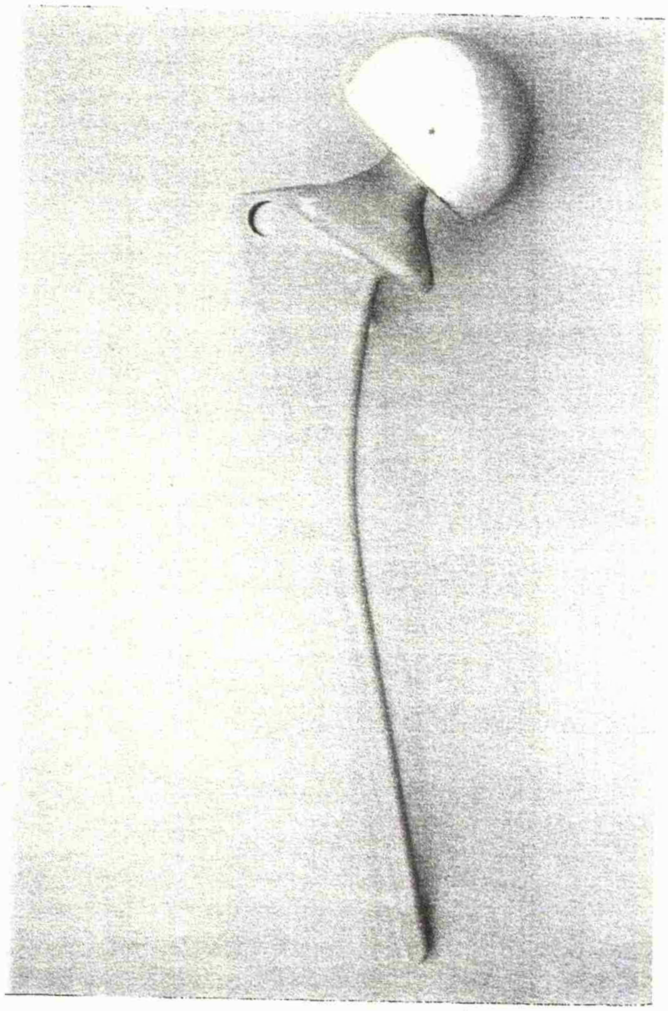


Fig 1.34 The Monk "soft top" prosthesis.

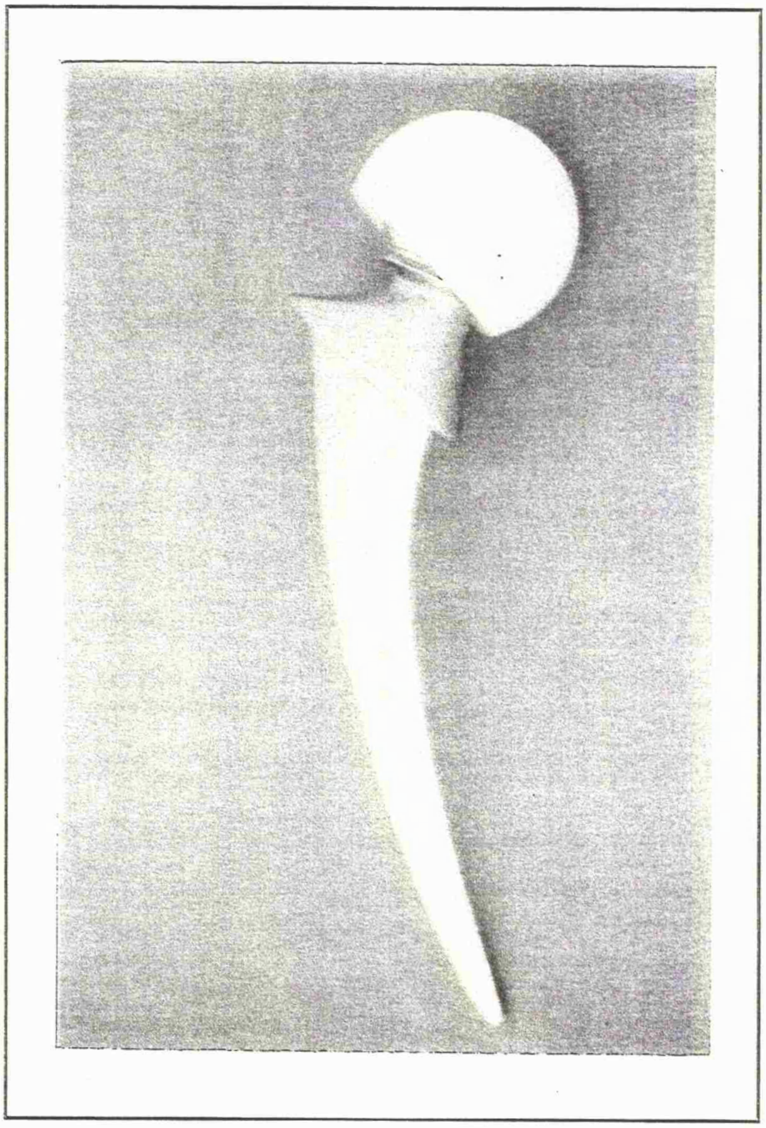
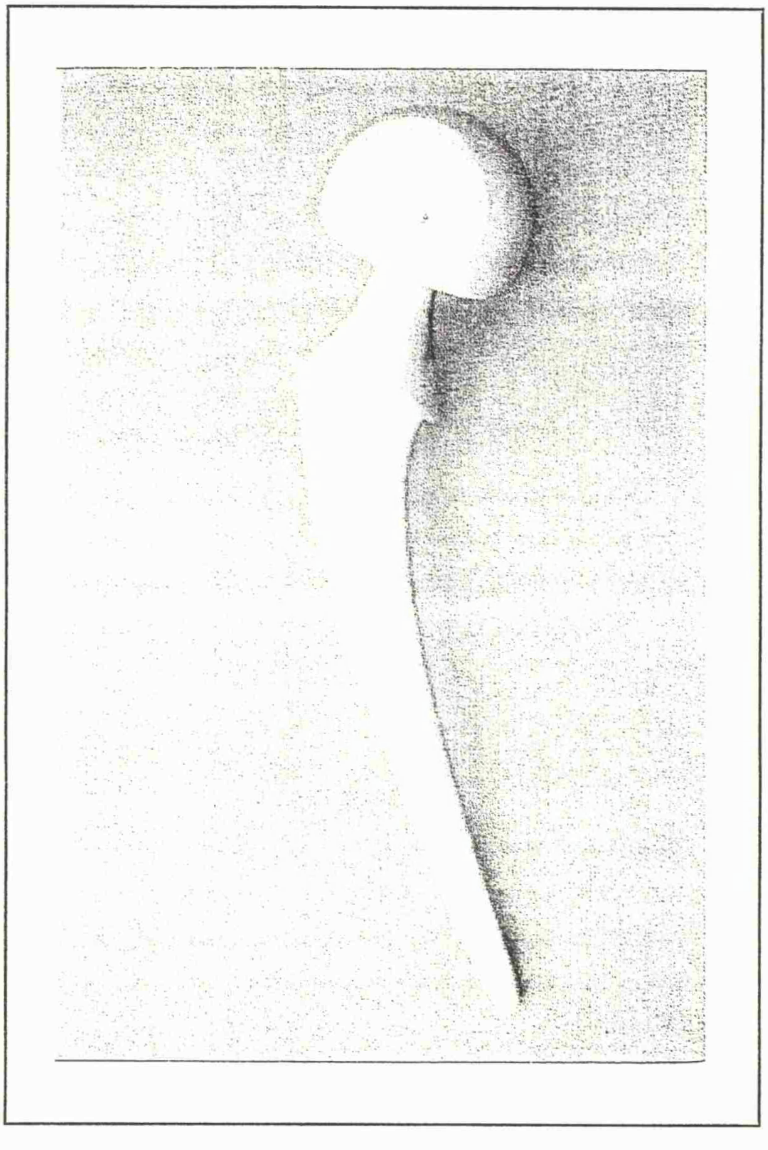


Fig 1.35 The Monk "hard top" prosthesis.



1.9.3 The treatment of displaced intracapsular fractures by total hip replacement

Because of the known complications of hemiarthroplasty and the fact that some patients with hemiarthroplasties will require revision to total hip replacement it has been suggested that total hip replacement should be the operation of first choice. Total hip replacement is a more complex and traumatic operation than either hemiarthroplasty or closed reduction and internal fixation and may be associated with higher complication rates.

There have been limited reports in the literature of primary total hip replacement for fresh intracapsular proximal femoral fractures, and the majority of these have very short review periods, some as little as 12 months (Sim 1980) which is too early to assess the results of total joint replacement.

Early complication rates from published papers (Sim 1980, Taine 1985, Delamarter 1987, Greenough 1988) are comparable with standard total hip replacement apart from the dislocation rate, which in some series is greater than 10% (Sim 1980, Taine 1985). These dislocation rates are much higher than in series of total hip replacements for degenerative disease. The reason for this difference in dislocation rates is unclear, but factors that could be operating include the relative laxity of the periarticular tissues in comparison to the fibrosis and joint contractures around a degenerative hip. Perhaps a more important factor is the mental state of the patient, with a higher proportion of intracapsular proximal femoral fracture patients being cognitiveley impaired in comparison to patients undergoing total hip replacement. Mortality is also higher in these patients but not significantly higher than comparable series of femoral neck fractures treated by other means.

Following total hip replacement up to 37% of patients do not regain their prefracture mobility levels at one year post fracture (Sim 1980), which is comparable to the proportion from other series of different methods of treating proximal femoral fractures.

The main argument of those who propose total hip replacement is the supposed lower requirement for revision surgery. Greenough et al (1988), who had the longest follow-up period of an average of 55 months found 49% of patients had, or were waiting for, revision surgery. They, in addition reported a further 11% of patients had evidence of radiological loosening. These results are disastrous, and are in a younger group of patients (under 70 years of age) who would most benefit from the supposedly increased longevity of total joint replacement as opposed to hemiarthroplasty.

These disastrous results may reflect some peculiarities of implant or technique, but other series have reported revision rates of 12% at 3 years (Taine 1985).

From the majority of published literature there does not appear to be a clear indication that total hip replacement is superior to other methods of treatment, indeed in some cases it may be inferior. In addition to this are the economic implications of treating all intracapsular proximal femoral fractures with total hip replacements. Total hip replacements cost more than fixation devices or hemiarthroplasties, they take longer to perform and require more specialised theatres. To give a local example, if total hip replacement was instituted as a method of primary treatment in Leicester, more than one total hip replacement would be performed every day in a non clean air theatre by junior trainees and without consultant supervision in the majority of cases.

These factors together with the lack of a proper randomised prospective trial comparing total hip replacement with other methods of treatment mean that total hip replacement for intracapsular fractures should be reserved for special cases ie preexisting degenerative hip disease or some pathological fractures through tumour.

1.10 Complications of intracapsular proximal femoral fractures

1.10.1 General

The major complication of proximal femoral fractures, however treated, is mortality. Mortality rates at 6 months vary between 12 and 40%, with the highest increase in mortality being in the first 3 months following fracture (Bauer 1990) .

The mortality following fracture increases with increasing age. In a study of 209 patients 6 month mortality was 19% in patients aged between 65-69 years of age and increased to 63% in patients over 85 years of age (Evans 1979(a)).

In the same study another important factor determining mortality rates was mental function. A scoring system was used which was a variation of the mental function score devised by Blessed (Blessed 1968). A mental test score (MTS) using a maximum 13 point scoring system showed a significant difference in mortality between patients with high MTS (greater than 11) than those patients with a low MTS (Less than 3) (Evans 1979(a)).

These results have been confirmed in a multivariate analysis of factors predicting survival using the same mental function score. Patients greater than 75 years of age and who had a low mental test score had a much higher mortality than patients with high mental test scores (Ions 1987). Very few studies of proximal femoral fractures have taken into account this very important variable.

Other factors that are significantly related to early mortality are place of injury (whether the fracture was sustained inside or outside the house) and post operative chest infection (Wood 1992).

Although studies comparing primary prosthetic replacement with internal fixation must be interpreted with care there seems to be little difference in mortality between the two methods of treatment. (Riley 1978)

Although the cause of death in the majority of studies is not known accurately because of the lack of post mortem data thromboembolic disease may account for up to a 10% of early mortality following emergency hip surgery (Sevitt 1961, Hull 1986) and deep venous thrombosis may occur in 40 - 50% of patients who do not receive thromboprophylaxis (Stevens 1968, Hamilton 1970).

Pressure sores are a serious complication of hip fracture, occurring in nearly 30% of patients sustaining this injury (Jensen 1987). The most common site for these sores is the sacrum and buttock area (55%) and the heel and calcaneal region (29%) (Jensen 1987). The most important factor in developing sores is the age of the patient, with the majority of sores developing in patients over 80 years of age (Versluysen 1985). The consequence of pressure sores is an increase in length of hospital stay, nearly doubling the stay of patients in one study (Jensen 1987)

1.10.2 Complications following prosthetic replacement

Rates of dislocation following primary prosthetic replacement vary between 5 and 10% with a higher dislocation rate associated with posterior approaches to the hip joint (Chan 1975, Wood 1979-80). The higher dislocation rate seen following prosthetic replacement for trauma as compared to replacement for degenerative disease may reflect laxer pericapsular tissues or the mental state of the patient and postoperative confusion. Specific conditions that increase the dislocation rate are hemiplegia, Parkinsons disease or epilepsy. Dislocation is a potentially serious complication and has been reported to be associated with an increase in post-operative mortality of up to 50% (Paton 1989).

When a bipolar endoprosthesis is used dislocation of the prosthesis may be accompanied by interprosthetic dislocation which can only be treated by open reduction and reassembly or replacement of the prosthesis (Anderson 1978, Moller 1983, Rae 1988, Harvey 1991).

A late complication of prosthetic endoprostheses is acetabular erosion which may cause pain (Fig 1.36). The rates of acetabular erosion have been reported as high as 64% at 5 years and protrusio acetabulae as 24%. Acetabular wear may be higher if the prosthesis is cemented (Maxted 1984). The bipolar prosthesis is designed to reduce the incidence of acetabular wear, however studies have been non-randomised and until the results of randomised prospective trials are available this remains unproven.

Originally both the Moore and the Thompson endoprosthesis were designed to be used without cement and provide an interference fit between the prosthesis and bone. With the advent of polymethylmethacrylate it came to be used to secure the prosthesis to the bone. There is still controversy as to whether the Thompson prosthesis should be used with or without cement.

Infection following elective total hip replacement is reported to be 1-2% (Charnley 1969), however infection rates following hemiarthroplasty for proximal femoral fractures is reported to be much higher (Arnold 1974). Infection following hemiarthroplasty should be treated as any other infection, however in the elderly frail patient these infections may be associated with a high mortality, sometimes as high as 60% (Hinchey 1964).

These reports of high infection rates were often in the absence of prophylactic antibiotic treatment (Chan 1975). Double blind studies comparing prophylactic antibiotic use with placebo have shown consistent reductions in rates of infection when prophylactic antibiotics were used, with infection rates being reduced from just under 5% with antibiotics to just under 1% with antibiotics (Boyd 1973).

Fracture or perforation of the femur may occur at the time of surgery, if such a fracture or perforation is recognised at the time of occurrence and treated accordingly results should be satisfactory. Late fractures occur often in the presence of osteopenia and may be difficult to manage with high rates of non-union (Parrish 1964, Harrington 1978, Cooke 1984) (Fig 1.37).

Fig 1.36 An anteroposterior radiograph showing acetabular erosion and secondary loosening of the femoral stem of a Thompson prosthesis.

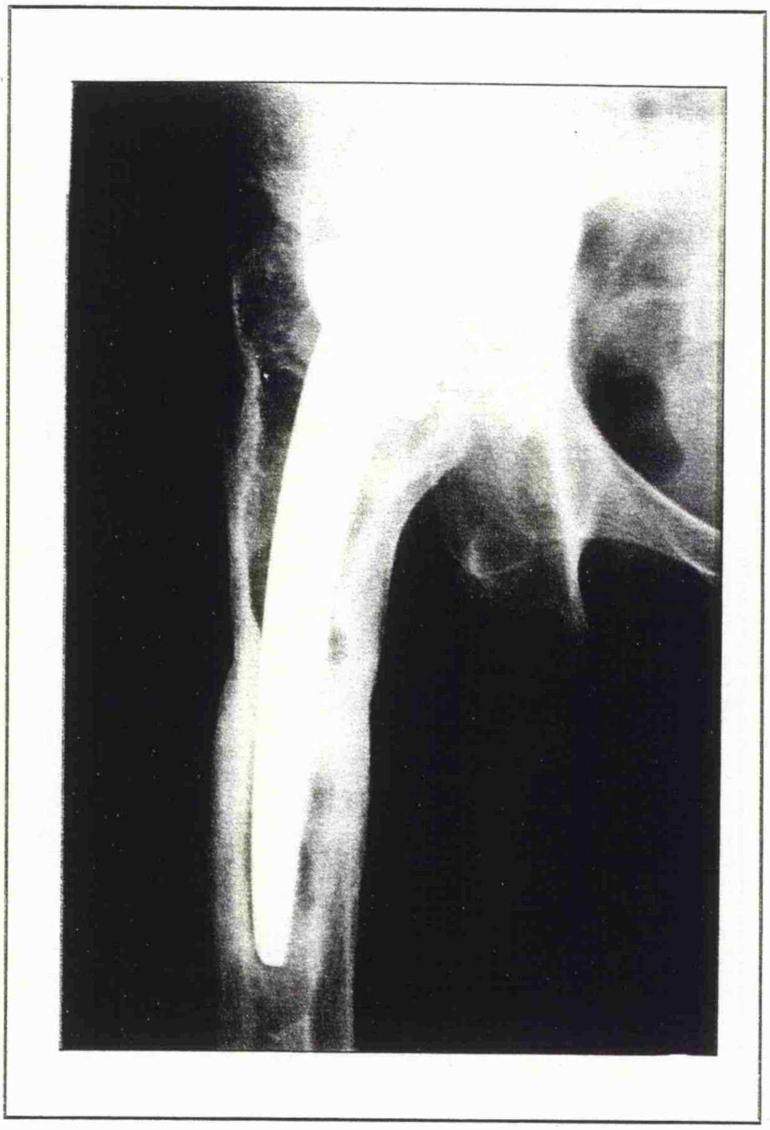
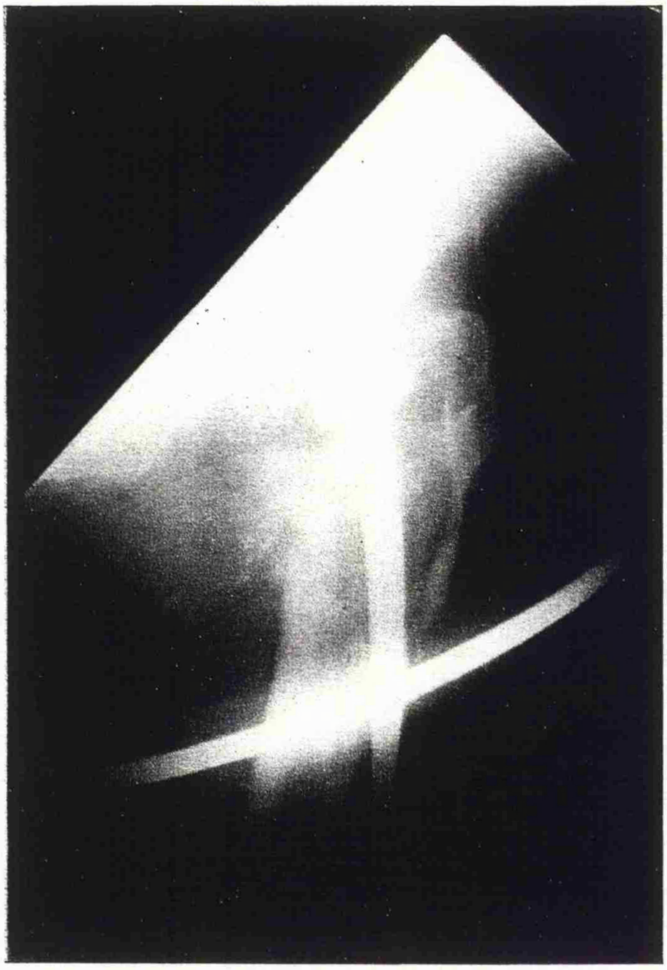


Fig 1.37 A lateral radiograph showing a femoral fracture around the stem of a Thompson prosthesis.



1.10.3 Complications following internal fixation.

1.10.3.1 Non-union.

Astley Cooper recognised that if a displaced intracapsular proximal femoral fracture was untreated it was highly unlikely to unite.

The incidence of non-union is related to the stage of fracture as defined by Garden with Stage 4 fractures having a higher rate of non-union (Garden 1961).

The incidence of non-union is increased by poor reduction and inadequate fixation (Garden 1961, Arnoldi 1974, Kofoeld 1980, Holmberg 1987).

Using modern methods of fixation rates of non-union in displaced fractures can be reduced to around 20% (Wood 1991, Stromqvist 1992).

Although non-union is probably closely related to the degree of vascular injury to the femoral head at the time of fracture (Hulth 1965) adequate fixation may produce union even in the presence of a diminished blood supply (Stromqvist 1983), whereas inadequate fixation by inexperienced surgeons increases the rate of non-union (Holmberg 1987).

1.10.3.2 Osteonecrosis.

Osteonecrosis following intracapsular proximal femoral fracture is probably the result of a combination of damage at the time of fracture and compression of the intracapsular vessels left supplying the neck by intracapsular haematoma (Tucker 1950, Stromqvist 1983, Stromqvist 1985, Wingstrand 1986). Osteonecrosis may lead to structural failure and late segmental collapse (Fig 1.38).

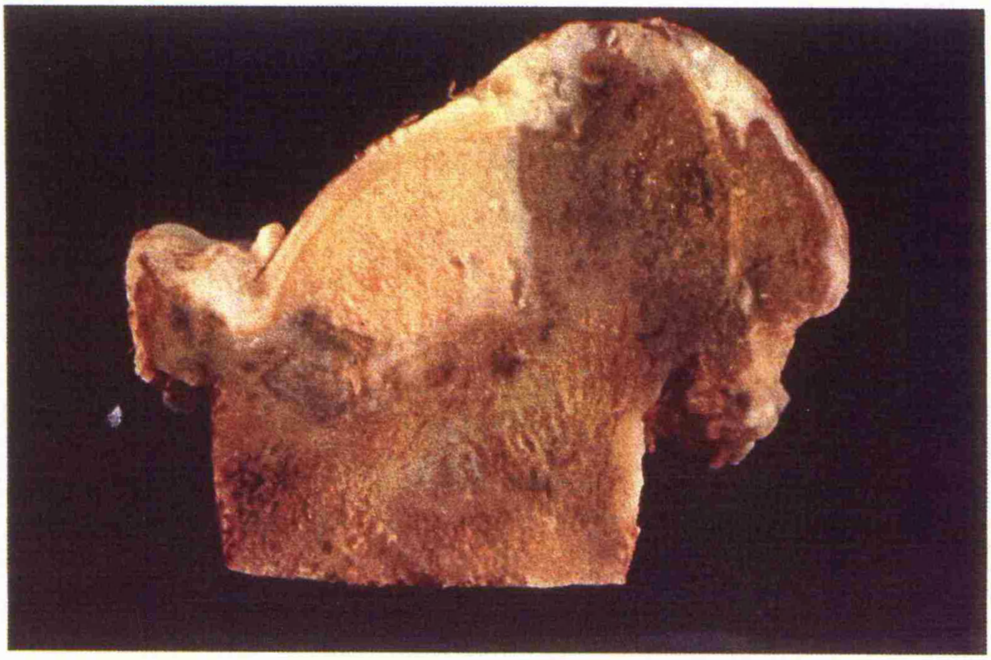
The incidence of osteonecrosis following fracture is not known, because osteonecrosis itself may be asymptomatic.

Sevitt in a arteriographic examination of retrieved femoral heads found evidence of partial or total necrosis in 84% of the 25 femoral heads studied (Sevitt 1964). These results have been corroborated in other studies (Catto 1965(a)). Often the retinacular vessels were torn or damaged and the femoral head relied on supply from the ligamentum teres which was intact and injected in all but two cases of Sevitt's series. In the two cases where the ligament was torn one had been caused by the egress of a nail. However nailing of intact previously injected cadaveric specimens has shown little effect on femoral head vascularity by the nail.

Union can occur in the presence of osteonecrosis, as has been well demonstrated by several authors (Phemister 1939), and whether the presence of poor vascularity is more likely to lead to early failure remains to be conclusively proven, although scintigraphic studies have suggested that poorly vascularised femoral heads are more likely to suffer from early healing complications (Stromqvist 1987).

Revascularisation itself may be a cause of late failure. The process of revascularisation may lead to a revascularisation front between dead and alive bone and it is through this area that subchondral fracture and late segmental collapse may occur. Avascular necrosis per se does not cause pain. Symptoms develop either as a result of the subchondral plate fracture and segmental collapse or are due to subsequent degenerative disease.

Fig 1.38 A sagittal section of a femoral head showing avascular necrosis and segmental collapse.

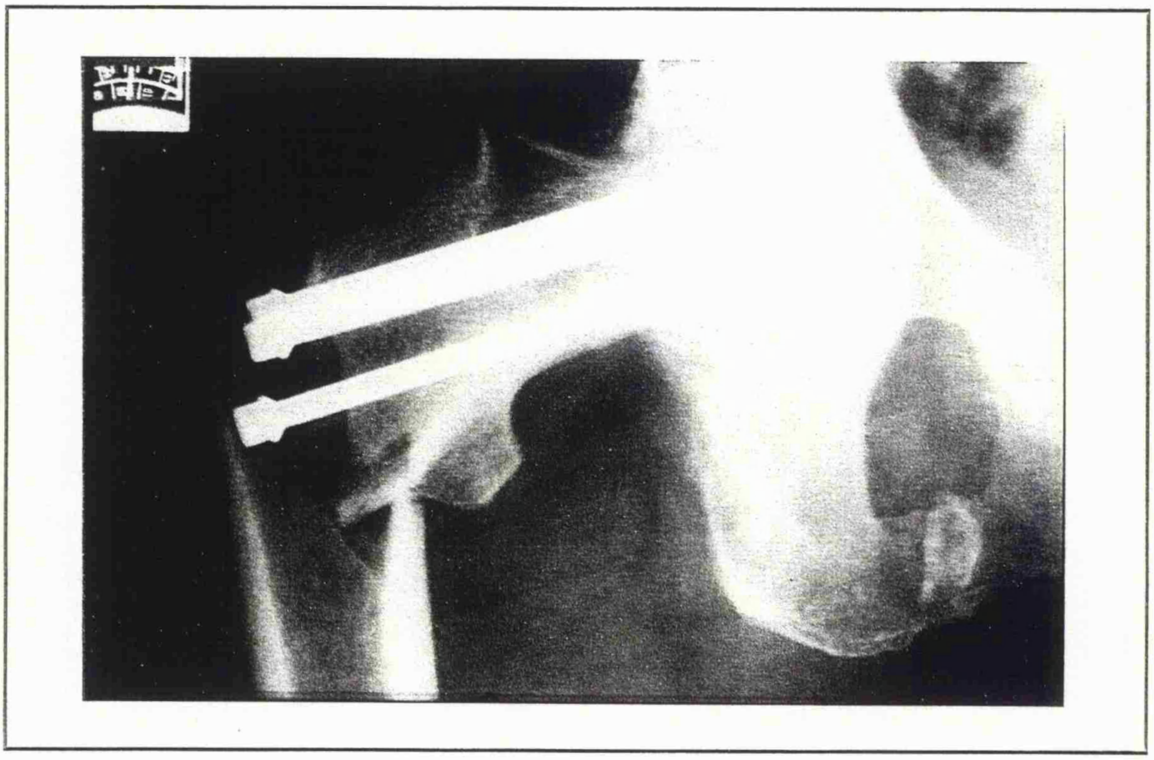


1.10.3.3 Fracture

Subtrochanteric fracture following multiple pin fixation has been reported by several authors (Fig 1.39). The devices implicated have been Garden Screws (Andrew 1984) and Gouffon pins (Neuman 1990). The incidence of this fracture is reported to be approximately 2% following multiple screw fixation. The fracture seems to be associated with distal insertion at the level of the lesser trochanter. The fracture can be treated by insertion of a sliding hip screw leaving one or two of the pins in situ to maintain reduction of the femoral head.

To prevent fracture Neuman (Neuman 1990) recommends; 1) use of three pins, two superior and one inferior, 2) introducing a pin into the distal guide wire hole, 3) to not place pins distal to the proximal level of the lesser trochanter, 4) predrilling.

Fig 1.39 Subtrochanteric fracture following multiple screw fixation.



2. Aims, objectives and design of the Study.

As has been shown in the introduction to this thesis there is a considerable diversity of opinion concerning the optimal way to manage intracapsular proximal femoral fractures. Eight areas of particular concern were identified for further investigation.

1. Although there are many reports from specialist centres concerning specific devices for the operative treatment of intracpasular fractures there are no published reports of how the average orthopaedic surgeon manages intracapsular proximal femoral fractures in the average hospital in the United Kingdom.

2. Although there have been some publications concerned with the incidence of missed fractures in hospital populations there has been no study looking at the outcome of a cohort of patients who present to hospital following trauma, have a painful hip but a normal radiograph. The number of these patients who have an undisplaced and undetected hip fracture is not known.

3. Computerised tomography has not been used to study the morphology of proximal femoral fractures to ascertain whether the use of this technique would influence choices of treatment.

4. Clinical studies of the treatment of proximal femoral fractures are abundant but very few of them are randomised prospective controlled trials. As has been shown in the introduction to this thesis there are many areas of controversy with regard to the

management of intracapsular proximal femoral fractures. Three areas were identified for further study.

1) It is known that the severely demented elderly patient fares poorly following surgery, however, although there have been reports of good results with conservative treatment, no prospective randomised trial has been undertaken to compare operative versus conservative treatment of displaced intracapsular proximal femoral fractures in this group of patients. If this group of patients could be managed successfully conservatively there would be no requirement for their transfer to an acute orthopaedic ward.

2) When using a hemiarthroplasty for the treatment of displaced intracapsular proximal femoral fractures there is a choice between using an uncemented or cemented prosthesis. The potential advantages of an uncemented prosthesis are shorter operating time, no risk of cement toxicity and, if the prosthesis does require revision, theoretically an easier revision procedure. There are only 4 reported series in the literature comparing cemented and uncemented hemiarthroplasty in proximal femoral fractures and non of these are randomised and prospective and thus no firm conclusion can be drawn as to whether hemiarthroplasties should be used with or without cement.

3) There is considerable debate as to the optimal treatment of displaced intracapsular fractures in the younger, mentally alert and ambulant patient. The most controversial area is whether these patients should be treated by replacement of the femoral head with a prosthesis or by internal fixation. Both methods of treatment have their advocates. However before a prospective randomised trial can be undertaken

comparing fixation with replacement it is important to know the optimal method of fixation. At the time of commencement of this study no prospective randomised trial had been published comparing multiple parallel cancellous screws with a sliding hip screw plate, the two most common methods of fixation employed in the United Kingdom.

In an attempt to answer these three questions a prospective randomised trial was undertaken. During the trial period all intracapsular proximal femoral fractures admitted to the Leicester Royal Infirmary were assessed by the author and entered into one of three trials.

Patients with certain conditions were excluded from the trial.

Patients with symptomatic osteoarthritis or rheumatoid arthritis prior to fracture were excluded because fractures with coexistent degenerative disease are better treated by total hip replacement.

In the presence of neoplastic disease patients could not be entered into a rigid trial protocol and therefore were treated by the most appropriate method as judged on clinical grounds.

In patients with untreated osteomalacia, uncontrolled Parkinson's disease or on long term steroid therapy failure rates following fixation are high and these patients were excluded.

Patients who declined entry into the trial were excluded.

To allocate patients into the three treatment groups a mental test score system and the patients age were used to determine which limb of the trial the patient entered.

The rationale for these divisions was based on the known higher failure rates for the more elderly patients (Barnes 1976) and the shorter life expectancy of the demented patient (Evans 1980).

The mental test score used was a 13 point score designed by Evans and has been used extensively in Newcastle for investigation of proximal femoral fractures. The lower the score the more cognitively impaired is the subject and scores below three represent severe dementia.

Allocation and design of the three trials is outlined below.

Trial 1 - A prospective randomised trial of conservative versus operative treatment of displaced intracapsular proximal femoral fractures in elderly minimally ambulant and severely demented patients.

Patients over 80 years of age with a mental test score of 3 or less were eligible for inclusion in this study.

Trial 2 - A prospective randomised trial of cemented and uncemented Thompson hemiarthroplasty for displaced intracapsular proximal fractures.

This trial consisted of 3 groups of patients:-

a) Patients over 80 years of age with displaced intracapsular proximal femoral fractures and a mental test score above 3.

b) Patients 80 years of age or younger with intracapsular proximal femoral fractures and a mental test score below 3.

c) Patients over 80 years of age with a mental test score below 3 who had been allocated to the trial comparing conservative versus operative treatment of intracapsular proximal femoral fracture. Those patients in trial 1 who randomised to treatment with hemiarthroplasty were entered into trial 2 and randomised for treatment with either or uncemented Thompson hemiarthroplasty.

Trial 3 - A randomised prospective study comparing internal fixation of the proximal femoral fractures with either a sliding screw and plate or multiple parallel cannulated screws. Patients 80 years of age or younger with a mental test score above 3 were allocated to this trial.

The allocation of patients is summarised in Fig 2.1.

The mental test score and weighting of questions is shown in table 2.1.

Informed consent was obtained from the patient, relative or person having legal responsibility for the patient before entering patients into the trials by the author following discussion with the person giving consent. A patient information sheet (Appendix 2), in general use at the time of these trials, was also supplied to each patient.

4) There is some evidence to suggest that increased levels of intracapsular

pressure may be found following proximal femoral fractures. To further clarify the problem a study was undertaken to ascertain the level of intracapsular pressure following proximal femoral fracture.

5) Increased levels of intracapsular pressure may have a tamponade effect on femoral head blood flow following intracapsular proximal femoral fracture. This reduction in femoral head blood flow may lead to subsequent avascular necrosis and late segmental collapse. If the intracapsular pressure is relieved by aspiration of the intracapsular haematoma femoral head blood flow may improve thereby reducing the risk of avascular necrosis. A study was undertaken to ascertain the effect of intracapsular pressure on femoral head blood flow and whether relieving that pressure improved blood flow.

Prior to commencement of the clinical studies local ethical committee approval was obtained.

In the prospective randomised trials randomisation was the last digit of the patients accident and emergency number; an odd digit randomised to one limb of the trial an even to the other.

As the duration of these trials was time limited power calculations were deemed to be redundant.

For long term review of these patients survival analysis would be more appropriate than the analysis used in the short term review.

Fig 2.1 Flow chart showing clinical trial design.

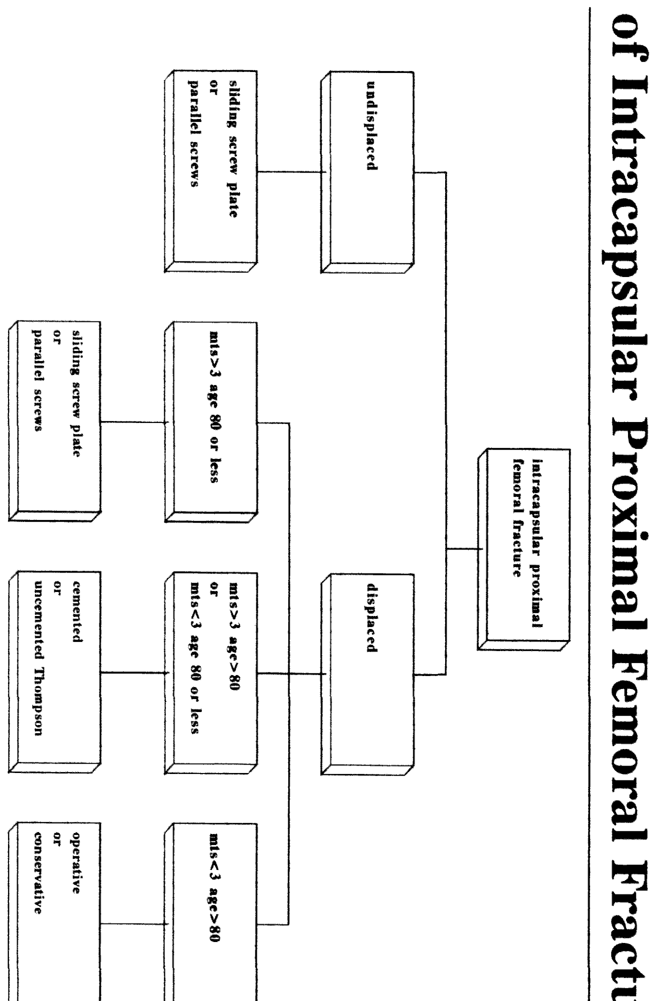


Table 2.1 Questions asked and the weighting used to obtain the mental test score.

question asked	score
age to nearest year	0 1
time to nearest hour	0 1
address for recall	0 1 2
date	0 1 2 3
day of week	0 1
name of hospital	0 1
date of birth	0 1
year of first world war	0 1
name of present monarch	0 1
count backwards from 10	0 1
maximum total	13

3. Clinical Studies

3.1 A postal survey of methods of treatment of displaced intracapsular fractures in the United Kingdom.

3.1.1 Introduction

Although there have been many publications concerned with methods of treatment of intracapsular proximal femoral fractures, little is known about the methods of treatment used for these fractures in this country by individual orthopaedic surgeons and whether their methods of treatment have been influenced by the few prospective or randomised published trials. To correct this deficiency in the literature, and also to obtain information to enable trials relevant to present British clinical practice to be undertaken, an investigation of the current practice of orthopaedic surgeons in the United Kingdom, with regard to treatment of displaced intracapsular proximal femoral fractures, was performed.

3.1.2 Materials and method.

642 consultant orthopaedic surgeons were identified who practised in hospitals concerned with the management of trauma, and were therefore likely to be involved in trauma management themselves. The source of this information was the Directory of Operating Theatres and Departments of Surgery (CMA Medical Data Ltd 1989). A simple questionnaire was devised which could be answered by simply ticking boxes, although space was left at the end of each question to enable comments to be made (appendix 1).

The questions asked were;

1) preferred method of treatment of displaced intracapsular proximal femoral fractures in patients in three age groups, under 70 yrs, 70 - 80 yrs and over 80 yrs of age.

2) most often used method of internal fixation

3) most often used prosthetic replacement

4) frequency of use of polymethylmethacrylate bone cement with prosthetic replacement.

5) surgical approach used for prosthetic replacement

The questionnaires were sent to the identified consultants with an enclosed addressed envelope to enable return of the questionnaire.

Replies were entered into a custom designed database (Dataease, Sapphire Software 1989) and data analysis was conducted within the database.

3.1.3 Results.

485 replies were received for analysis which represented 76% of the study population. The option was given for the replies to be anonymous and therefore no data is available for regional variations in treatment practice.

Methods of primary treatment in patients over 70 years of age consistently favoured replacement of the femoral head with a prosthesis with 93% of surgeons performing primary prosthetic replacement between 70 and 80 years of age and 97% when the patient was over 80 years of age (Fig 3.1.1). When patients were under 70 years of age 39% of surgeons would still opt for primary prosthetic replacement. Some replies commented that under 70 yrs of age the choice between primary prosthetic replacement and fixation would depend on the physiological age of the patient, although only three surgeons mentioned that they would use a mental test score system to help in their assessment.

The majority of surgeons opted for either a sliding hip screw or multiple cannulated screws as their method of primary internal fixation of displaced intracapsular fractures, (Fig 3.1.2). Of other types of fixation used 23 used non cannulated cancellous screws, 15 used the hook pin system, 11 used fixed nail plates, and 11 sliding nail plates. The other methods of fixation employed were varieties of thin threaded pin and 2 used single nails of the Smith Peterson type. Overall 33% of surgeons used sliding screw plate devices and 57% some sort of cannulated or non-cannulated multiple cancellous screw system.

With regard to femoral head replacement the majority of surgeons favoured some form of hemiarthroplasty (92% of responses). Analyzing the type of hemiarthroplasty used, 62% favoured simple hemiarthroplasties and 30% bipolar hemiarthroplasties. For simple hemiarthroplasty surgeons favoured either the Austin Moore prosthesis or the Thompson prosthesis in equal numbers (Fig 3.1.3).

Age of the patient did not affect choice of replacement if the surgeon elected to replace the femoral head in a younger patient, with over 90% of surgeons using a hemiarthroplasty in patients under 70 years of age, 60% of the hemiarthroplasties being of the unipolar type (Fig 3.1.4).

Overall use of cement with femoral head replacements varied from 38% of surgeons who always cemented their replacements to 23% who rarely or never cemented their replacements (Fig 3.1.5). The use of cement with Thompson, Austin Moore and bipolar replacements is shown in figures 3.1.6 - 3.1.8.

Use of cement with Thompson hemiarthroplasty in different age groups is shown in figure 3.1.9.

Surgical approach used for prosthetic replacement is shown in figure 3.1.10.

Fig 3.1.1 Histogram showing preferred method of treatment of displaced intracapsular proximal femoral fractures in three age groups.

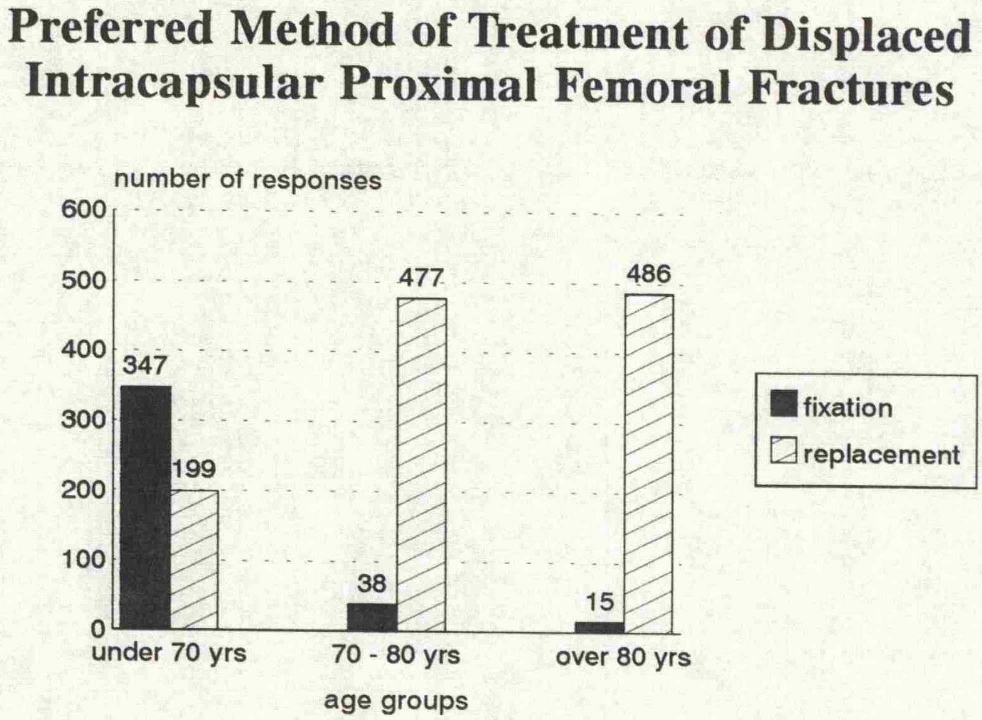


Fig 3.1.2 Pie chart showing overall usage of types of fixation device for displaced intracapsular proximal femoral fractures.

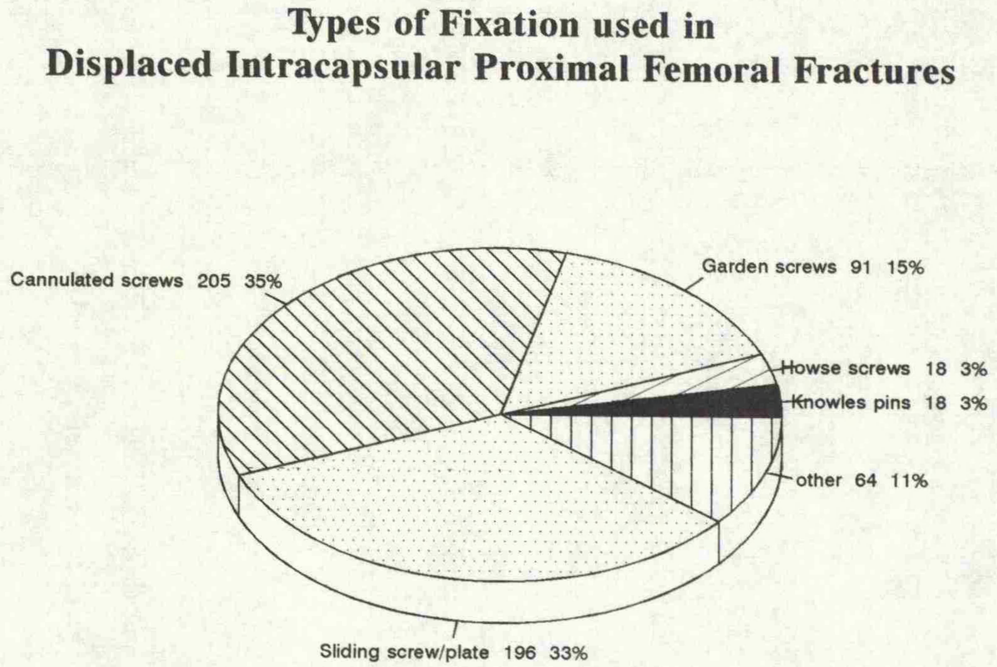


Fig 3.1.3 Pie chart showing type of prosthesis favoured when replacing the femoral head in displaced intracapsular proximal femoral fractures.

Types of Replacement used in Displaced Intracapsular Proximal Femoral Fractures

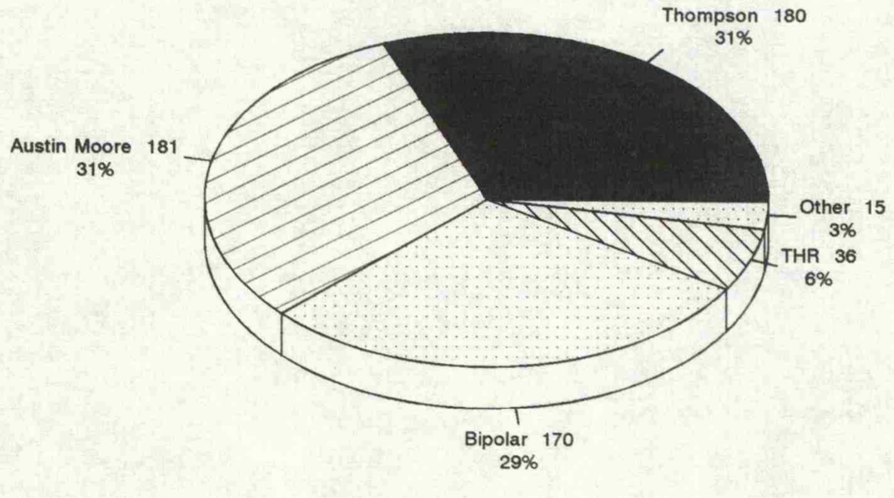


Fig 3.1.4 Pie charts showing types of prosthesis used when replacing the femoral head in displaced intracapsular proximal femoral fractures in three age groups.

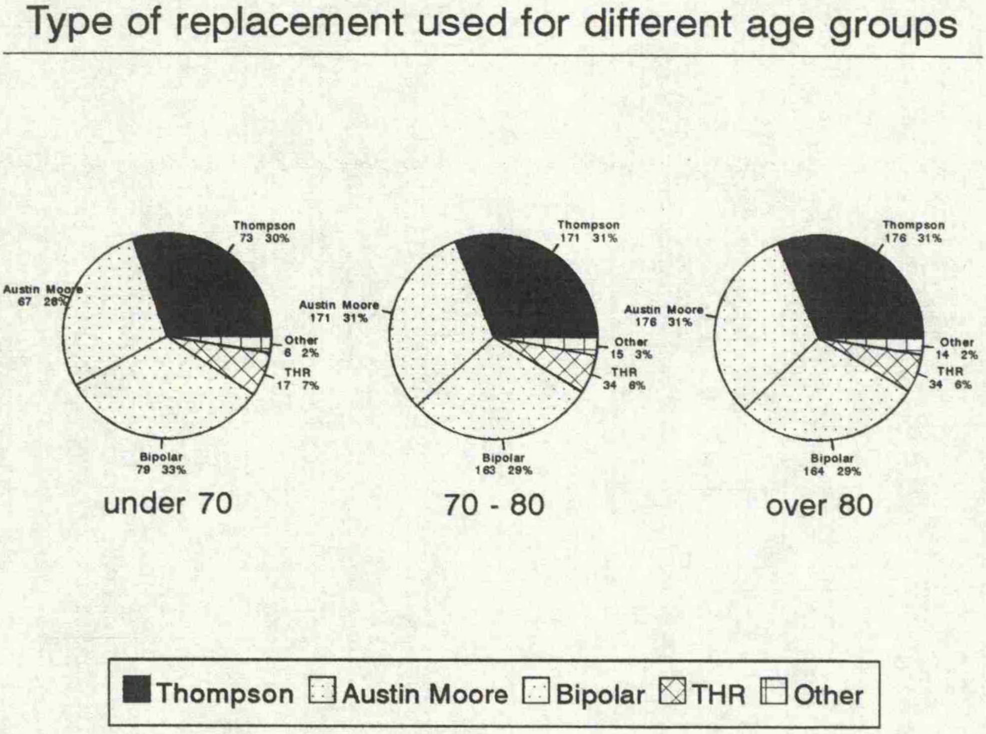


Fig 3.1.5 Pie chart showing overall use of cement with prosthetic replacement.

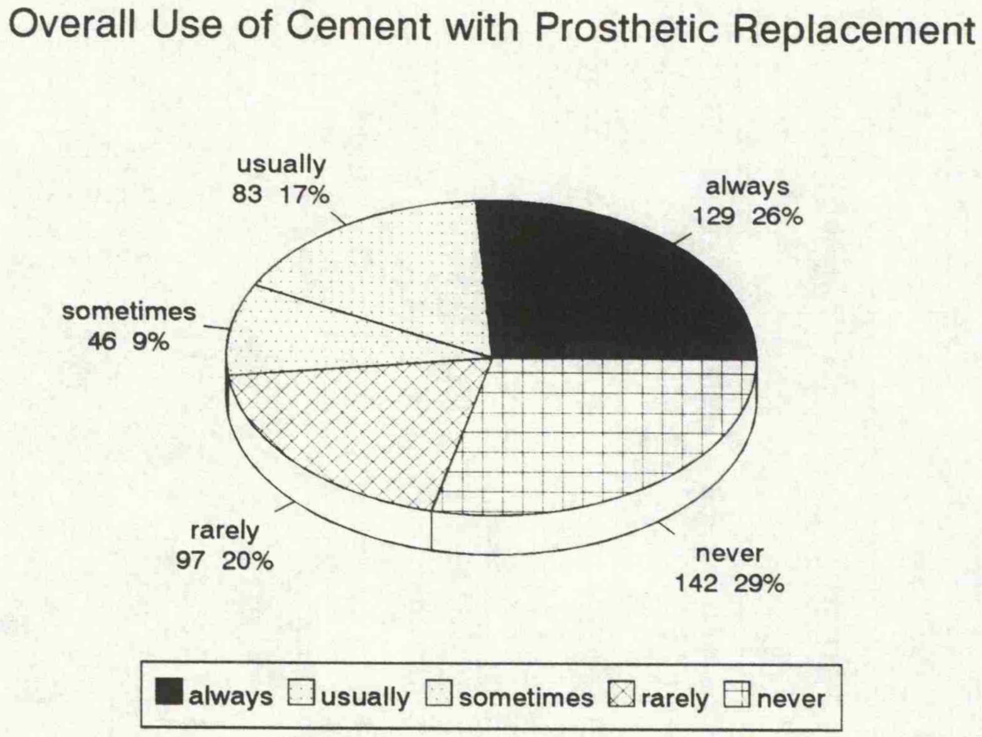


Fig 3.1.6 Pie chart showing use of cement with the Thompson prosthesis.

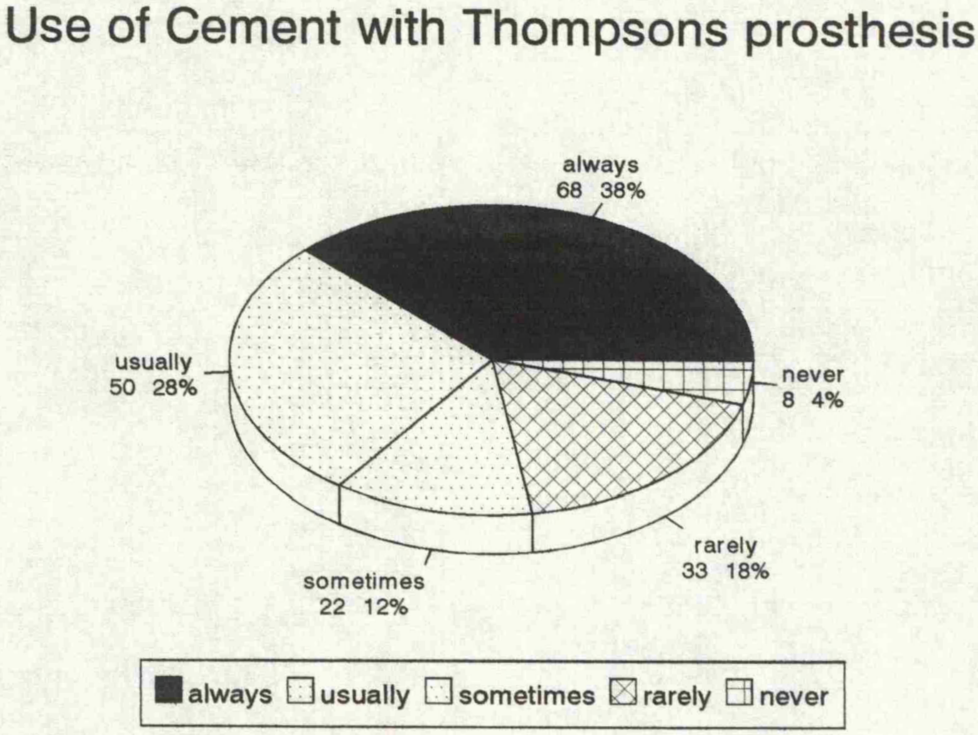


Fig 3.1.7 Pie chart showing use of cement with the Austin Moore prosthesis.

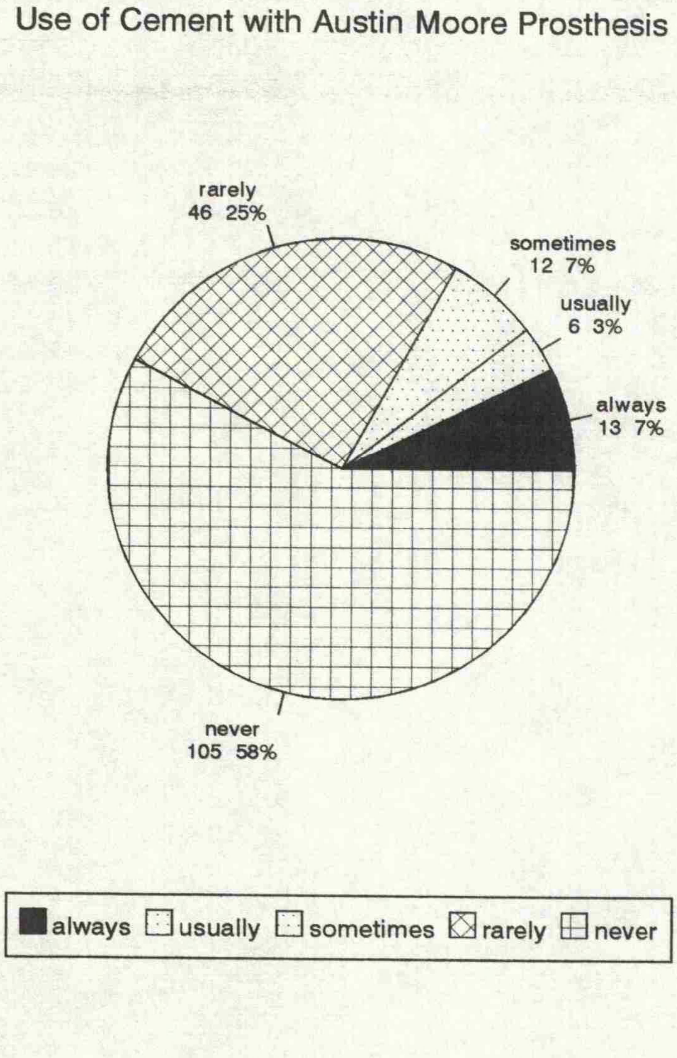


Fig 3.1.8 Pie chart showing use of cement with bipolar prostheses.

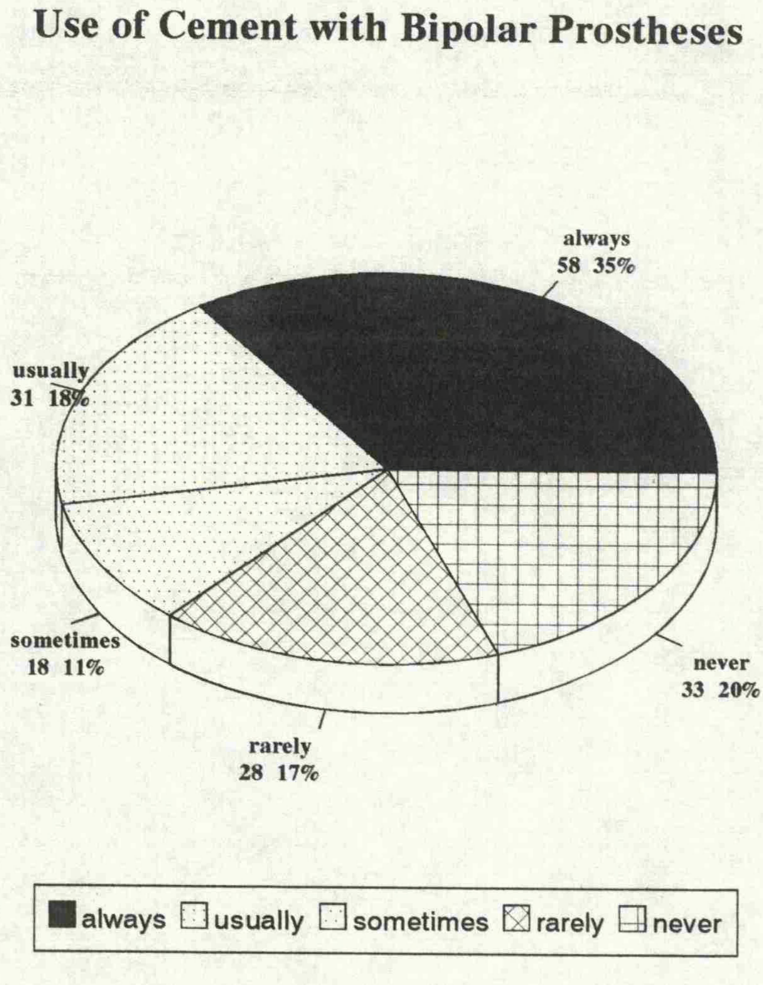


Fig 3.1.9 Pie charts showing frequency of use of the Thompson prosthesis in three different age groups.

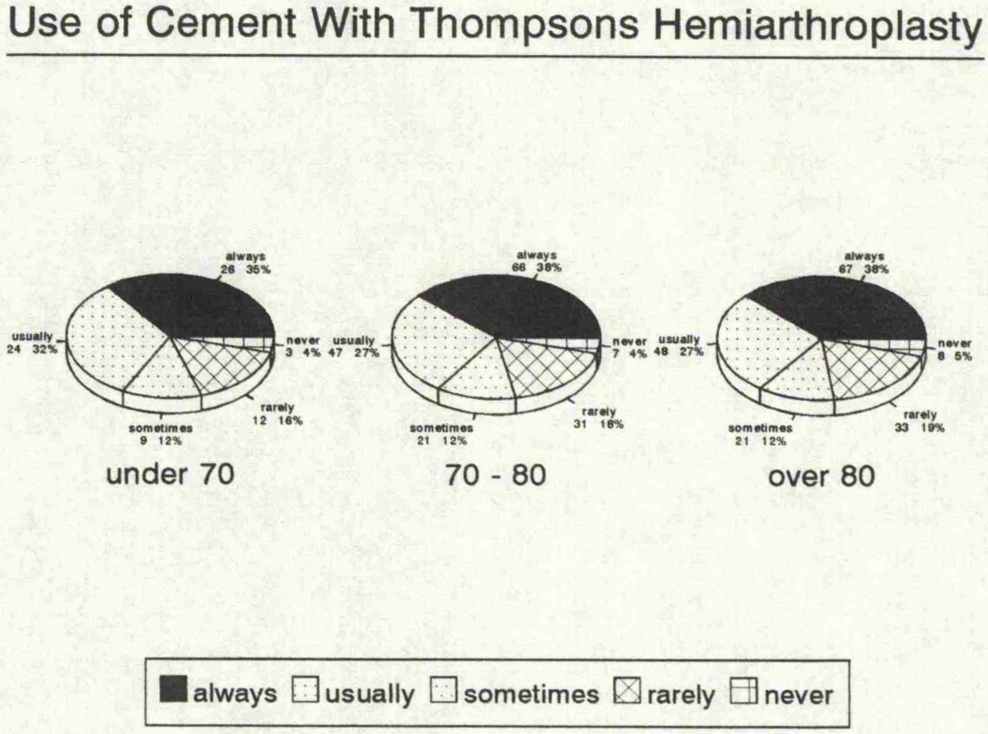
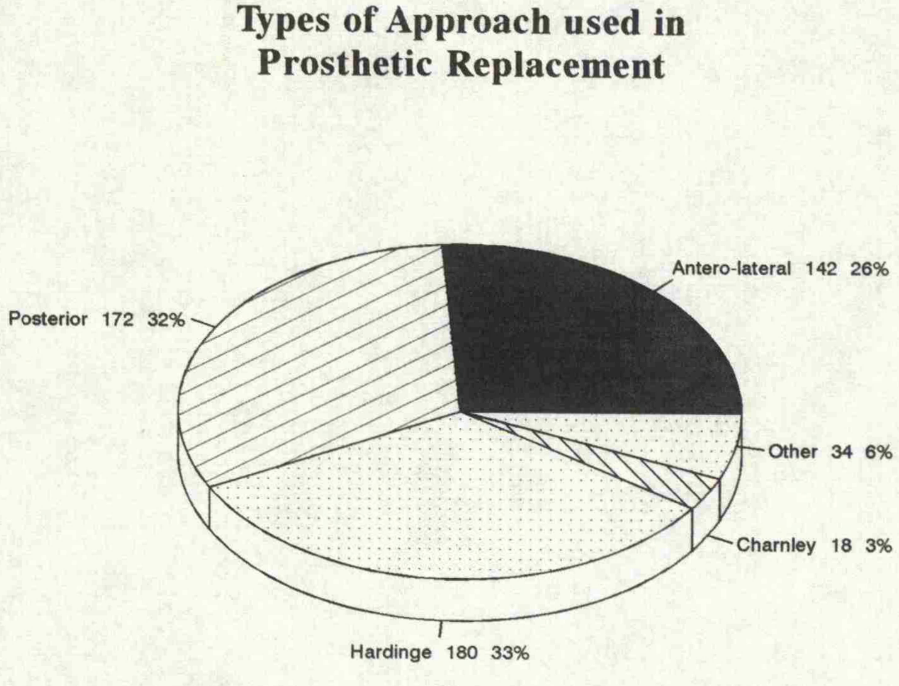


Fig 3.1.10 Pie chart showing surgical approach preferred when performing prosthetic replacement.



3.1.4 Discussion and conclusions.

A study such as this may be open to criticism because of the simplicity of the questions asked. It is difficult to strike a balance in a postal questionnaire between completeness of questioning and willingness to respond. The questions were designed to make response easy and this is reflected in the good response rate of 76%. Another factor involved in the response rate may have been that, although questions were directed at consultant surgeons, the operations were performed by junior staff with little senior input and the questionnaire was completed by these same trainee surgeons. Inevitably compromises have to occur, and the question that provoked most criticism was the first question dividing patients into age groups. In retrospect this could have been increased to include more age bands. The particular criticism that was levelled by some respondents was that their decision was based on the physiological age of the patient not the biological age. This criticism is valid, however only two respondents stated that they employed a mental test score to help in patient assessment, despite the fact that it has been shown to be the most important determinant of outcome in intracapsular proximal femoral fractures. (Ions 1987, Wood 1992).

The choice between internal fixation or replacement is one that has not been adequately resolved in the orthopaedic literature. Of the four prospective papers addressing this problem (Riley 1978, Sikorski 1981, Soreide 1979, Skinner 1989) none have sufficiently long follow-up to assess the long term complications of prosthetic replacement, which is known to be high in patients with intracapsular proximal femoral fractures (Hunter 1980, Greenough 1988), in contrast to the long term results of modern fixation, which are reported to be good (Nilsson 1989). Despite the lack of evidence for superiority of prosthetic replacement there was a almost a uniformity of opinion amongst UK surgeons that patients over 70 years of age with displaced intracapsular proximal femoral fractures should be treated by discarding the patient's femoral head and replacing it with a metal ball. In contrast, although the majority of surgeons treated patients under 70 years of age with internal fixation, a large proportion, (36%), of surgeons would treat such patients with a prosthetic replacement despite reports of poor results with hemiarthroplasty in younger patients (Pun 1988). Methods of fixation used were, on the whole, the most modern methods, with over 68% of surgeons using either a cannulated screw system or a sliding screw plate system. Both systems have been reported to give good results when reported separately (Skinner 1986, Wood 1991), however no study has compared a cannulated screw system with a sliding screw plate in a randomised prospective trial. However one study has compared non-cannulated multiple screw fixation with a sliding screw/plate (Madsen 1987). This study can be criticised for having few numbers at long term follow-up and also for using an additional screw superior to the sliding hip screw, which unless placed parallel with it, may cause jamming of the screw within the barrel of the plate thus preventing sliding of the screw and impaction of the fracture. This could explain the apparent superiority of the multiple screw system in this study. It is interesting that the hook pin system which has comparable results to the cannulated hip screw or the sliding screw plate (Stromqvist 1992) was only used by 15 surgeons. The use of devices such as fixed nail plates, single nails or multiple pins must be seriously questioned because of the reported poor results from fixation with these devices (Barnes 1976).

The choice of prosthesis for hemiarthroplasty was divided evenly between the

Thompson, Austin Moore and bipolar prostheses. There was widespread use of bipolar hemiarthroplasties with approximately one third of UK surgeons using them as their primary method of treatment of displaced intracapsular proximal femoral fractures. Although the results of simple hemiarthroplasties are poor (Hunter 1980, Pryor 1990) and some reports of bipolar prostheses suggest better results others suggest results comparable to the simple prosthesis the theoretical reduction in acetabular erosion remains unproven (Bochner 1988). At present prices (Johnson and Johnson Co Ltd, 1991) the cost of bipolar prostheses is approximately three times that of unipolar designs and until a prospective randomised trial proves the superiority of one type over another the wholesale adoption of a prosthesis of unproven long term benefit must be viewed with circumspection.

Although the Thompson's prosthesis was originally used without cement upon the introduction of polymethylmethacrylate the prosthesis was commonly used with cement. Today 1 in 5 UK surgeons do not use the prosthesis with cement routinely despite some evidence the results are inferior without cement (Follaci 1969).

It is also surprising that 10% of surgeons nearly always cement the Austin Moore prosthesis despite the fact that it was specifically designed to be implanted without cement and the fenestrations in the prosthesis allow bone ingrowth and may make revision of the cemented prosthesis difficult because of the cement in the fenestrations. 32% of surgeons favoured the posterior approach for hemiarthroplasty despite reports of higher complication rates with this approach (Chan 1975).

This is the only survey of contemporary UK practice and reveal inconsistencies and illogicallities of treatment.

In the United Kingdom replacement of the femoral head is favoured for patients over

70, whereas in Scandinavia fixation is preferred (Bauer 1990). There is no evidence from a prospective trial that one method of treatment is superior in the long term to another. There is an equal division between usage of cannulated screws and sliding screw plates for fixation, however these two devices have never been subjected to a randomised prospective trial. There is widespread use of bipolar replacements with little evidence of superiority over standard prostheses.

Out-dated fixation devices are used, unproven prostheses are being inserted, cement may or may not be used depending on whim and surgical approaches associated with high complication rates are used by one third of surgeons.

From these results prospective trials can be planned that logically address the current practice of UK surgeons.

3.2 A study of the outcome of elderly patients presenting to an accident and emergency department with a painful hip following trauma and with no evidence of fracture on radiographs.

3.2.1 introduction

A problem facing all surgeons involved in the treatment of the elderly is the patient who, following a fall, has a painful hip and difficulty walking. Most usually the patient is referred to an Accident and Emergency Department and a radiograph is performed. In the presence of a fracture the disposal of the patient is a relatively easy procedure, in that referral is immediately made to an Orthopaedic Department. A difficult problem is those patients who are seen in hospital with a painful hip and difficulty in mobilising following trauma, and do not have a fracture on their initial radiograph. It has been suggested that these patients who have a normal radiograph on initial presentation, may in fact have an undisplaced proximal femoral fracture (Eastwood 1987).

With intracapsular fractures there is a risk that if the hip is not protected or internally fixed displacement could occur as the patient mobilises (Bentley 1968), thus converting a fracture which is undisplaced into a displaced fracture. The results of internal fixation of undisplaced fractures are exceptionally good (Bentley 1968), however, once the fracture has displaced, the results of internal fixation become much worse, with failure rates varying from 20 to 40%. (Barnes 1976).

There are undoubtedly a group of patients in whom a fracture is missed on the initial radiograph and this group accounted for 12 of the 36 delayed diagnoses of hip fracture in one series (Eastwood 1987). However, a more contentious issue is whether there is a group of patients who present with a painful hip following trauma, usually minor, have a normal radiograph on first attendance and subsequently a fracture of the proximal femur becomes apparent. Previous studies have addressed the problem in relation to in patient admissions and have discovered that a small proportion of hospital admissions with pain in the hip following trauma and a normal initial radiograph subsequently display a fracture on later radiographs (Fairclough 1987).

This has led some authors to suggest more extensive investigations of these patients to try to find the small proportion who have a fracture. Suggested methods of investigation to discover occult fractures are repeat radiographs, bone scans, computerised tomography and MRI (Fairclough 1987, Alba 1992).

A study was undertaken to discover the incidence of hip fracture in a cohort of patients presenting to an accident and emergency department with pain in the hip following trauma and no fracture on their initial radiograph.

3.2.2 Materials and method

Patients who attended the accident and emergency department of the Leicester Royal Infirmary, for a one year period, March 1988 to February 1989, with hip pain following trauma sufficient to limit mobility were identified from the computerised records of the accident and emergency department. In Leicestershire, all patients transported by ambulance are seen in the Accident and Emergency Department based at the Leicester Royal Infirmary, and all Orthopaedic Trauma admissions are to the same hospital. For this reason it was possible to identify any patient who was seen in the Accident and Emergency Department and subsequently treated by the Orthopaedic Trauma Service for a hip fracture.

Patients were included in the study if they presented with hip pain following trauma, had limitation of mobility and had a no fracture on their initial radiograph.

The radiographs were all assessed by a Consultant Radiologist and the author and agreement reached on whether there was a fracture visible.

Patients were followed up by scrutiny of hospital admissions and phone contacts with General Practitioners. This review took place 3 to 12 months after their initial presentation to the accident and emergency department and details were obtained on all patients originally identified.

3.2.3 Results

123 patients who were identified the criteria of hip pain and normal initial radiograph. The mean age of the patients was 77.8 (SD 9.2) years, and the patients were predominantly female with a sex ratio of 3:1. The mechanism of injury was in 107 cases a fall, usually a fall in their place of residence (Fig 3.2.1).

All patients were recorded as having difficulty mobilising.

The majority of patients were discharged from the accident and emergency department to their place of residence.

When reviewed 13 patients had died. None of those who had died had sustained hip fracture between attendance and death. Of the remaining 110 patients, Five had sustained a fracture, but only three had sustained a hip fracture. Two of these fractures were extracapsular, and one was intracapsular. All these fractures were sustained or documented within three months of initial presentation. Of the 45% who were immobile at the time of initial presentation, 11 had died by the time of review. Of the patients reviewed 20% had been admitted to hospital because of other problems between time of attendance to the accident and emergency department and review.

Fig 3.2.1 A histogram showing method of injury.

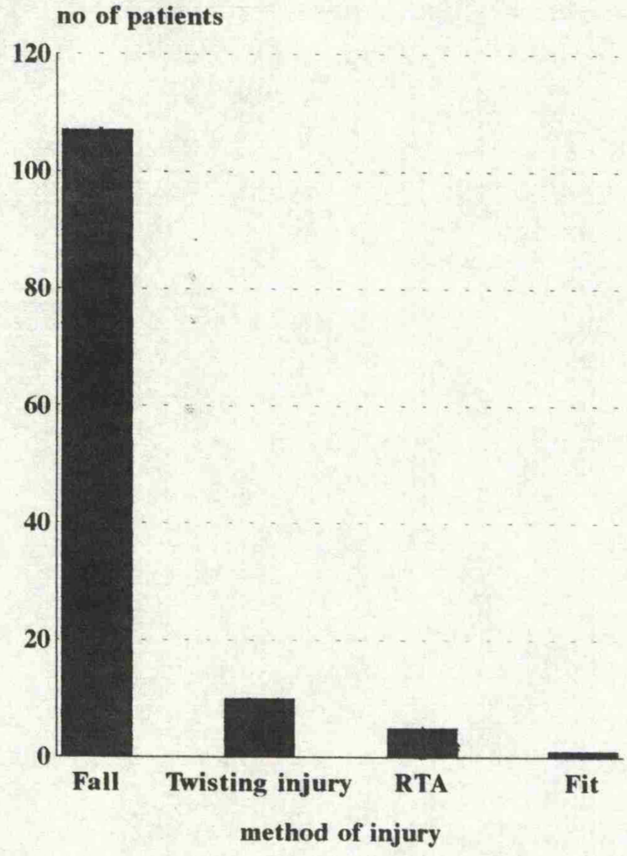
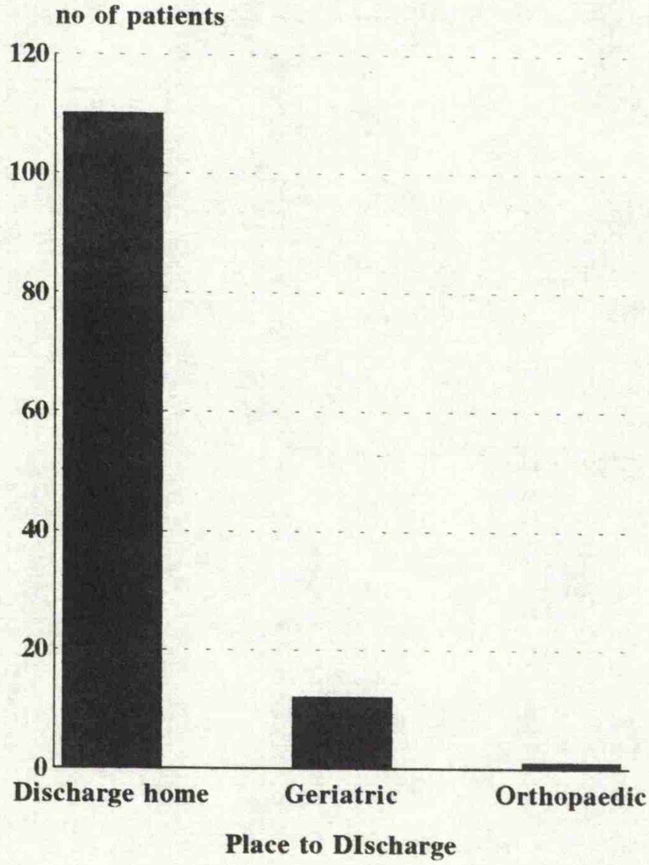


Fig 3.2.2 A histogram showing place to discharge of patients from the Accident and Emergency department.



3.2.4 Discussion and conclusions.

This study suggests that there is a very low incidence (2.5%) of late presentation of hip fracture among a cohort of patients who presented to an accident and emergency department with pain, limited mobility following a fall and a normal initial radiograph. It is impossible to know from the 5 patients who sustained a hip fracture, whether the hip fracture was present when they originally presented but not apparent on initial initial radiograph or whether the fracture occurred following another event. Of note is that three of the patients who developed a hip fracture, gave a history of a second injury to their hip. Thus it is impossible to define exactly the true incidence of the invisible fracture on initial radiographs.

10% of patients had died prior to review and 20% had been admitted to hospital with conditions other than fracture. Cause of death was impossible to elucidate because almost always the patients died at home and no post mortem data was available. This high mortality and morbidity rate is reflected in the fact that falls in the elderly are a predictive factor for increased morbidity and mortality (Hindmarsh 1989, Campbell 1990)

A fall in an elderly patient is a significant life event. Even in the presence of a painful hip, a patient with a normal hip radiograph does not require admission to an orthopaedic trauma ward but should be admitted to a rehabilitation or orthogeriatric ward and be assessed by physicians for comorbidity, and also by Orthopaedic Surgeons to exclude a missed fracture. Although the incidence of fracture in this group of patients is very low if the hip is still painful a further radiograph should be obtained one week after injury.

3.3 An investigation of the morphology of intracapsular proximal femoral fractures using computerised axial tomography.

3.3.1 Introduction.

Imaging techniques used for the diagnosis of intracapsular proximal femoral fractures have included plain antero-posterior and lateral radiographs, tomography and isotope bone scanning, magnetic resonance imaging but only rarely computerised axial tomography.

Computerised tomography is a method of imaging which allows data to be assessed from sequential transaxial images. Computerised tomography has been used to image the hip previously but in mainly pelvic and acetabular fractures (Pitt 1990) or to detect intracapsular haemarthroses (Egund 1990).

A study was undertaken to determine whether the sophistication of computerised tomography would be valuable in the assessment of the cross-sectional morphology of intracapsular proximal femoral fractures.

3.3.2 Materials and methods.

Twenty eight patients who had sustained an intracapsular proximal femoral fracture were studied. Selection of patients was dependant on the availability of the CT scanner which was determined in an independant non-systematic manner. All patients gave a history of acute injury to the hip no longer than one week prior to the investigation. Computerised tomography (CT) was performed using an IGE8 8000 CT scanner.

Patients were placed supine on the table of the scanner. The position of the pelvis was localised with a scout scan and from the scout scan the superior aspect of the acetabulum and the lesser trochanter were identified on the affected side (Fig 3.3.1). Between six and eight one centimetre slices were taken from the superior aspect of the acetabulum to the lesser trochanter. Images were initially displayed on a computer monitor screen and when acceptable were transferred to radiographic film to allow later evaluation. All CT scanning was performed under the supervision of a single radiologist.

Analysis of the images was performed without reference to the plain radiographs. The fractures as seen on CT scans were classified according to degree of displacement, site and degree of comminution and whether the appearances on the CT scan were consistent with a new or an old fracture.

3.3.3 Results.

Five fractures were undisplaced or minimally displaced on CT assessment (Fig 3.3.2). Displacement was seen in twenty two fractures (Fig 3.3.3). Of the undisplaced fractures three showed impaction (Fig 3.3.4) and six of the displaced fractures also showed some impaction, usually of the posterior cortex of the femoral neck into the head (Fig 3.3.5). Comminution of the cortex of the femoral neck was present in the majority of the displaced fractures with twenty one displaced fractures having some degree of comminution. Comminution of the anterior cortex of the femoral neck was more common than posterior comminution with sixteen fractures showing anterior comminution, nine posterior comminution and four both anterior and posterior comminution.(Fig 3.3.6)

Six of the fractures assessed had morphology on the CT scan which was suggestive of an old fracture with loss of definition of the fracture edges and sclerosis at the fracture site (Fig 3.3.7)

Fluid in the hip joint, as characterised by a radiolucent line around the femoral head was demonstrated in only eight of the fractures and no effusion was present in those fractures that showed signs of being old fractures (Figs 3.3.8).

Fig 3.3.1 Scout scan showing localisation of the hip and slice selection for image analysis.

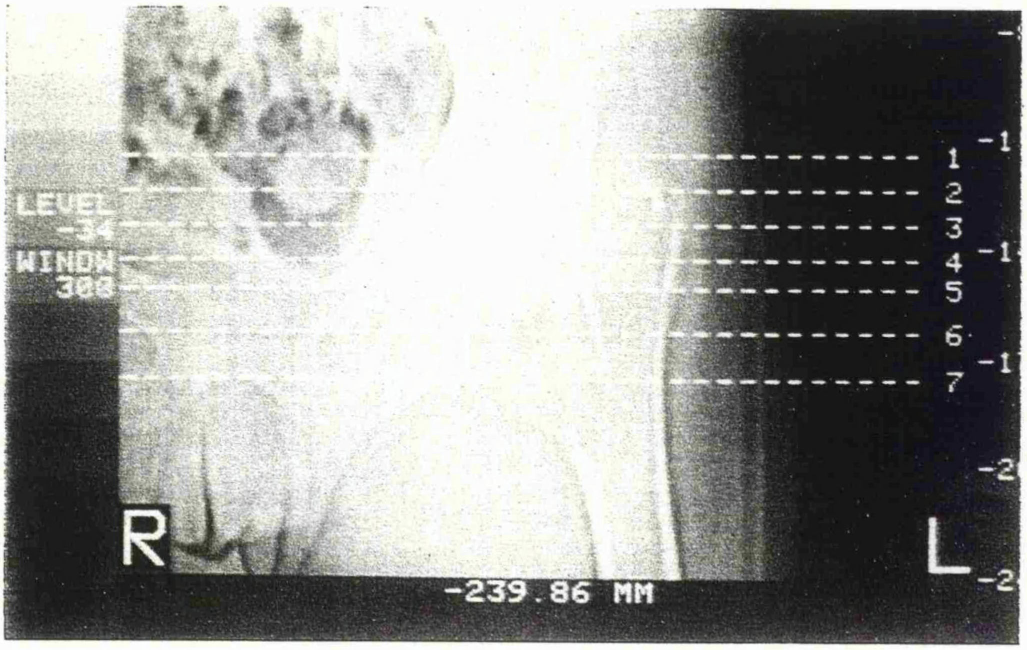


Fig 3.3.2 A CT scan of an undisplaced intracapsular proximal femoral fracture.

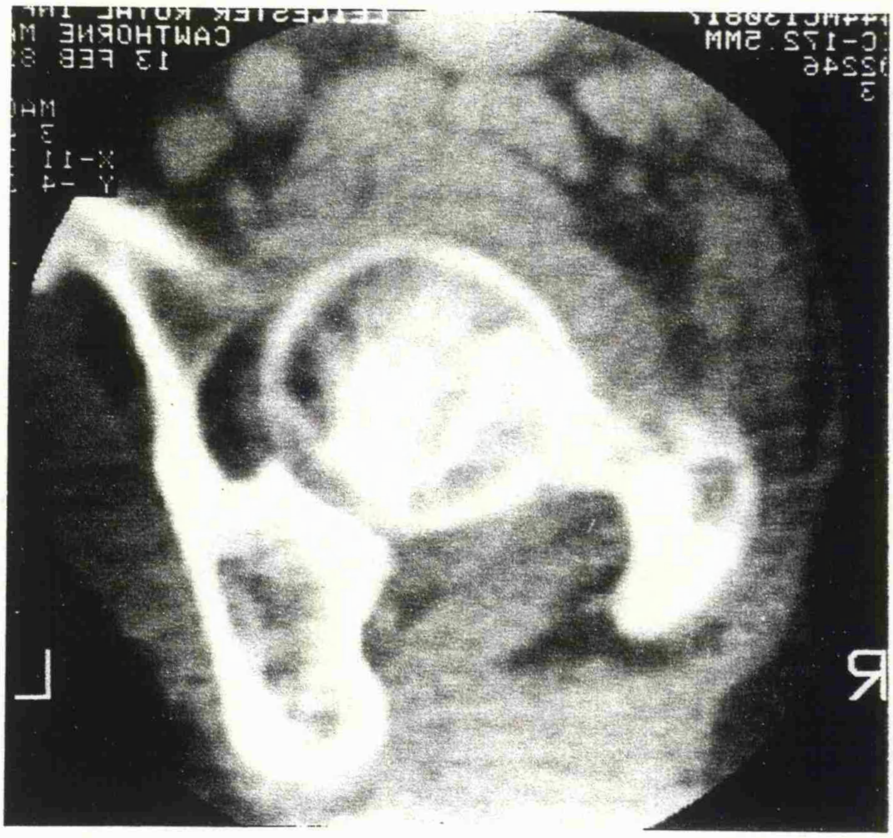
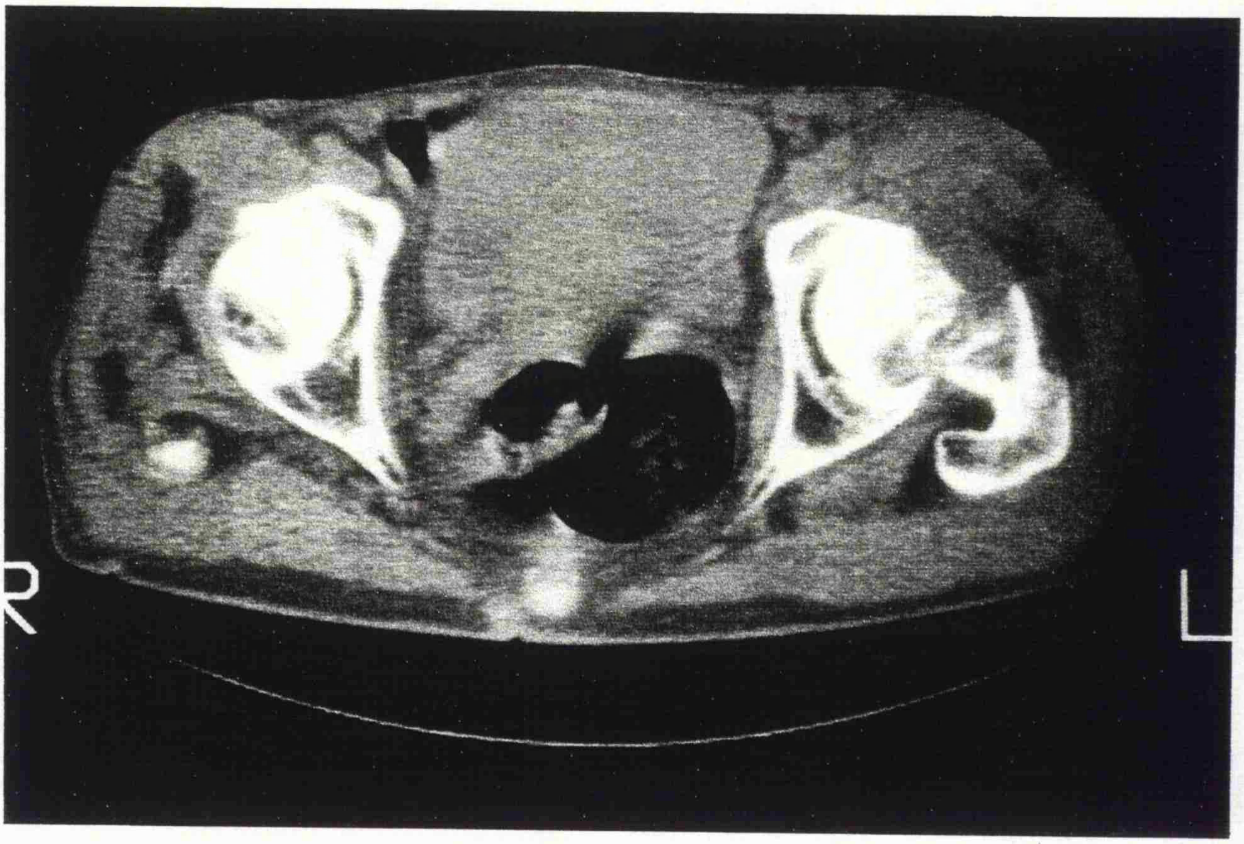


Fig 3.3.3 A CT scan of a displaced intracapsular proximal femoral fracture.



<u>Fig 3.3.4 A CT scan of an undisplaced and impacted proximal femoral fracture.</u>

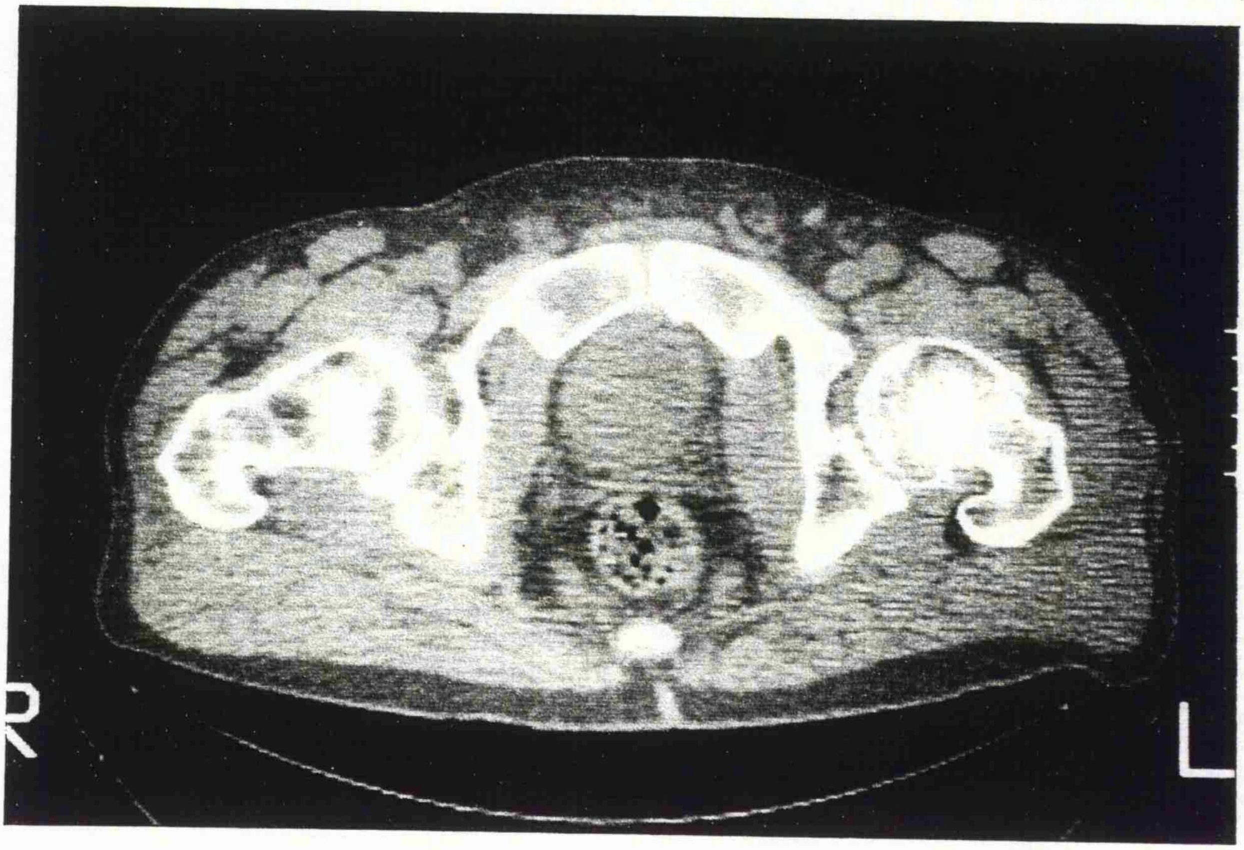


Fig 3.3.5 A CT scan showing a displaced fracture with impaction of the posterior neck into the head.

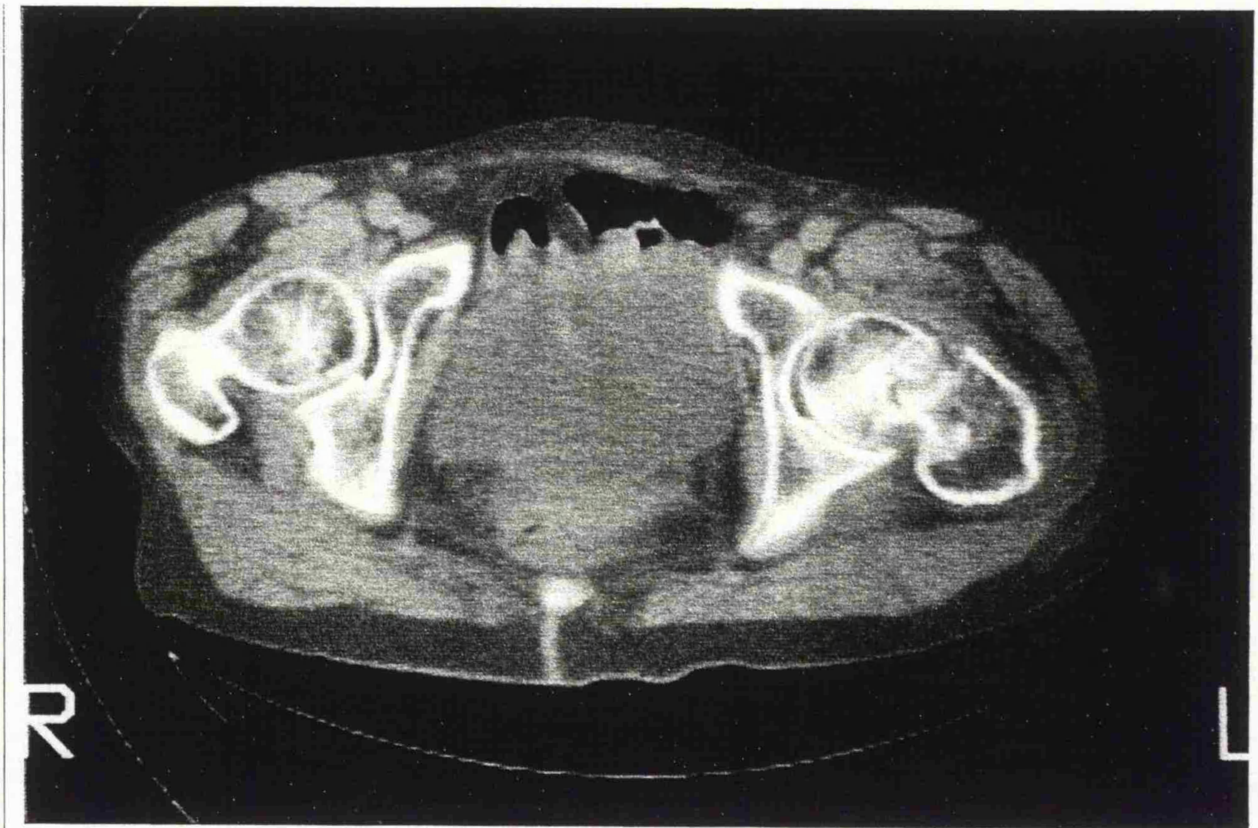


Fig 3.3.6 A CT scan showing both anterior and posterior comminution.

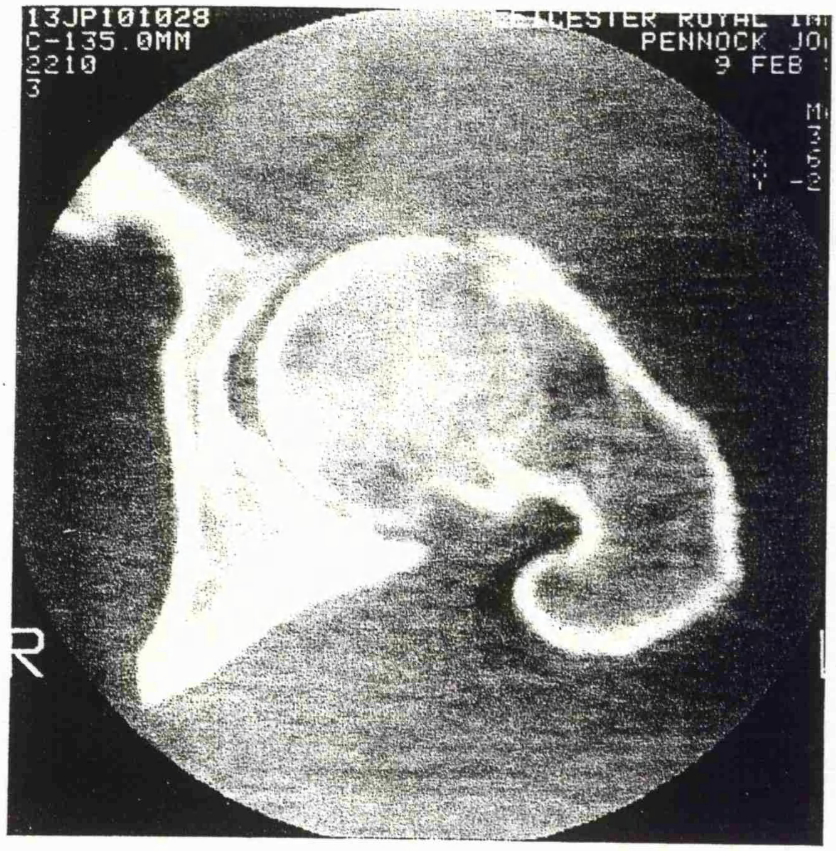
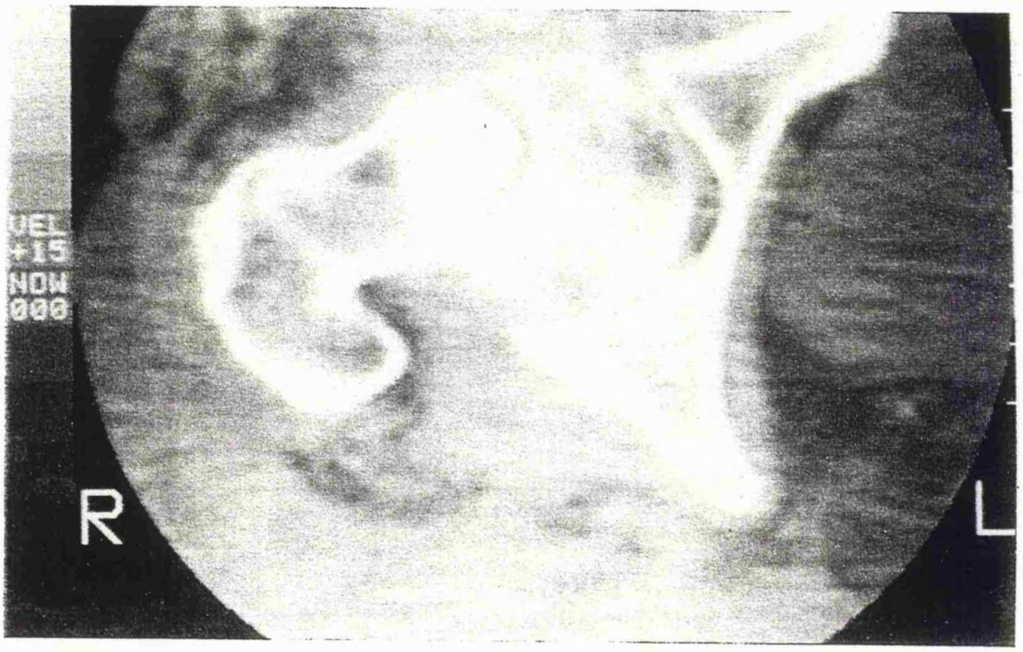
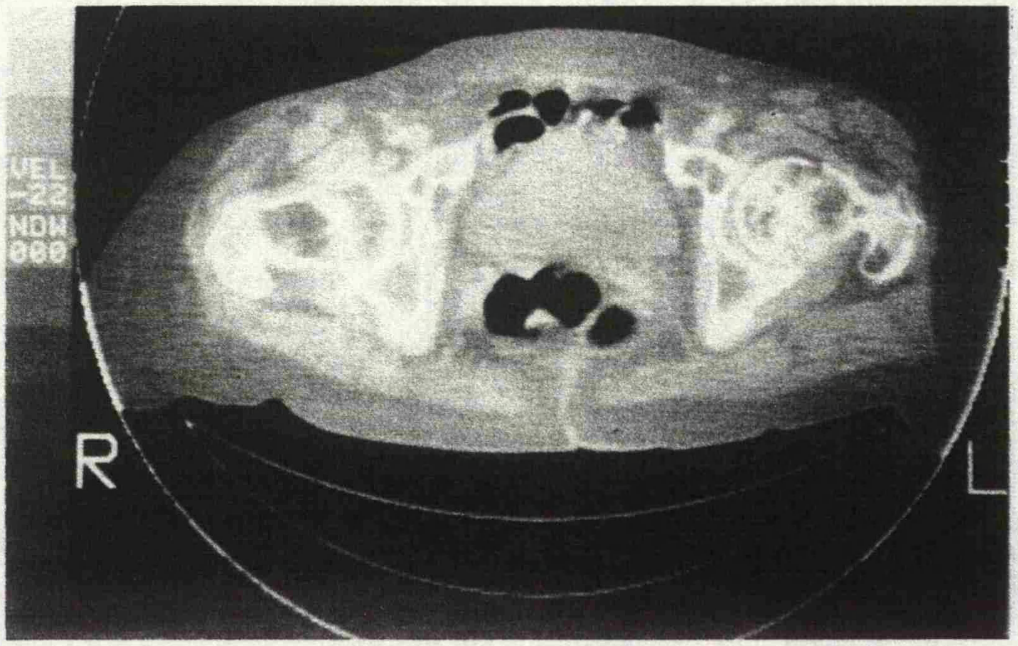


Fig 3.3.7 A CT scan showing a fracture which exhibits radiological features consistent with an old injury.



<u>Fig 3.3.8 A CT scan showing the presence of fluid within the hip joint characterised by a lucent line anterior to the head of the femur on the left side.</u>



3.3.4 Discussion and conclusions.

Comminution was present in the majority of fractures, but surprisingly anterior comminution was more common than posterior comminution, although the anterior comminution was often minor.

Many authors stress the importance of posterior comminution in contributing to instability of the fracture and adding to the damage to the retinacular vessels (Meyers 1973, Meyers 1980). The significance of anterior comminution, which was a common finding in the patients studied, is not known. It may be that anterior comminution represents a more severe injury and therefore signifies a worse prognosis following fixation of the fracture.

Fluid, presumably haematoma, was visible in the hip joint in eight patients. The presence of fluid within the hip joint may indicate the need to aspirate the hip, because it has been suggested that intracapsular fluid may cause a tamponade of the blood flow to the femoral head (Wingstrand 1986, Wingstrand 1988, Stromquist 1988).

CT scanning is expensive and inconvenient and as such is probably not the best method to detect a haemarthrosis when easier methods such as ultrasound are available.

The most interesting finding was the detection of some fractures which had the appearances of an old fracture. All patients in this study had a good history of injury in the week preceding the scan and no previous history of fracture. It is, of course, impossible to prove that these represented old injuries, but none of them had a haemarthrosis within the hip joint. It can be conjectured that these patients had had a previous fracture which had developed a fibrous non-union and that the trauma that caused the admission had disrupted that union

3.4 A prospective randomised study comparing operative versus conservative treatment of displaced intracapsular proximal femoral fractures in the elderly demented patient.

3.4.1 Introduction

Elderly, minimally ambulant and severely demented patients have a high morbidity and mortality following intracapsular proximal femoral fracture (Ions 1987, Wood 1992). This finding has led some authors to suggest that these patients should not undergo operative treatment but instead have conservative treatment of the fracture with intensive and appropriate medical treatment (Lyon 1988).

Although a comparative study of the outcome following conservative and operative treatment of these fractures has been performed (Lyon 1988), there has been no randomised prospective study comparing these two methods of treatment.

An attempt was made to perform such a trial.

The trial was planned to run for at least one year, however had to be abandoned because of dissatisfaction with the results of conservative treatment by health care professionals associated with the care of these patients. The author also had personal ethical difficulty continuing the trial after it had been running for six months.

Informed consent for entry into the trial could not be obtained from the patient and was therefore sought from the patients relatives or legal representative. Local ethical committee approval had been gained for the trial.

3.4.2 Materials and methods.

The trial ran from 1st January 1989 until it was terminated in August 1989. Patients with a displaced intracapsular fracture who were admitted during this time period were assessed on admission. Patients who had a mental test score of three or below, indicating severe dementia (Evans 1979), and who were minimally ambulant (house bound and mobilised only with a walking aid) were eligible for inclusion in the study. Nine eligible patients were not included because of lack of consent or inability to find someone capable of giving consent.

Those patients randomised to operative treatment were entered into a trial comparing cemented and uncemented hemiarthroplasties.

Conservative treatment

Patients were treated by studied neglect of the fracture. From the day after admission the patient was allowed to sit out of bed and mobilisation, with the aid of physiotherapy staff, was commenced.

Operative treatment

Patients were entered into a study comparing cemented and uncemented Thompson prostheses. Operation was performed as soon as possible following fracture and following operative treatment patients were allowed to sit out of bed and mobilise the day after operation.

All patients were referred to geriatricians for further rehabilitation.

Patients were reviewed two to three months following admission in a dedicated hip fracture clinic.

3.4.3 Results.

Twenty one patients were included in the study, 9 were randomised to conservative treatment and 12 to operative treatment. Demographic details are shown in table 3.4.1.

All patients sustained their fractures whilst indoors.

Of those treated operatively only 3 patients were living in their own home, with support from relatives and care services, the remainder were either in residential care (5 patients) or resident on geriatric or psychogeriatric wards (4 patients).

One patient treated conservatively came from a home environment, 3 from residential care and 4 from geriatric or psychogeriatric wards.

Three patients in the conservative limb of the trial were operated upon within 2 weeks of admission because of perceived poor performance and pain. This decision was made by the consultant in charge of the patient. These patients were treated with a cemented Thompson hemiarthroplasty.

One patient who had been treated operatively died during the time of the initial hospital stay.

Mean hospital stay for those patients treated conservatively was 18.8 days (SD 16.6, range 2 - 57 days) and those treated operatively 11.9 days (SD 5.1, range 5 - 23 days). No statistical tests were applied to these figures because of the small number of patients.

Only 3 patients were reviewed in the outpatient clinic, 1 who had been treated operatively and two who had been treated conservatively. None were waking independently and none were reported to be in pain by their health care workers. Two patients in the conservative limb of the trial were referred back because of difficulties in management for consideration of treatment by hemiarthroplasty.

Case histories.

An 89 year old caucasian female who was severely demented and walked only with assistance, was initially randomised to conservative treatment. Informed consent for randomisation was obtained from her children. She was transferred to geriatric rehabilitation care after 12 days. Two months following transfer it was felt by the geriatric senior registrar that although she did not seem to be in pain she was not walking and therefore rehabilitation would prove to be difficult. After consultation with her son and daughter the decision was made to treat her with a hemiarthroplasty. She was transferred to the orthopaedic trauma care facility for this to be performed. Following operative treatment she did not walk independently and died 2 months following discharge.

An 85 year old Caucasian male was admitted from his own home and was randomised to conservative treatment. He was cared for by his wife, was severely demented and walked only with assistance. He failed to walk whilst on the acute orthopaedic ward and was transferred to acute geriatric care after 57 days. During that time he developed sacral and bilateral heel sores and a chest infection. Four months following fracture he was referred again to the orthopaedic department for consideration of femoral head replacement. On examination at that stage he had pain on movement of his affected leg and was not walking. He also had severe chest and myocardial disease, which, coupled with his pressure sores made him unfit for surgery. He died six months following fracture still an inpatient on a geriatric ward.

Table 3.4.1 Demographic details of patients entered into the trial comparing operative and conservative treatment.

	HEMIARTHROPLASTY	CONSERVATIVE
MALE	2	2
FEMALE	10	7
MEAN AGE	85.92 (SD 3.5)	86.33 (SD 3.2)
AGE RANGE	82 - 91	81 - 92
MEAN MENTAL TEST SCORE	1.17 (SD 1.34)	0.89 (SD.0.77)

3.4.4 Discussion and conclusions.

This trial was stopped after nine months because of difficulty in recruitment, pressure from other health care professionals, most particularly nurses and the geriatric senior registrar concerned with the assessment of ortho-geriatric patients, and most particulary because of the author's concern with the results in patients treated conservatively. The two case histories illustrated above indicate some of the problems associated with conservative treatment.

Although operatively treated patients did not appear to perform better in terms of mobilisation or mortality the practical aspects of care were much easier in this group of patients. In conservatively treated patients there was always the suggestion that if operated upon they would perform better. When a patient was treated operatively it was felt by his carers that "everything that could be done from an orthopaedic point of view had been done".

This study does not address the question as to whether the patients treated conservatively would have been better treated in their own environment rather than being transferred to an orthopaedic ward and entered into a trial comparing operation with no operation, which may have introduced a bias because of the possibility of direct comparison by relatives and care workers with those patients who had had surgery.

The experience of the author has been similar to that of Winter (Winter 1987) and the conclusion of Lyon that the most humane treatment and economically suitable method of treating these patients is conservatively has not been upheld by this limited study (Lyon 1988).

3.5 A prospective randomised trial comparing cemented and uncemented Thompson hemiarthroplasty in the treatment of displaced intracapsular proximal femoral fractures.

3.5.1 Introduction.

The Thompson prosthesis is used by approximately 31% of surgeons in the United Kingdom for the treatment of displaced intracapsular proximal femoral fractures. Of those surgeons who use the prosthesis 34% regularly use the prosthesis without cement.

There have only been four papers in the literature comparing cemented and uncemented prostheses. Follacci and Charnley performed a retrospective review of cemented and uncemented Thompson prostheses and concluded that better results were obtained with the cemented prosthesis (Follaci 1969). Sonne-Holm compared cemented and uncemented Moore prostheses and concluded that pain relief and gait was improved with a cemented prosthesis (Sonne-Holm 1982). Wrighton retrospectively compared uncemented Moore prostheses with a cemented Thompson prosthesis (Wrighton 1971) and Sadr (Sadr 1976) retrospectively compared cemented Thompson prostheses with uncemented Thompson prostheses, however the uncemented prosthesis was coated with proplast, a porous substance which supposedly allowed ingrowth of bone. The conclusion of these last two trials was the same as the other studies that cemented hemiarthroplasties perform better than uncemented.

The balance of opinion in the literature is that cemented hemiarthroplasties are superior to uncemented, still over 30% of UK surgeons perform a replacement with a Thompson prostheses without cement.

Because only one trial had compared standard Thompson prostheses, and that study was retrospective, a study was devised to compare cemented and uncemented Thompson prostheses.

3.5.2 Materials and methods.

All patients admitted to the Leicester Royal infirmary with displaced intracapsular proximal femoral fractures between 1st January 1989 and 1st January 1990 were assessed for inclusion in the study.

Three types of patient were eligible for inclusion

i) Patients over 80 years of age with a mental test score above 3.

ii) Patients under 80 years of age with a mental test score of 3 or below.

iii) Patients over 80 years of age with a mental test score of 3 or below and who had been randomised in the trial comparing operative to conservative treatment to the operative limb of the trial.

Patients were randomised to treatment with either a cemented or uncemented prosthesis.

Informed consent was obtained from the patient, relatives or legal guardian and local ethical committee approval had been granted for the study.

Patients were operated upon as soon as possible following admission.

Operative technique.

All operations were performed with the patient supine with a sandbag under the affected buttock. A direct lateral approach was used without removal of the trochanter. The femoral head was excised and the neck osteotomised with a saw. The excised femoral head diameter was measured and a prosthesis of appropriate size used.

For uncemented prosthesis the femoral cavity was only partially reamed and the appropriately sized prosthesis inserted. If the prosthesis did not achieve a tight fit in the femoral canal the prosthesis was removed and reinserted with cement, the patient being withdrawn from the trial. The prosthesis was reduced and tested for stability. A suction drain was used for 48 hours postoperatively.

For cemented prostheses the femoral canal was fully reamed.

Polymethylmethacrylate cement was inserted by a finger packing technique without a cement restrictor. The appropriate prosthesis was inserted into the cement filled femoral canal and the cement was left to cure. As in the uncemented technique the prosthesis was reduced and stability assessed. A suction drain was used.

Post operatively patients were encouraged to sit out of bed 24 hours after surgery and walking was commenced following a post operative radiograph, usually 48 hours after surgery.

Patients were assessed daily and following discharge were reviewed in dedicated hip fracture clinic at 2 to 3 months following surgery.

3.5.3 Results

One hundred and thirty seven patients were included in the study, 71 patients were randomised to treatment with a cemented Thompson prosthesis and 66 to treatment with an uncemented.

Demographics of the patients are shown in table 3.5.1.

One patient randomised to the cemented group died during surgery upon insertion of cement into the femoral cavity, three remaining patients in the cemented group died on the ward prior to discharge. Two patients treated with uncemented prostheses died before discharge.

Five patients sustained dislocations, four within 2 weeks of operation (3 cemented and 1 uncemented), all were treated by closed reduction. One patient with a cemented Thompson presented at the review clinic with a dislocated prosthesis 2 months following surgery, the time of dislocation was not known and because of the patients general poor condition no further action was taken.

There were 5 superficial infections (2 cemented and 3 uncemented) and 1 deep (cemented). The superficial infections resolved with antibiotics. The deep infection was treated with antibiotics and the patient was left with a pain free hip but a discharging sinus.

Mean stay on the acute orthopaedic ward was 16.56 (SD 6.34) days for uncemented prostheses and 14.38 (SD 9.54) days for cemented prostheses.

By 3 months following surgery 12 patients in the cemented group had died and 6 in the uncemented group. By one year post surgery 20 patients had died in the cemented group and 17 in the uncemented group.

29 patients with cemented prostheses and 31 with uncemented prostheses were reviewed at 8 to 12 weeks following surgery in the special hip fracture review clinic. All had a decline in mobility when compared to pre-fracture status, 3 in the cemented

group and 5 in the uncemented group only mobilised with assistance of others. Of those patients who were able to give an account of themselves 9 in the uncemented group and 3 in the cemented complained of pain in the affected leg.

Statistical analysis was performed using a chi square test.

Table 3.5.1 Demographic details of patients entered into the trial comparing cemented and uncemented Thompson hemiarthroplasty.

	CEMENTED THOMPSON	UNCEMENTED THOMPSON
MALE	17	18
FEMALE	54	48
MEAN AGE	84.2 (SD 6.0)	82.07 (SD 10.8)
AGE RANGE	60 - 100	64 - 98
MEAN MENTAL TEST SCORE	6.66 (SD 4.12)	6.83 (SD 4.15)

3.5.4 Discussion and conclusions

This study of the early results of cemented and uncemented Thompson hemiarthroplasty, showed a significant difference in early mortality (within 3 months) in the cemented group ($p < 0.05$), but no difference in mortality at 1 year between the two groups. This increase in early mortality may be explained by the possibility of emboli and toxic monomer during cement insertion causing transient hypotension. There was one death during cement insertion.

This study also looked at the incidence of early pain in the affected thigh following surgery. More patients with uncemented prostheses experienced thigh pain than patients with cemented prostheses, although this was not significant.

The majority of patients in this study were elderly and a large number were cognitively impaired. This group of patients put limited demands on their hip and it behooves the surgeon to provide them with the most optimum of treatments. If the decision is made to replace the femoral head with a hemiarthroplasty this should be performed using the best available technique.

Thigh pain has been reported following uncemented total hip replacement (Callaghan 1988) and this thigh pain has been attributed to poor fitting of the femoral component in the femoral canal (Young-Hoo 1993). The Thompson prosthesis comes with a universal stem size which will fit the medullary canal tightly in some patients and loosely in others, it is probable that the prostheses with poor fit will produce poor results.

The results of this study, although only a short term review, do confirm the results of previous studies (Follaci 1969, Wrighton 1971, Sadr 1976, Sonne-Holm 1982) and recommendation cannot be given to use of an uncemented Thompson prosthesis.

3.6 A prospective randomised trial comparing multiple parallel cannulated screws with a sliding hip screw and plate in the treatment of displaced intracapsular proximal femoral fractures.

3.6.1 Introduction.

As was shown in the chapter 3.1 the two most common methods of fixation of displaced intracapsular proximal femoral fractures are either with multiple screws or a sliding screw with attached side plate. There have been many reports of the use of the devices(Skinner 1986, Hegge 1989, Wood 1992), but few randomised trials comparing these two devices (Madsen 1987). A study was devised to compare, in a randomised prospective trial, the two devices for the treatment of intracapsular proximal femoral fractures.

3.6.2 Materials and methods.

The two devices chosen for comparison were the Ambi hip screw (Richards Medical) and cannulated hip screws (Richards Medical).The Ambi hip screw is a lag screw which attaches to a side plate (Fig 3.6.1). Rotation of the lag screw in the barrel of the plate is prevented by a clip and compression by a screw which fits into a thread into the shaft of the lag screw distally. The cannulated hip screw system consists of screws which are inserted over guide wires (Fig 3.6.2). The guide wires are positioned in the femoral head with a guide which allows parallel placement of the wires (Fig 3.6.3 - 3.6.4).

Patients 80 years of age or younger and with a mental test score above three and patients with undisplaced fractures were eligible for inclusion in the study. Patients admitted to the Leicester Royal Infirmary between 01/01/89 and 01/04/90 were eligible for inclusion in the study.

All patients with intracapsular fractures were assessed the day after admission by the author and mental function was assessed by the Mental Test Score (Evans 1978). If patients were eligible for inclusion in the study informed consent was obtained and following agreement to be included they were then randomised into one of the two treatment arms.

All operations were performed by the author as soon as possible after admission, normally on a dedicated hip fractures list. Anaesthesia was usually by general anaesthetic, however choice of anaesthetic was left to the discretion of the anaesthetist. Fixation was performed on a hip fracture table under biplanar image intensification (Fig 3.6.5 - 3.6.6).

For the patient to continue the trial an adequate reduction and fixation had to be achieved.

No specific manoeuvre was used to reduce the fracture, but usually a combination of gentle traction, internal rotation and adduction was sufficient. Reduction was checked by an antero posterior and lateral radiograph taken before fixation (Fig 3.6.7 -3.6.8). Adequate reduction was defined as an AP Garden angle between 180 and 150 degrees and a lateral garden angle 20 degrees either side of 180 (Barnes 1976). If an adequate reduction could not be achieved the patient did not continue in the trial and the decision was taken to either pin in situ, perform an open reduction or to proceed to replacement of the femoral head.

A lateral approach to the proximal femur was used for fixation (Fig 3.6.9).

Following reduction the hip joint was routinely aspirated, in some cases following measurement of intracapsular pressure.

The method of fixation was different for the two implants.

Ambi hip screw.

Under image intensification a guide wire was introduced into the femoral head through the lateral femoral cortex. The guide wire was positioned so that its tip lay in the centre or slightly inferiorly in the head on the antero-posterior view and in a central or posterior placement in the lateral view. Following adequate positioning of the primary guide wire two more guide wires were inserted superiorly to prevent rotation of the femoral head during reaming or screw insertion. The length of screw required was then directly measured from the primary guide wire (Fig 3.6.10) and the proximal femoral neck and head reamed to allow insertion of the lag screw (Fig 3.6.11). The lag screw and plate was assembled on an introducer (Fig 3.6.12) and the lag screw was then inserted into the femoral head over the primary guide wire (Fig 3.6.13) and attached to a two hole side plate which was secured to the femoral shaft with two cortical screws. The guide wires were then removed. A clip was inserted into the barrel of the plate to prevent rotation of the lag screw in the plate (Fig 3.6.14). A compression screw was only used if the bone quality of the femoral head was judged to be good (Fig 3.6.14).

Fixation was assessed with antero-posterior and lateral radiographs and was considered to be adequate if the screw was in a central or inferior position on the antero-posterior radiograph and a central or posterior position on the lateral radiograph. In addition the tip of the lag screw had to be not less than a centimetre from the subchondral bone on both the antero-posterior and lateral radiographs (Fig 3.6.16 - 3.6.17).

Cannulated screws.

As with the ambi hip screw fixation was through a lateral incision. Three guide wires were inserted using the parallel guide. Guide wires were inserted with one inferior and two superior, with the inferior screw lying just above the calcar.

A reamer was used over each guide wire, and the three screws inserted over the guide wires (Fig 3.6.18), the guide wires were then removed. Adequate positioning of the screws was essential for continuation of the patient in the trial. The three screws had to converge or diverge no more than 10 degrees and two of the three screws had to lie within one centimetre of the subchondral bone on both the antero-posterior and lateral radiograph (3.6.19 - 3.6.20).

Post operative regime.

The post operative management was the same for both treatment groups. The patient was allowed to mobilise protected weight bearing with either crutches or a frame 24 hours postoperatively.

The patient was allowed to move onto a walking stick as comfort allowed. No attempt was made to enforce a regime of non-weight bearing.

When the patient was sufficiently mobile discharge was either to home or a rehabilitation facility.

Follow-up was in a special hip clinic at 6 weeks, 3 months, six months, one year and eighteen months post-operatively. Radiographs were taken at each attendance. If a healing complication occurred the patient was referred back to the consultant under whose care he was originally admitted.

Failure was defined as the development of healing complications, either failure of fixation, non-union or avascular necrosis, sufficient to warrant revision surgery.

As this was a short term review statistical analysis of failure was performed using the chi square test, however for a long term review survival analysis would be more appropriate.

Fig 3.6.1 The Ambi hip screw.

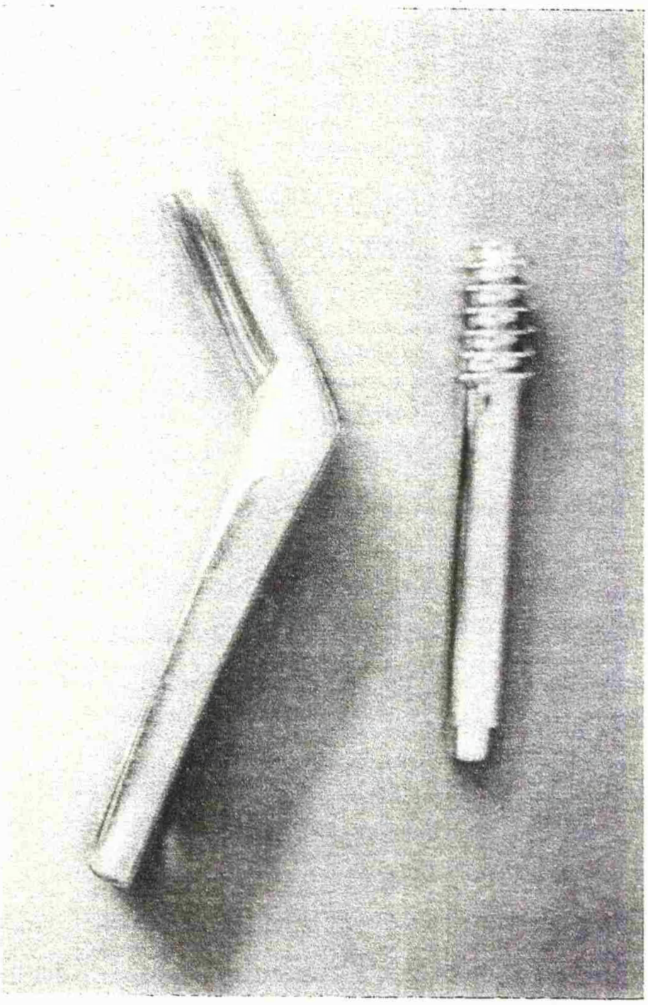


Fig 3.6.2 A cannulated hip screw.

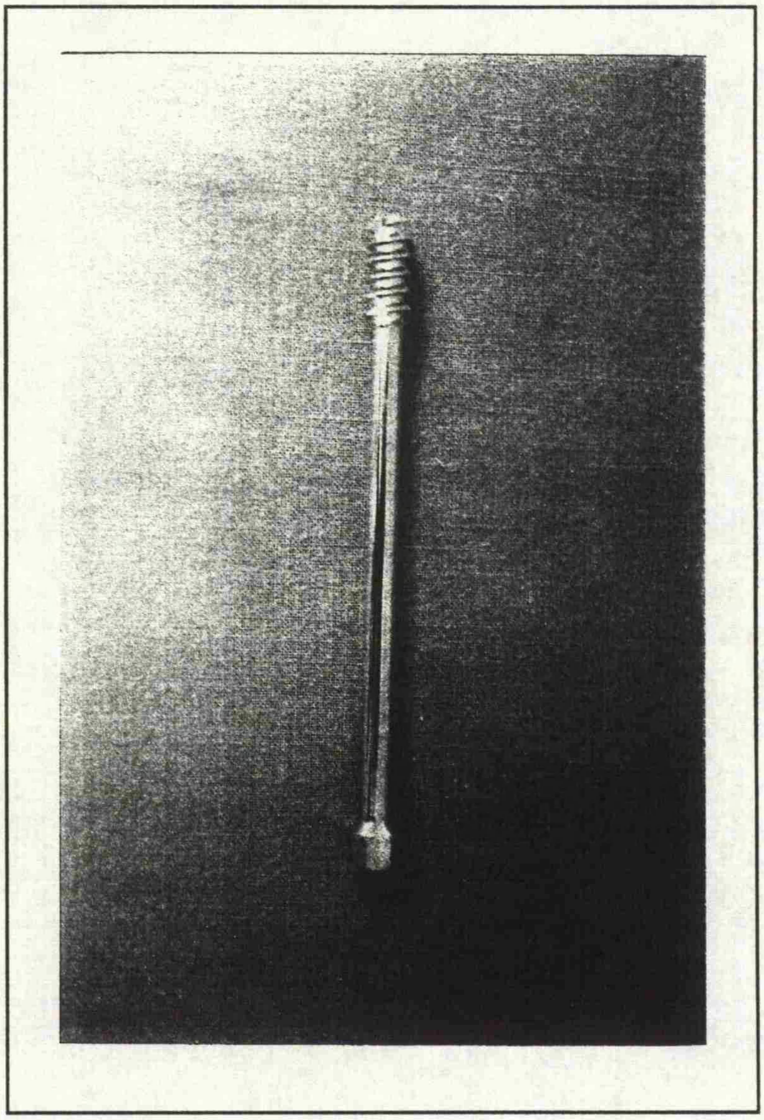


Fig 3.6.3 Disposition of holes in the barrel of the guide.

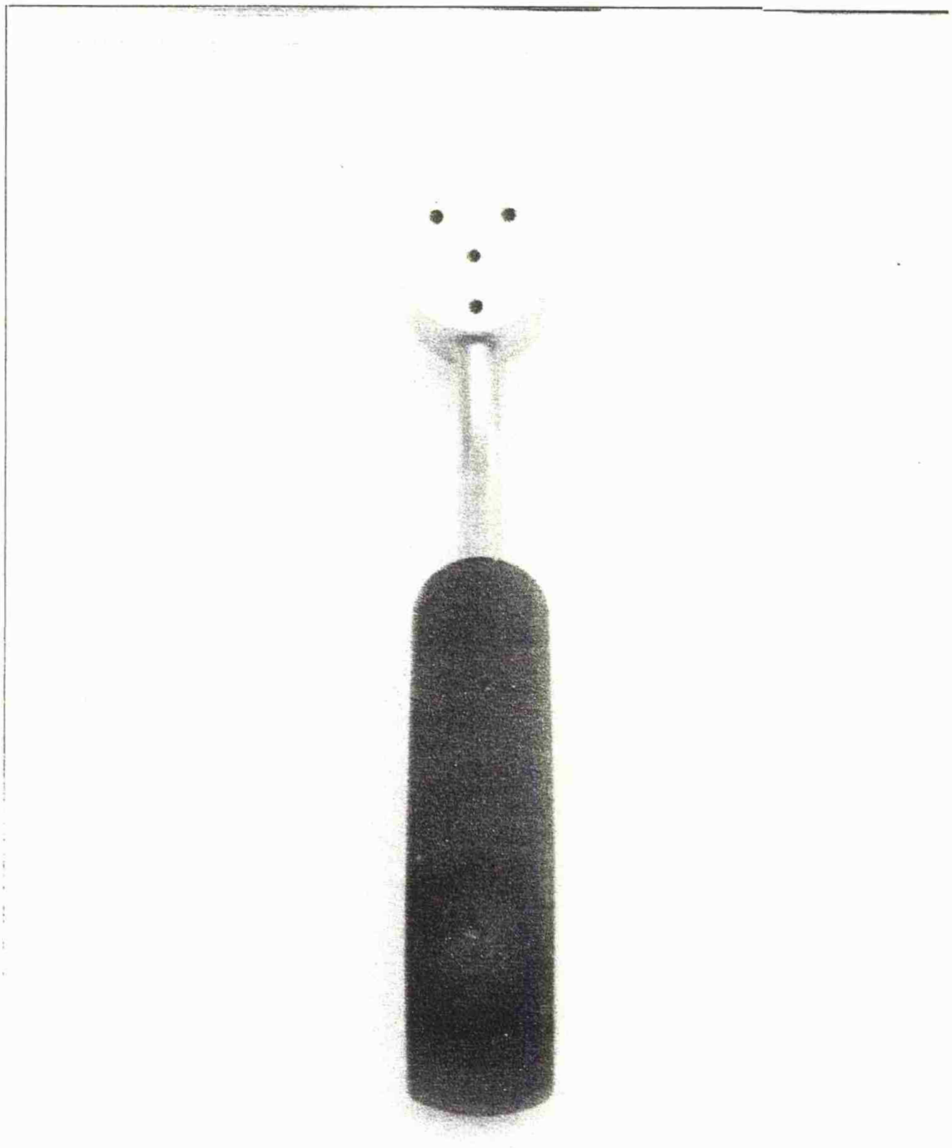


Fig 3.6.4 Photograph to show guide wires passing through barrel thereby allowing parallel placement of wires.

Fig 3.6.5 Position of image intensifier to obtain intra-operative antero-posterior view of hip.

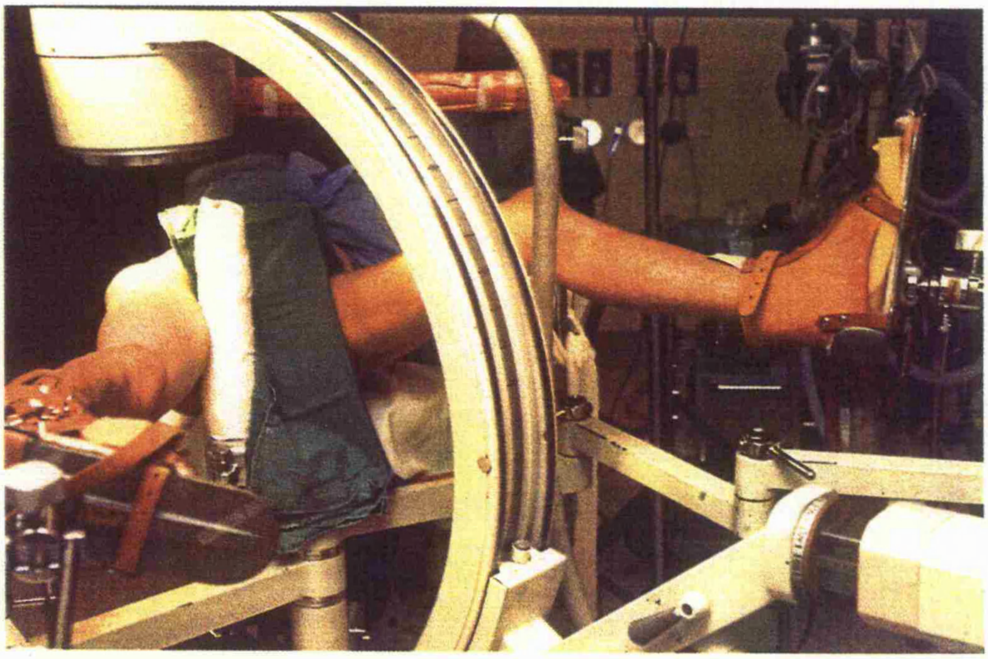


Fig 3.6.6 Position of image intensifier to obtain intra-operative lateral view of hip.

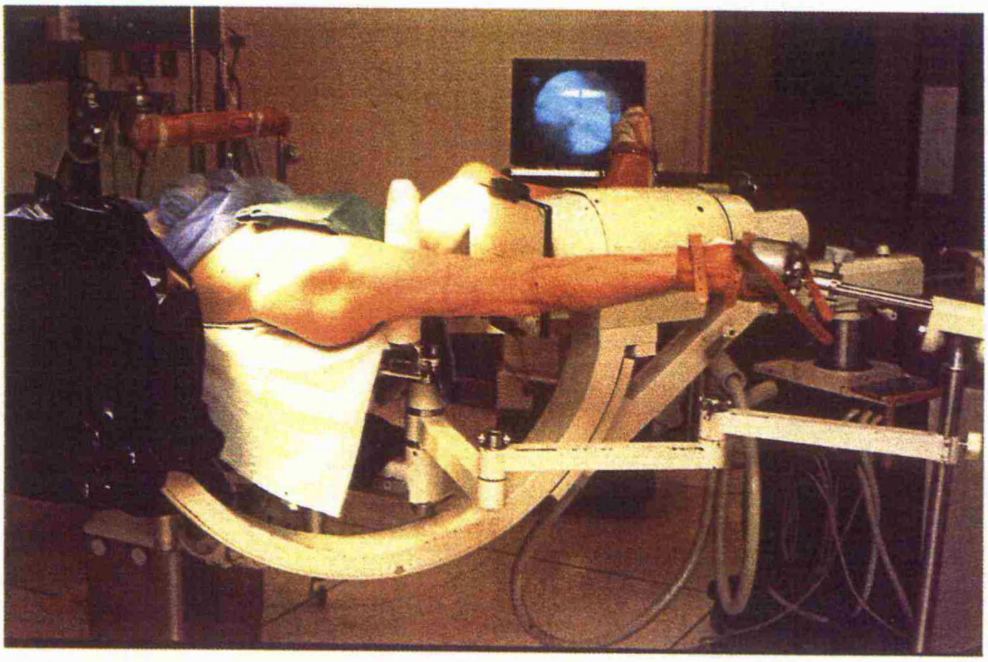


Fig 3.6.7 Intra-operative radiograph showing antero-posterior view of reduction.

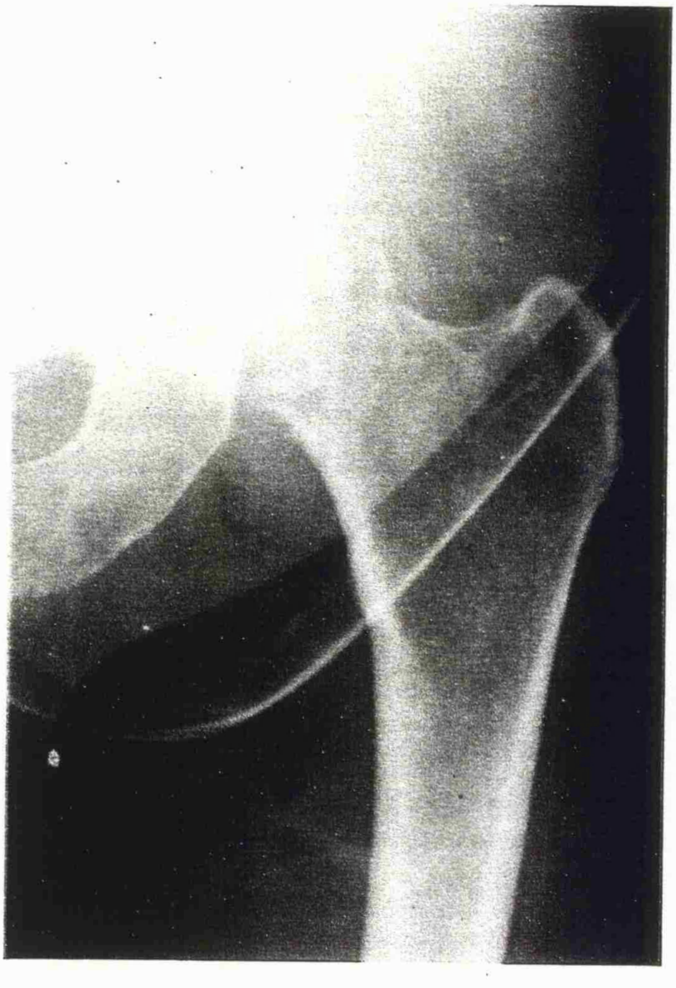


Fig 3.6.8 Intra-operative radiograph showing lateral view of reduction.

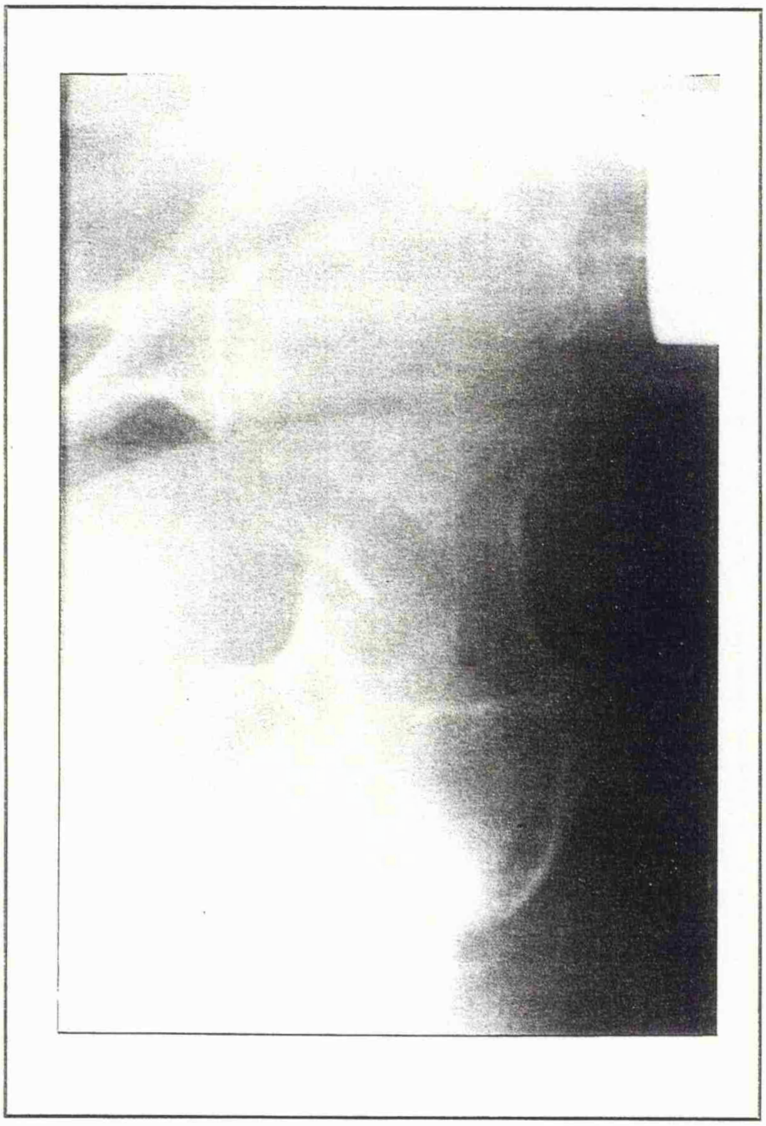


Fig 3.6.9 Photograph showing lateral approach used for fixation and presence of a large haematoma around the greater trochanter.

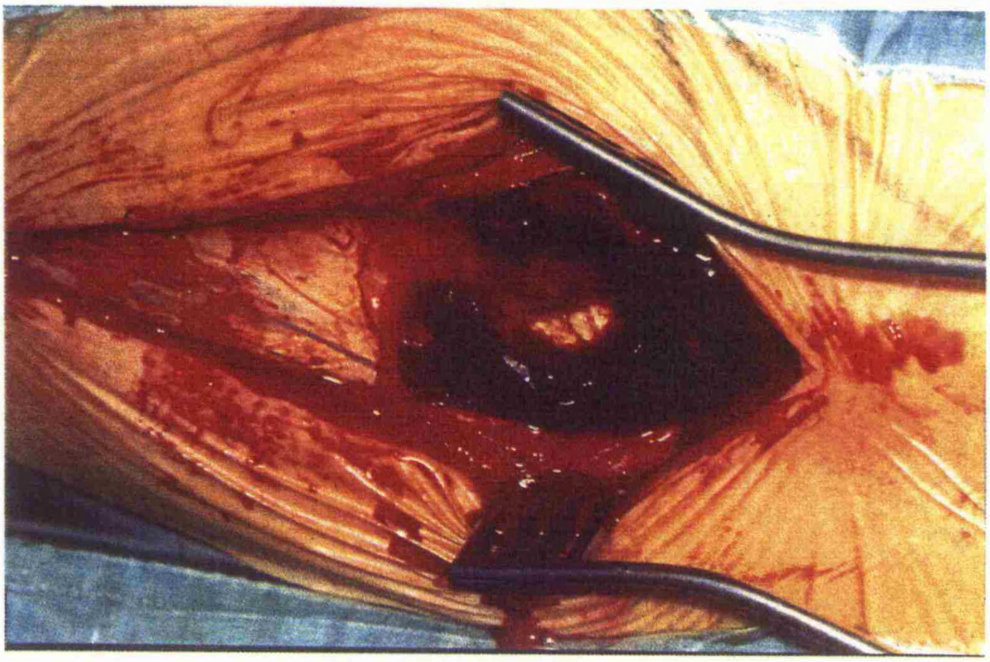


Fig 3.6.10 Method of direct measurement of length of screw from guide wire.

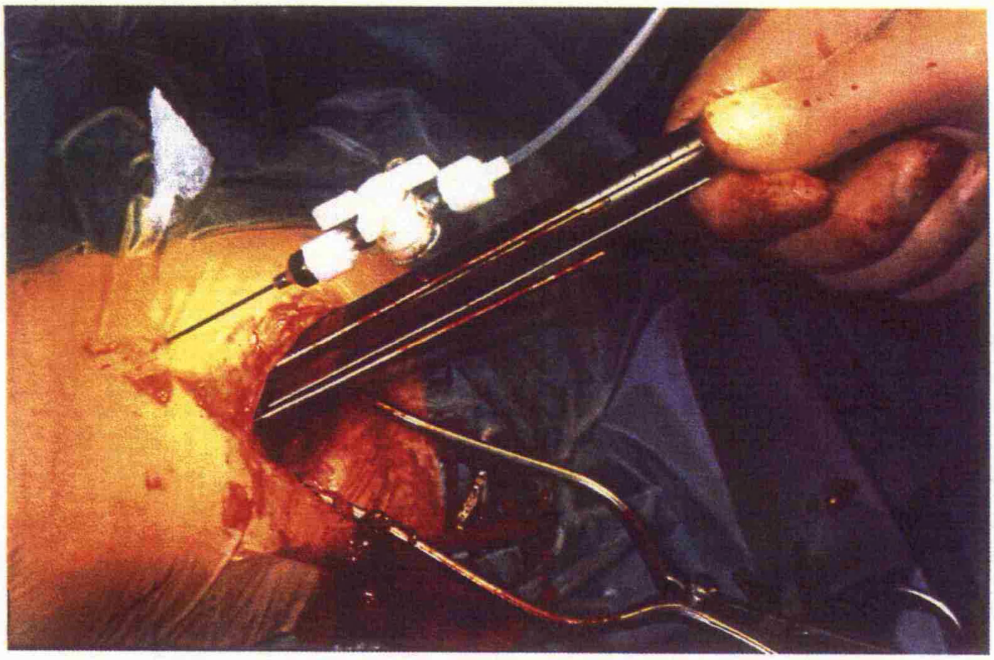


Fig 3.6.11 Reaming of tract for screw with two additional guide wires to provide stability to the femoral head.

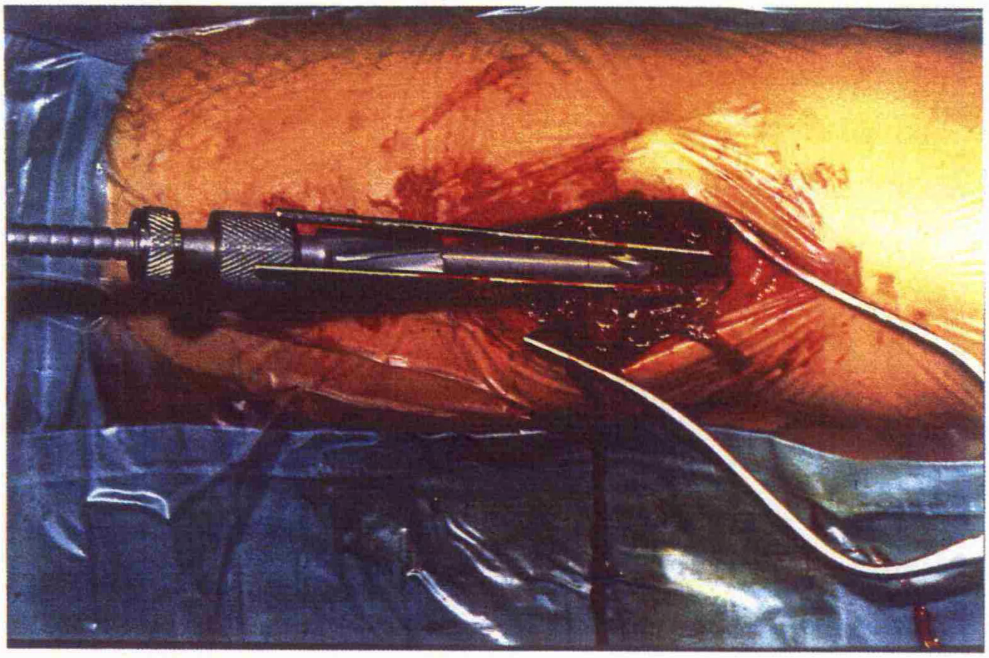


Fig 3.6.12 Lag screw and plate assembled prior to insertion.

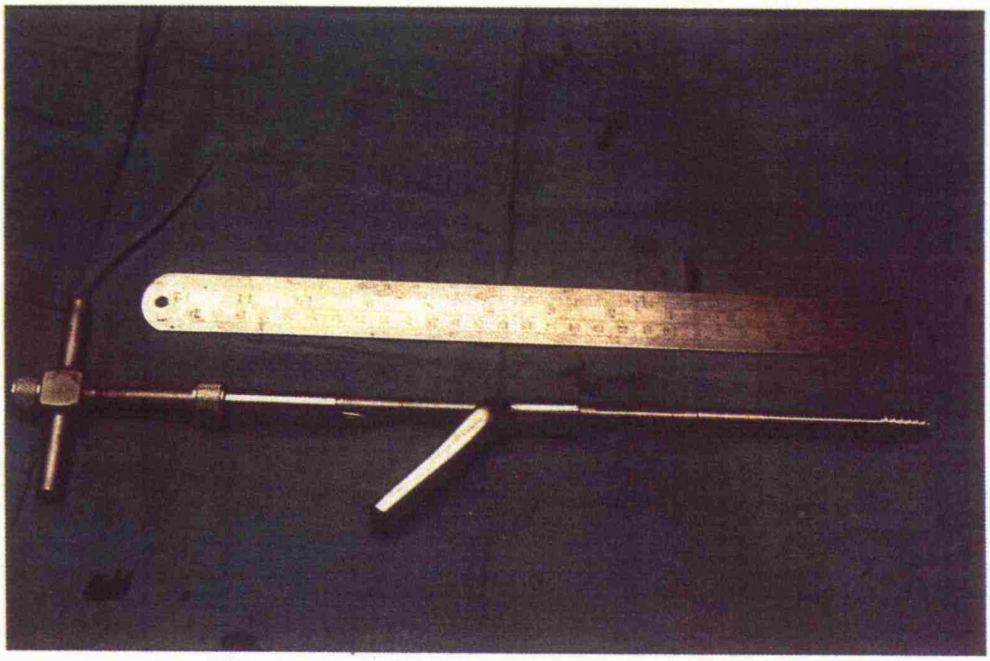


Fig 3.6.13 Insertion of lag screw over guide wire with two supplementary guide wires to prevent rotation of the femoral head.

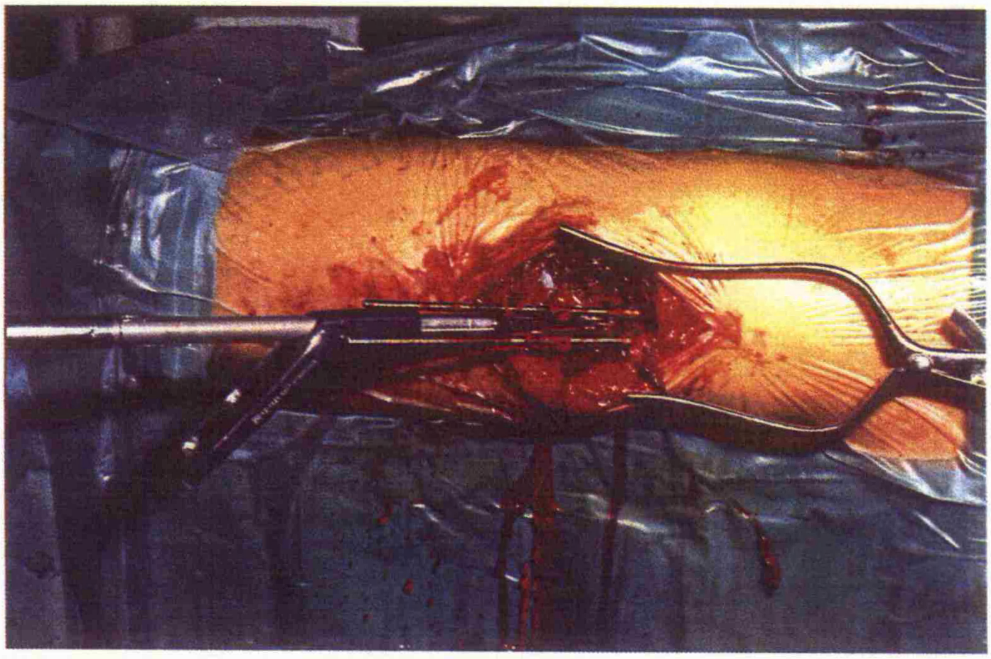


Fig 3.6.14 Insertion of clip to prevent rotation of the lag screw in the barrel of the plate.

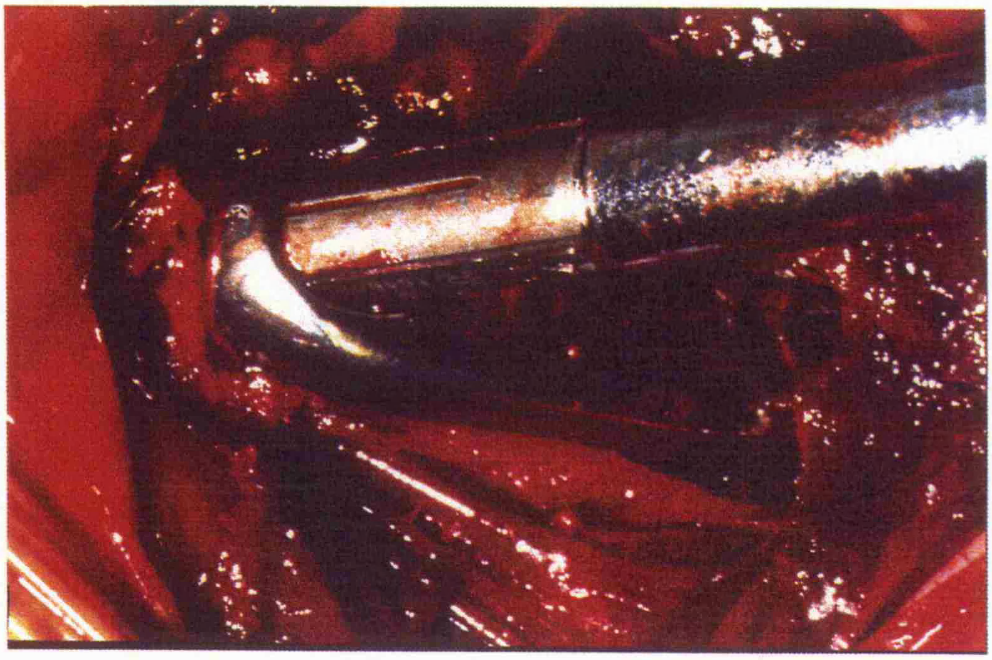


Fig 3.6.15 Insertion of a compression screw into the barrel of the lag screw.

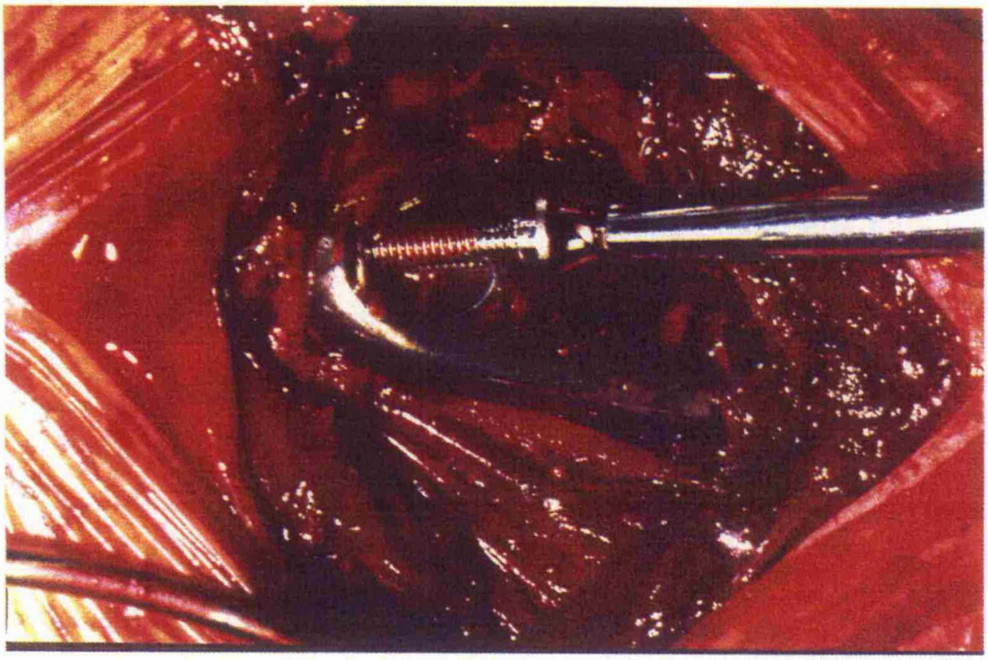


Fig 3.6.16 Antero-posterior radiograph showing position of Ambi hip screw.

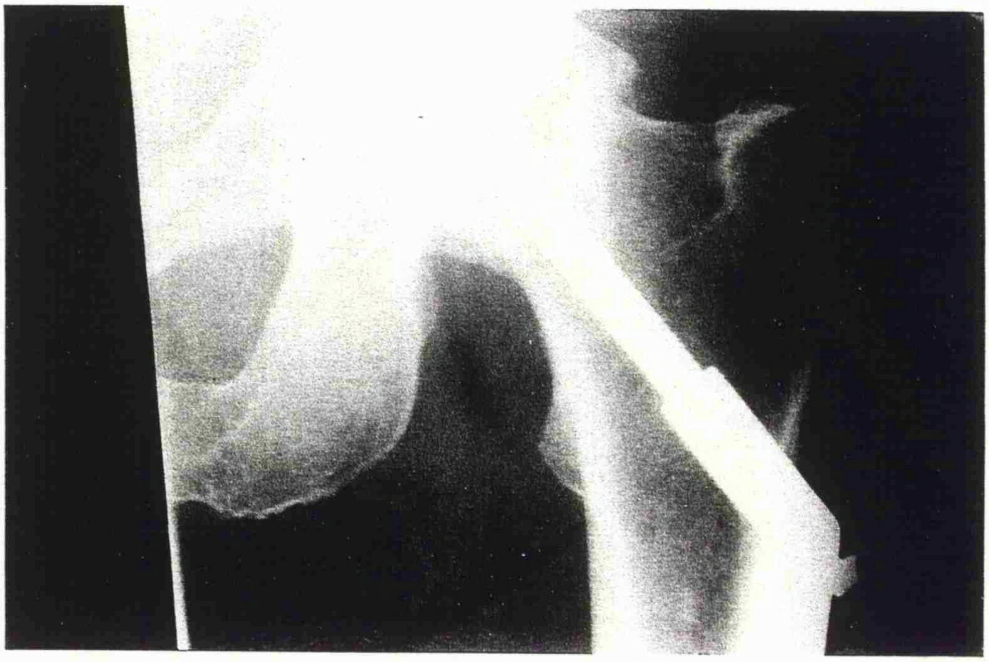


Fig 3.6.17 Lateral radiograph showing position of Ambi hip screw.

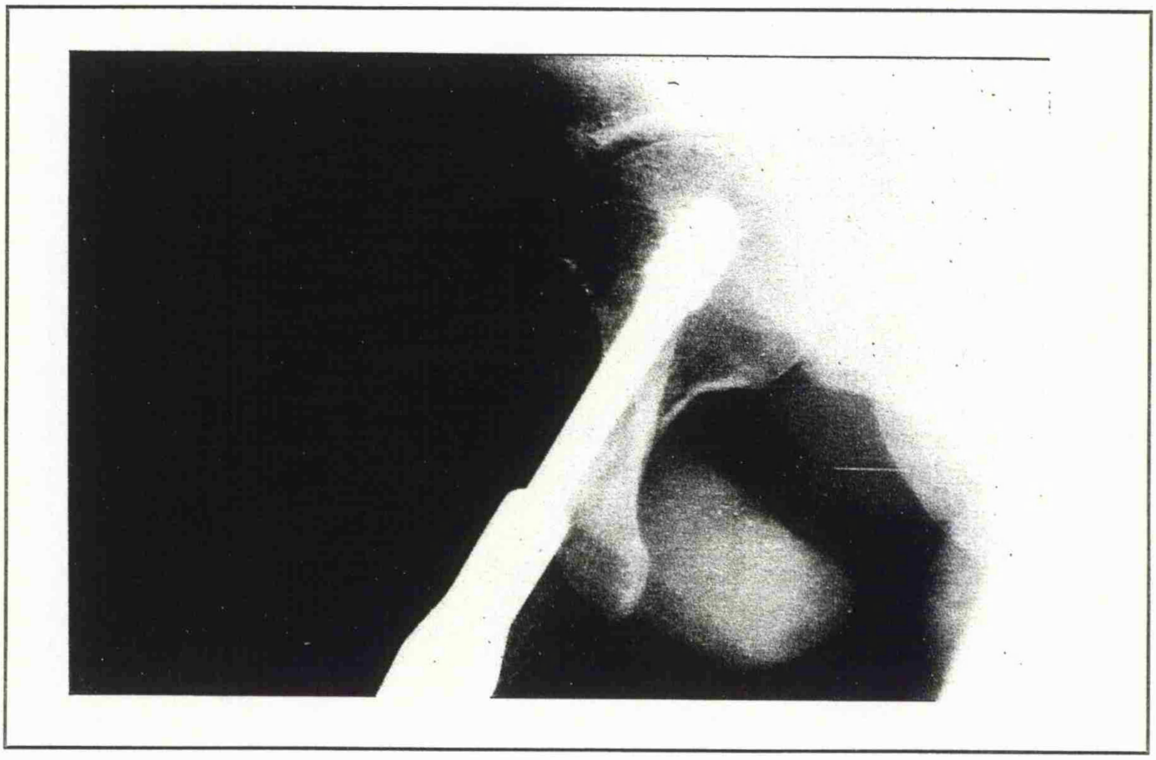


Fig 3.6.18 Insertion of cannulated hip screw over a guide wire.

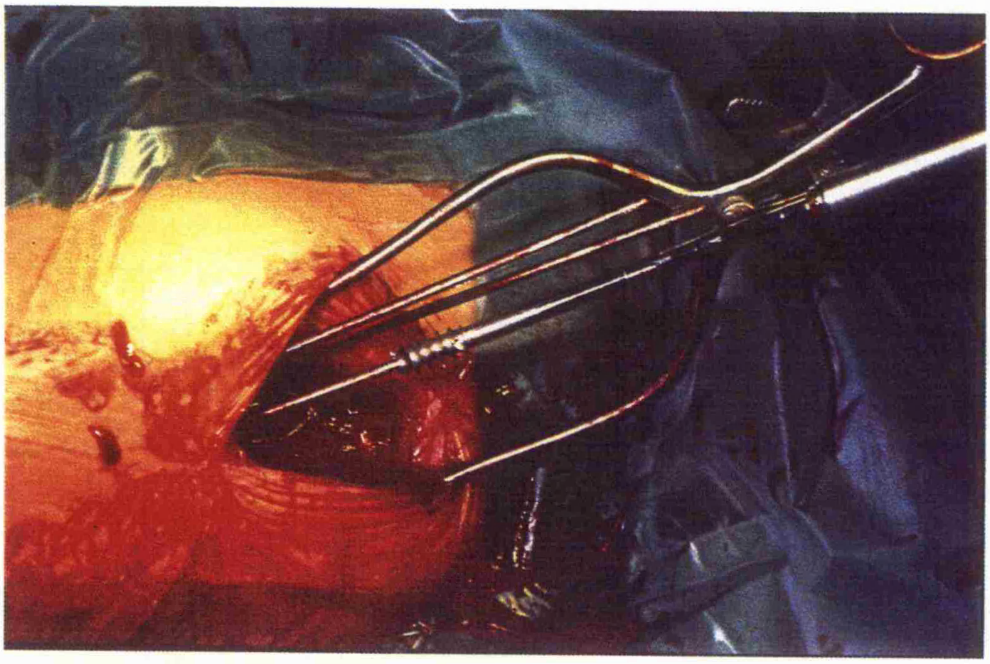


Fig 3.6.19 Antero-posterior radiograph showing position of cannulated hip screws.

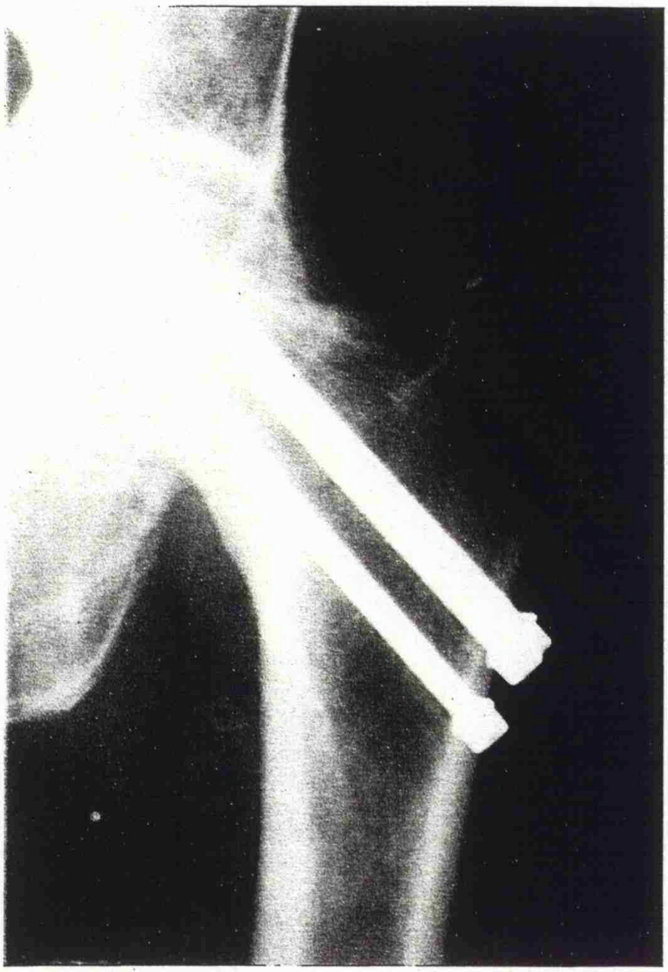
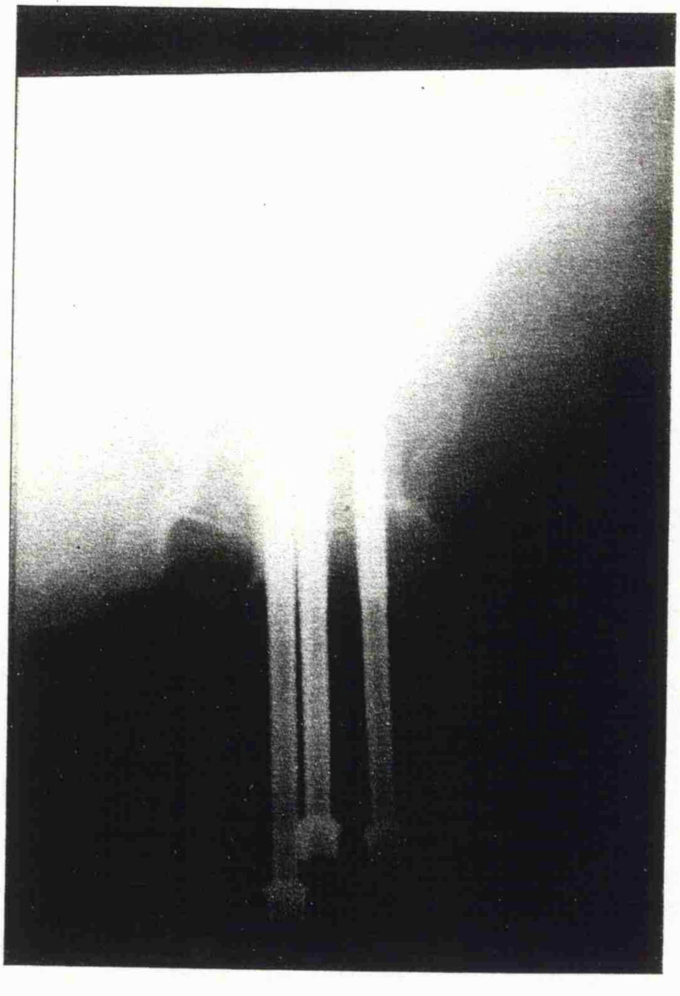


Fig 3.6.20 Lateral radiograph showing position of cannulated hip screws.



3.6.3 Results.

214 patients were eligible for inclusion in the study. One patient declined to participate in the trial, in two patients an adequate reduction could not be obtained and they were treated by femoral head replacement and in two patients cannulated screws could not be placed in an acceptable position and an alternative method of fixation was employed. These 5 patients were excluded from further analysis as they did not fulfil all the criteria for entry into the trial as defined in the trial protocol. Therefore 209 patients were entered into the study 102 patients were treated with an Ambi hip screw and plate (AHS) and 107 with multiple cannulated screws (CHS).

Using a t-test the distribution of age, sex, mental test score and time from fracture to operation was not significantly different between the two groups (Table 3.6.1).

Two patients in the AHS group died during their acute admission and 1 in the CHS group. Five CHS patients died within three months of surgery and 7 in the AHS group.By one year 9 patients had died in the CHS group and 10 in the AHS.

Patients were reviewed in the dedicated hip fracture clinic for 12 - 18 months following operation.

By 1 year 11 patients in the CHS group had failed and 9 in the AHS, failure being defined as revision of the implant to a replacement, either total or hemiarthroplasty, consequent upon the development of a healing complication (painful non-union, mechanical failure or painful late segmental collapse). This difference in failure rates was not significant. Survival analysis would be more appropriate for long term analysis of results.

Two patients in the CHS group sustained a post-operative subtrochanteric fracture.

Table 3.6.1 Demographic details of the patients entered into the trial comparing Ambi hip screw with multiple cannulated screws.

	AMBI HIP SCREW	CANNULATED HIP SCREWS
MALE	29	25
FEMALE	73	82
DISPLACED	82	91
UNDISPLACED	20	16
MEAN AGE	72.2 (SD 11.6)	71.9 (SD 10.2)
AGE RANGE	25 - 93	42 - 91
MENTAL MEAN TEST SCORE	10.49 (SD 2.57)	10.59 (SD 2.62)

3.6.4 Discussion and conclusions.

There has been no previous prospective randomised trial specifically comparing a cannulated screw system with a sliding screw plate system for the treatment of intracapsular proximal femoral fractures. Previous publications have either been reports of one or other of the devices (Skinner 1986, Wood 1992) or have been comparisons between sliding screw plates and non-cannulated screws (Madsen 1987).

A cannulated screw system has the theoretical advantage of more accurate placement of the multiple screws in the femoral head. The author, however, found the cannulated screw system more difficult to use, despite a period learning to use the device before commencement of the trial. It was extremely difficult to place the slender guide wires accurately because they tended to veer off course when striking hard bone. In contrast the guide wire of the Ambi hip screw system was much thicker and accurate placement was found to be much easier with this device.

To use the development of healing problem as a definition of failure is well recognised (Stromqvist 1984, Stromqvist 1992).

Using this definition there was no difference in failure rates between the two devices. The slightly better results obtained for the devices in this study than in other studies (Skinner 1986, Wood 1992) is likely to reflect the attention to accuracy of reduction and placement of implants, poor reduction and poor implant placement is associated with higher failure rates (Barnes 1976).

The most serious complication was a postoperative subtrochanteric fractures, which occurred in two of the patients treated with cannulated screws. No subtrochanteric fracture occurred in the group treated with an Ambi hip screw.

In the subtrochanteric fractures the screw insertion point was not distal to the lesser trochanter, which is associated with this problem (Neuman 1990).

Although technical imperfections of insertion may predispose to fracture the potential for fracture is inherent in any multiple screw system. As the intracapsular fracture unites and impacts the screws back out and leave an already osteoporotic femoral cortex further weakened by screw holes. This unprotected lateral cortex is thus more likely to sustain a stress fracture. A side plate removes this problem.

Although no difference could be found in failure rates between the two devices the difficulty of insertion and the risk of subtrochanteric fracture with multiple cannulated screws mean that this method of fixation cannot be recommended for intracapsular proximal femoral fractures.

3.7 An investigation into the levels of intracapsular pressure following proximal femoral fractures.

3.7.1 Introduction.

The aetiology of avascular necrosis following proximal femoral fracture remains controversial. There is no doubt that in intracapsular fractures there is considerable disruption to the blood supply (Catto 1965). This is most noted in displaced intracapsular fractures when the retinacular vessels may be torn or stretched. However avascular necrosis does also occur in undisplaced fractures where it is unlikely that there is significant damage to the retinacular vessels. In these fractures the main damage is to the intraosseous circulation.

A possible aetiological factor for avascular necrosis in undisplaced fractures is the presence of an haemarthrosis which causes tamponade and therefore obstruction of blood flow the femoral head (Stromqvist 1985).

An experiment was designed to study the levels of intracapsular pressure following proximal femoral fractures.

3.7.2 Materials and methods.

Fifty five patients were studied with proximal femoral fractures. There were 47 intracapsular fractures (31 displaced, 16 undisplaced or minimally displaced and 8 extracapsular fractures).

All their measurements were made under anaesthesia at the time of definitive fixation of the fracture. Informed consent and local Ethical Committee approval had been granted for the study.

Intracapsular pressure was measured with 125 mm 18 gauge spinal needle. To the luer lock of the needle a three way tap was attached to which was attached a 150 mm manometer tube. The manometer tube was attached to a Gould p50 pressure transducer and then to an amplifier and chart recorder. The system was flushed with Saline before insertion of the needle. The system was zeroed with the tap open to atmosphere at the level of the insertion of the needle. The hip joint space was approached antero-laterally and percutaneously (Fig 3.7.1) and insertion was guided by image intensification. Resistance was felt to the needle tip as it passed through the capsule of the hip joint and then firm resistance was felt as it hit the bone of the femoral head (Fig 3.7.2). The needle was withdrawn slightly with the bevel facing anteriorly. Readings of intracapsular pressure were then taken. After intracapsular pressure readings had been taken the hip was aspirated until pressure fell to zero. After aspiration the intracapsular placement of the needle was confirmed by injection of 1 ml of radio-opaque dye (Nyopam). The hip was not moved during pressure readings. Statistical testing was performed using a two sample t-test.

Fig 3.7.1 Photograph showing percutaneous insertion of cannula to measure intracapsular pressure.

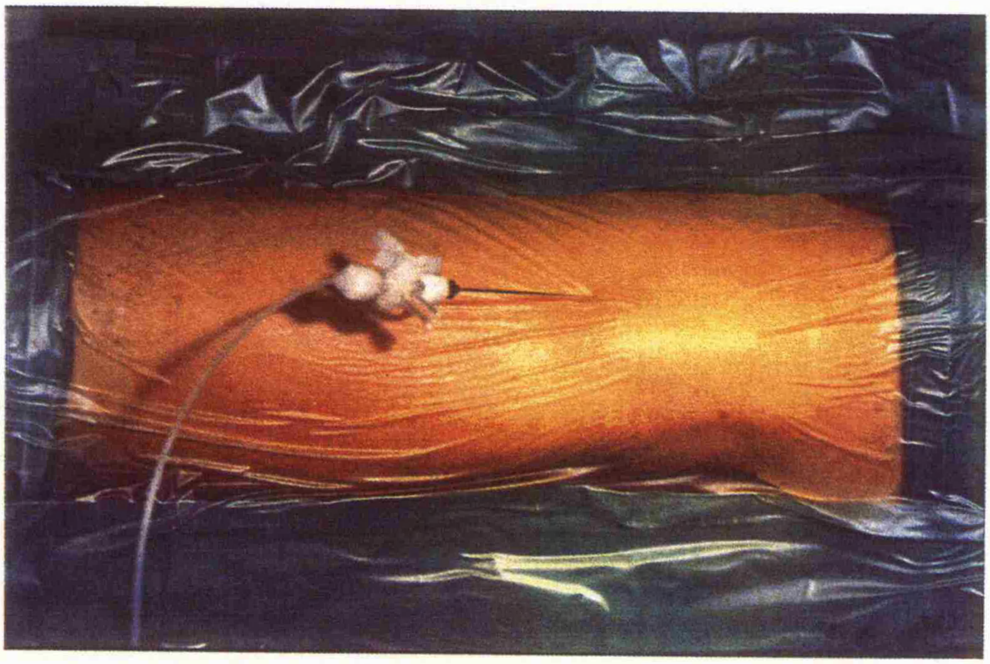


Fig 3.7.2 Lateral radiograph showing position of cannula within the hip joint.

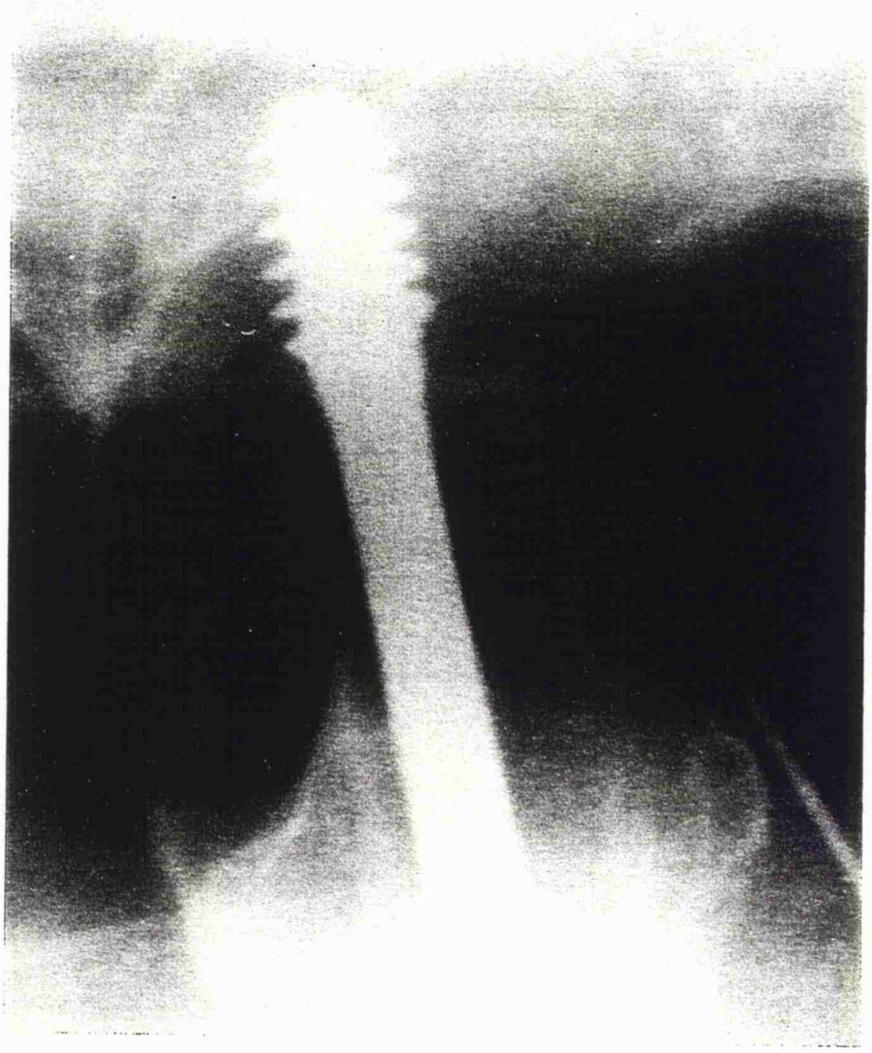
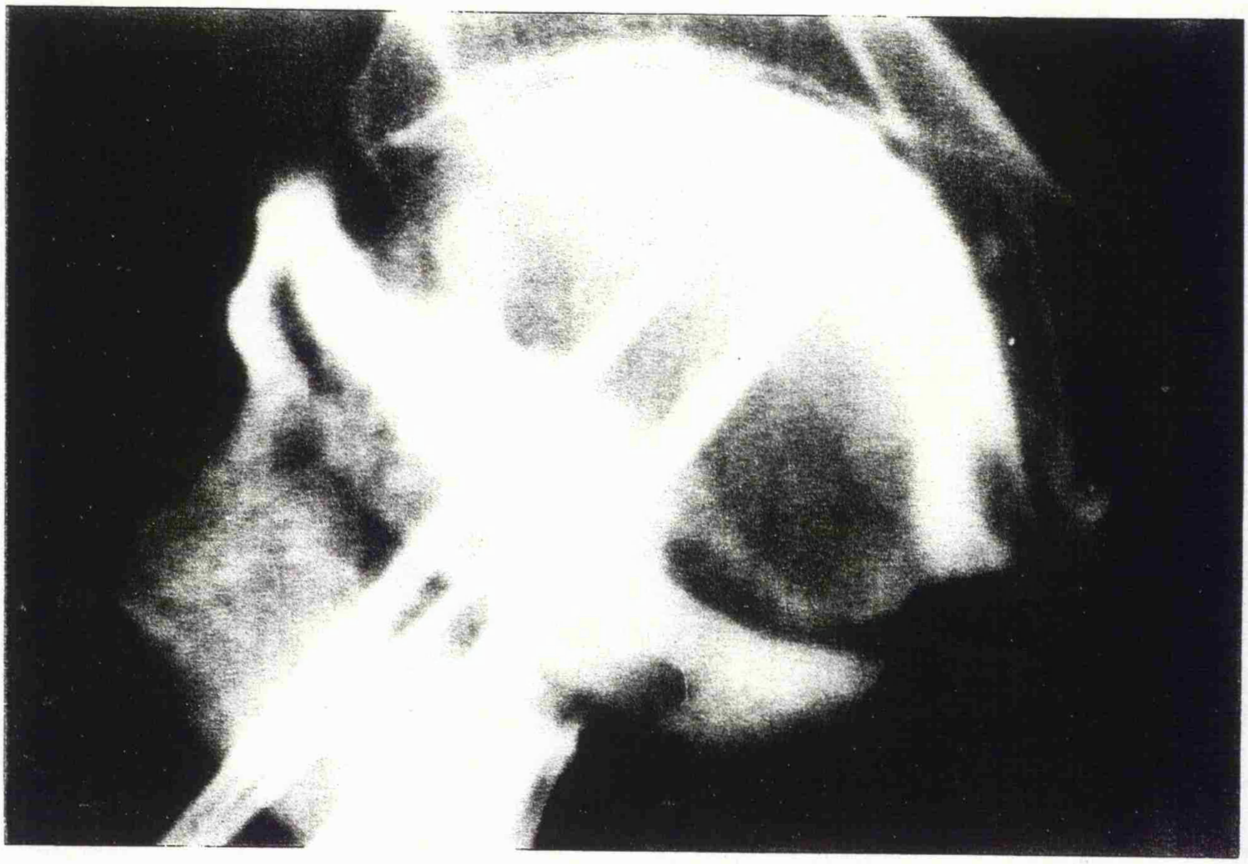


Fig 3.7.3 Antero-posterior radiograph showing arthrogram confirming intra-articular placement of cannula.

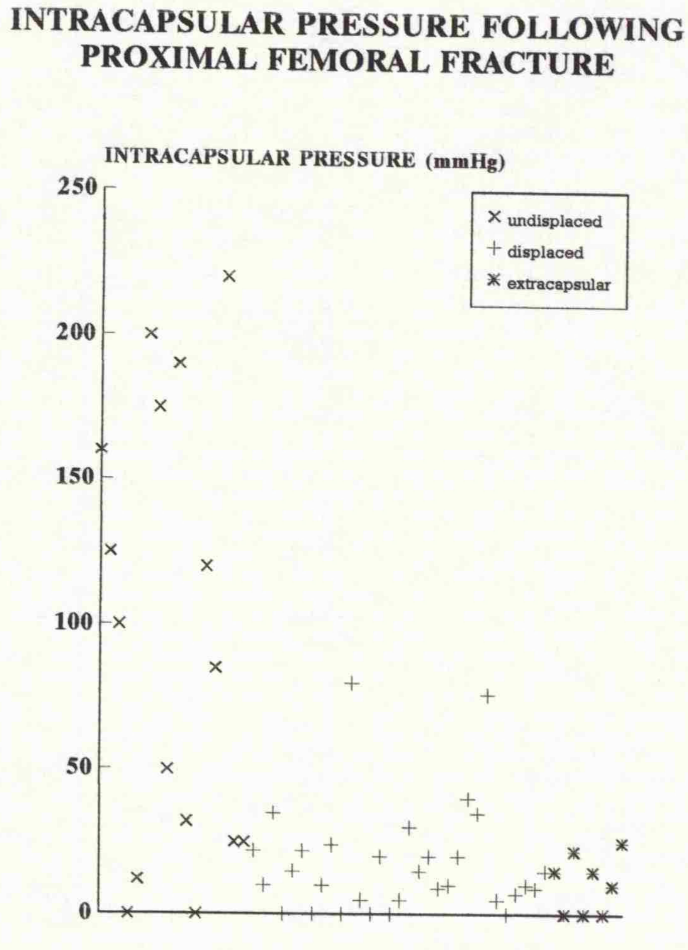


3.7.3 Results.

The mean intracapsular pressure for all patients before aspiration of the hip was 39.2 mmHg (range 0 - 220, SD 55.8). In undisplaced intracapsular proximal femoral fractures the mean intracapsular pressure was 94.9 mmhg (range 0 - 220, SD 74.4). In displaced intracapsular proximal femoral fractures the mean intracapsular pressure was 17.7 mmhg (range 0 - 80, SD 19.3). In extracapsular proximal femoral fractures the mean intracapsular pressure was 10.9 mmhg (range 0 - 25, SD 9.4) The values of intracapsular pressure for all three groups are shown in figure 3.7.4.

The mean intracapsular pressure was significantly higher in the group of undisplaced fractures than in either the displaced or extracapsular groups ($p<0.05$).

Fig 3.7.4 Graph showing values for intracapsular pressure in the three groups of fracture studied.



Each point on the graph represents the intracapsular pressure in one patient.

3.7.4 Discussion and conclusions.

It was initially surprising to find increased intracapsular pressure in some of the extracapsular fractures. Theoretically there should be no direct bleeding into the joint space following extra-capsular fracture. However, these fractures are almost always are produced by a fall (Jarnlo 1990) and such local trauma may produce an effusion. Following intracapsular proximal femoral fracture the blood flow to the femoral head may be severely impaired (Catto 1965(a)). This impairment comes from complete interruption of the intraosseous (or metaphyseal circulation) and partial disruption or complete disruption of the retinacular supply. The disruption of the retinacular supply may be due to tearing of the retinacular vessels or kinking secondary to displacement of the fracture. Because of this tenuous blood supply it has been suggested by various authors (Soto-Hall 1964, Stromqvist 1985, Crawford 1988) that increased pressure in the joint cavity occurring following an intracapsular fracture may reach levels sufficiently high so as to obstruct the remaining flow of blood to the femoral head. Experimental work with juvenile animals in which the situation is to some extent similar than to an intracapsular fracture have shown that sustained increases in intracapsular pressure even to levels of 40 mmHg in the rabbit can produce hypoxia and ischaemic changes in the femoral head (Vegter 1987, Svalagosta 1989). Intracapsular pressures well above diastolic have been reported in the clinical literature in humans and in this series intracapsular pressures to intracapsular fractures vary from 0-220 mmhg. It is possible that intracapsular pressures above the critical capillary closing pressure of 30 mm Hg can constrict remaining vessels that lie within the hip joint.

This study has shown that high intracapsular pressures are present following intracapsular proximal femoral fractures and this increase in pressure is more marked in undisplaced intracapsular proximal femoral fractures.

3.8 Measurement of intra-osseous pressure in the femoral head following proximal femoral fracture.

3.8.1 Introduction.

The major complications of intracapsular fractures of the femoral neck are failure of fixation, non-union and avascular necrosis. Avascular necrosis may be caused by damage to the retinacular vessels at the time of fracture or, possibly, by the tamponade effect of an intracapsular haematoma (Soto-Hall 1964, Kristensen 1989).

To attempt to measure the possible influence of intracapsular haematoma on femoral head blood flow intra-osseous pressure was used as a method of measuring changes in bone blood flow.

Intra-osseous pressure is not a measurement of arterial or venous pressure alone, but a combination of the two. Changes in pressure can be seen to parallel changes in blood flow. This relationship between bone blood flow and intra-osseous pressure has been demonstrated in animals, and although direct flow measurements cannot be measured changes in flow are reflected by changes in pressure (Azuma 1964, Shim 1972).

3.8.2 Materials and method.

50 patients with proximal femoral fractures were studied: seventeen of the fractures were extracapsular and thirty three intracapsular. Nine of the intracapsular fractures were undisplaced or only minimally displaced and twenty four were displaced. Informed consent was obtained from the patients for the measurements.

All measurements were performed under anaesthesia before the fracture was internally fixed during the same anaesthetic.

Intracapsular pressure was measured with a 125 mm , 18 G spinal needle (Steriseal Ltd). To the hub of the needle was attached a three way tap with luer lock connector which was connected to a 150 cm manometer tube. The manometer tube was connected to a Gould P50 pressure transducer and then to an amplifier and chart recorder.

The system was flushed and filled with saline prior to insertion into the hip joint. Pressures were measured with reference to a zero level obtained with the three way tap opened to atmosphere and placed at the level of insertion of the needle.

The hip joint space was entered percutaneously through an antero-lateral approach, guided by image intensification.

After all readings had been taken, including intra-osseous pressure, and the hip joint was aspirated, the intracapsular placement of the needle was confirmed by injection of one to five mls of radiopacque dye (Niopam) and intracapsular placement was confirmed by image intensification of the hip joint. Following confirmation of placement the hip was again aspirated.

For displaced fractures, pressures were measures after the fracture had been reduced, which often required the leg to be internally rotated, whilst in the remainder of the fractures the pressures were measured with the hip in a neutral position.

The hip was not moved during the pressure recordings.

Intra-osseous pressure was measured with a purpose-built stainless steel probe (Gaeltec Ltd) 120 mm in length and 2 mm in diameter. The pressure sensor was 2 mm from the tip and sideways facing (Fig 3.8.1). The advantage of this catheter-tip transducer is that it records the pressure at the site of interest with no intermediate manometer tubing and taps. The transducer was zeroed before insertion thereby ensuring all measurements were correct with regard to atmospheric pressure.

The size, shape and rigidity of the probe made it easy to introduce through a guide wire hole and its radio-opacity made it possible to achieve precise placement of the probe (3.8.2).

The transducer was connected to an amplifier and chart recorder to provide permanent recordings.

Following drilling of a guide wire into the femoral head through the lateral cortex the guide wire was removed and the probe inserted through the guide wire channel and its placement was confirmed by image intensification. Readings were taken from the trochanteric region and from the head both before and after aspiration of the hip.

From the readings obtained (Fig 3.8.3) pulse pressure was taken as the amplitude between the maximum and the minimum of the waveform and the mean pressure as the midpoint between them (Fig 3.8.4).

Intracapsular and intra-osseous pressures were measured simultaneously.

Statistical testing used paired t-tests as the same measurements were repeated in the same groups of individuals under different conditions.

Fig 3.8.1 Close up photograph of the pressure probe showing lateral position of the transducer (white).

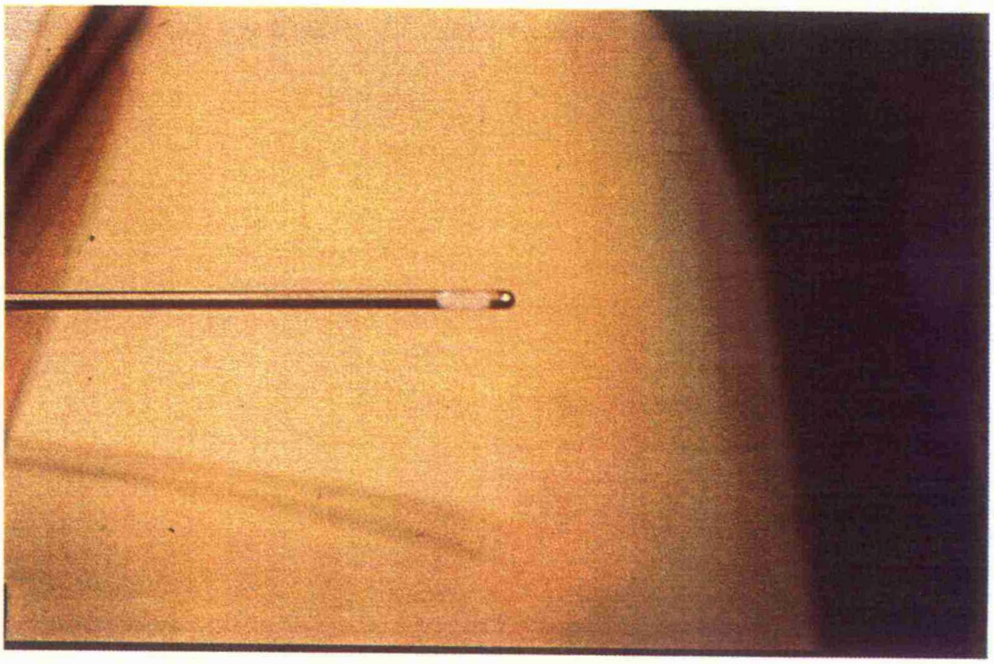


Fig 3.8.2 Antero-posterior radiograph showing position of pressure probe in head.

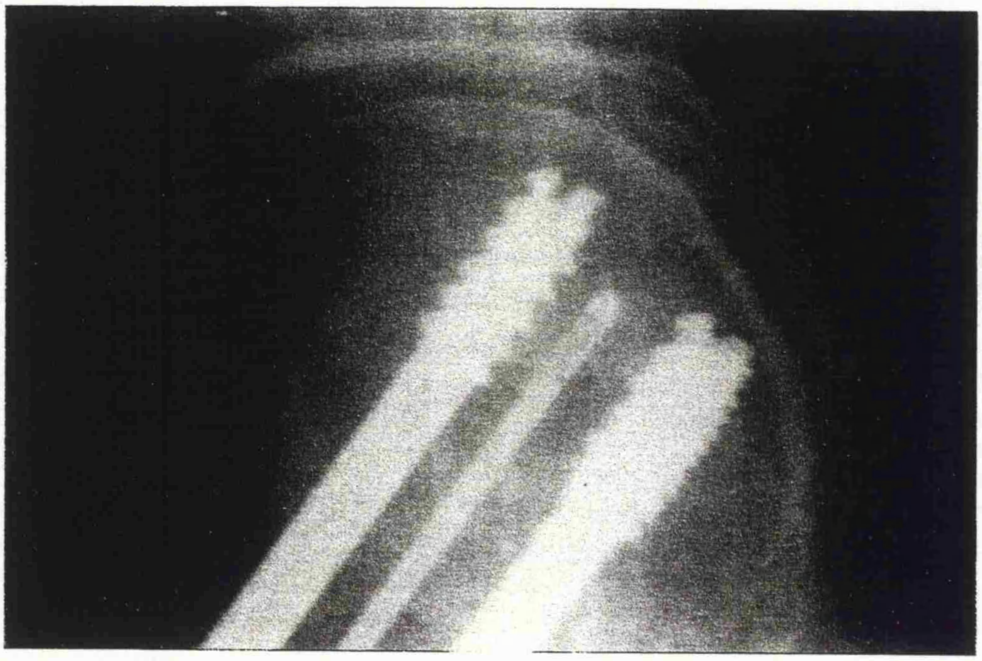


Fig 3.8.3 Intraosseous pressure tracing of pressure in the trochanter (upper trace) and femoral head (lower trace).

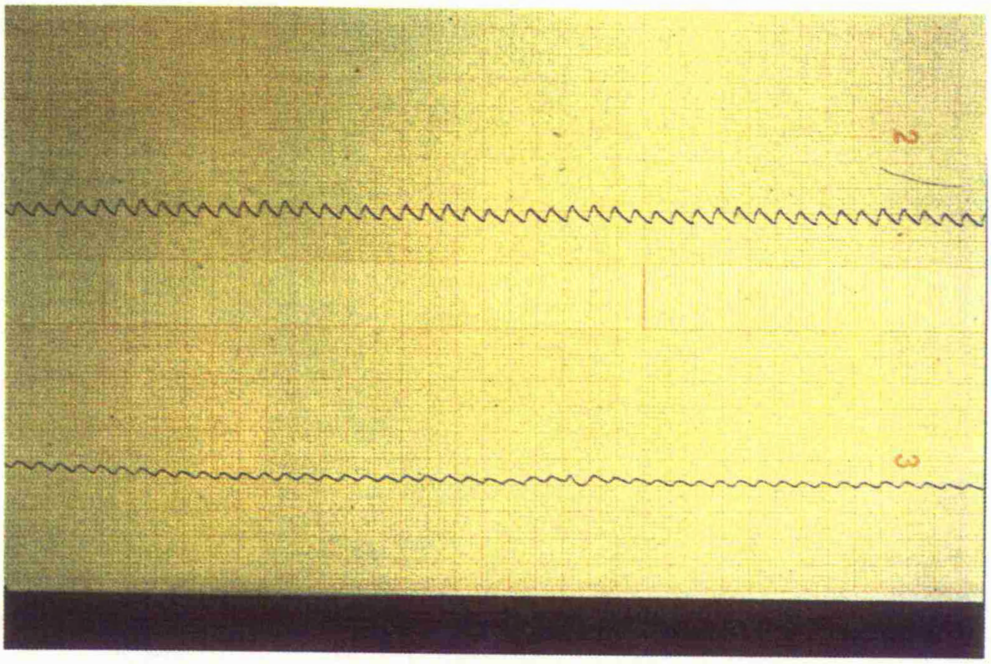
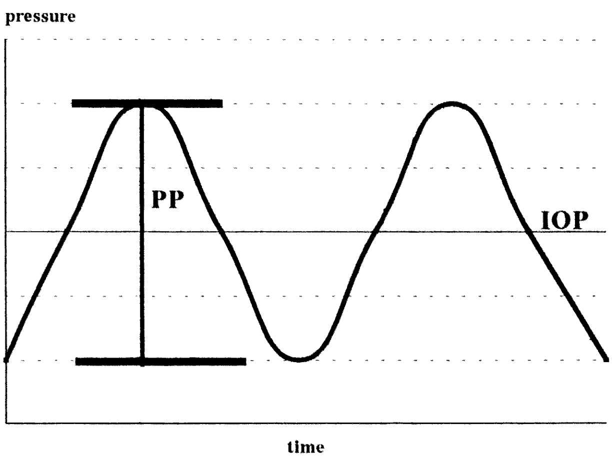


Fig 3.8.4 Illustration of method of calculation of mean intraosseous pressure and pulse pressure.



PP = PULSE PRESSURE

IOP = MEAN INTRAOSSEOUS PRESSURE

3.8.3 Results.

The mean intracapsular pressure before aspiration of the hip was 23.07 mmhg (SD 39.1) in extracapsular fractures and 30.03 mmhg (SD 47.48) in intracapsular fractures. The hip joint was aspirated with a 20 ml syringe until the intracapsular pressure fell to zero. The exact amount of blood aspirated was difficult to quantify because once the lateral femoral cortex had been perforated there was a slow leak of fluid from the joint.

There were no significant differences in the intraosseous or pulse pressures recorded in either type of fracture in the trochanteric region (Table 3.8.1).

In extracapsular fractures, there were no significant differences in the mean or pulse pressures in the femoral head before and after aspiration of the hip (Table 3.8.2, Table 3.8.3). However, in intracapsular fractures, the mean intra-osseous pressure in the femoral head fell by 4.56 mmhg and the mean pulse pressure rose by 0.65 mmhg following aspiration (Table 3.8.2, Table 3.8.3). These changes are statistically significant for both mean pressure ($p = 0.037$) and for pulse pressure ($p = 0.038$)

Table 3.8.1 Intraosseous pressures in the trochanteric region in proximal femoral fractures.

Fracture	Mean intraosseous pressure	Mean pulse pressure
Intracapsular n=33	38.33 SD 17.61	6.84 SD 4.36
Extracapsular n = 17	38.43 SD 13.52	8.14 SD 4.94

Table 3.8.2 Mean intraosseous pressures in the femoral head in proximal femoral fractures before and after aspiration of the hip.

	Mean pressure		
Fracture	**Before**	**After**	**Difference**
Intracapsular	**44.97***	**40.41***	**4.56**
n = 33	**SD 26.8**	**SD 20.0**	**SD 11.8**
Extracapsular	**49.06**	**49.94**	**0.88**
n = 17	**SD 18.3**	**SD 19.9**	**SD 6.2**

* p = 0.037

Table 3.8.3 Mean pulse pressures in the femoral head before and after aspiration of the hip.

Fracture	Mean pulse pressure		
	Before	After	Difference
Intracapsular n = 33	5.18* SD 5.9	5.84* SD 5.79	0.65 SD 1.72
Extracapsular n = 17	7.94 SD 4.4	7.82 SD 4.62	0.12 SD 0.48

* p = 0.038

3.8.4 Discussion and conclusions.

Measurement of intra-osseous pressure has been used by other authors as a means of measuring bone blood flow (Azuma 1964, Shim 1972,), but earlier methods were restricted by technical shortcomings. The method described, using a catheter-tip pressure transducer, has the advantage that the pressure sensor is in direct contact with the site to be measured. This technique is easier and gives far greater reproducibility.

The large standard deviations in the results are a feature of all work involving intra-osseous pressure; this makes direct comparison between individuals difficult. However, in each individual subject the values are reproducible if the pressure is recorded from the same place, as in this clinical study. Therefore if external conditions are altered and cause a change in bone blood flow, this will be reflected by changes in intra-osseous pressure.

In individual cases changes in intra-osseous pressure probably do reflect changes in bone blood flow: venous obstruction will cause an increase in pressure, abolition of arterial flow will be reflected by abolition of the pulse pressure (Azuma 1964). Various authors have suggested that increased pressure in the joint cavity, after an intracapsular fracture, may reach a level sufficiently high to obstruct the flow of blood to the femoral head. (Soto-Hall 1964, Crawfurd 1988).

In the previous study (3.7) intracapsular pressures as high as 220 mmhg were recorded following intracapsular fracture. However, there has been little direct evidence in man that these intracapsular pressures can stop or decrease the bone blood flow to the femoral head. Stromqvist showed indirectly, using bone scanning techniques, that some femoral heads showed increased uptake, suggesting increased blood flow, following aspiration of the hip. However, other factors may have influenced this result: the hips were scanned twenty four hours after aspiration and after osteosynthesis (Stromqvist 1988). Kristensen showed increases in femoral head PO_2 following aspiration of the hip in two of nine patients with intracapsular fractures, but in this study intracapsular pressures were not measured (Kristensen 1989).

The fall in mean intra-osseous pressure after aspiration of the hip in intracapsular fractures may be interpreted as being due to relief of an initial venous obstruction by removal of an intracapsular haematoma. Similarly the associated increase in pulse pressure may be interpreted as showing an increase in bone blood flow. These results add further evidence that an intracapsular haematoma, in the presence of a damaged intra-osseous circulation after an intracapsular fracture may cause ischaemia of the femoral head which can be reversed by aspiration of the joint. If this is to prevent osteocyte death, then it should be performed as soon as possible after the fracture.

4. General discussion and conclusions.

Proximal femoral fractures are a common problem that confronts an orthopaedic surgeon daily. These fractures commonly occur in the most elderly and vulnerable section of the community. Although there are many publications concerned with these fractures very few studies are randomised or prospective. The incidence of these fractures is increasing and they will continue to be a major cost to the National Health Service. It is important that strategies for the management of these fractures are based on sound scientific principles.

Proximal femoral fractures can be subdivided into two types, intracapsular and extracapsular. Although the economic and social implications of both fractures are similar it is the management of intracapsular proximal femoral fractures that is the most controversial.

The most controversial area is whether, following an intracapsular proximal femoral fracture, the femoral head should be discarded or preserved, and if the femoral head is to be discarded with what it should be replaced.

In a survey of practising United Kingdom orthopaedic surgeons (3.1) the majority of surgeons favoured replacement of the femoral head in patients over 70 years of age. There was, however, no consensus view as to what sort of replacement should be used, with 30% favouring an Austin Moore, 30% a Thompson and 30% a Bipolar prosthesis. Similarly there was no consensus as to whether the prosthesis should be cemented or uncemented.

When the surgeon elected to treat the fracture with osteosynthesis a wide variety of implements were used, but the majority of surgeons favoured either multiple cancellous screws or a sliding screw and plate.

A further area of controversy is whether some intracapsular proximal femoral fractures may not be detected on initial radiographs. A cohort of elderly patients were identified who presented to an accident and emergency department with painful hips following trauma (3.2). None of them had a fracture on initial radiographs.

On follow-up only a very small percentage (2.5%) had subsequently developed a hip fracture, however a considerable percentage had either died or been admitted to hospital with conditions other than fracture. If the phenomenon of undetectable fracture does exist it occurs in only a small proportion of people with painful hips and normal radiographs following trauma.

An analysis of the morphology of proximal femoral fractures was conducted using computerised tomography (3.3). This study showed comminution to be a common feature following intracapsular proximal femoral fracture. An interesting finding was the detection of some supposedly new fractures which had the radiographic features of an old fracture. At present the cost and inconvenience of computerised tomography precludes its routine use.

Although studies of the morphology of proximal femoral fractures using computerised tomography did not prove of value in this study it may be that more sophisticated methods of computerised tomography using bone density measurement of the femoral head may prove useful in finding fractures likely to fail following internal fixation.

A study comparing operative versus conservative treatment of displaced intracapsular proximal femoral fractures in the elderly and severely demented was attempted. It proved impossible to continue this study because of the perceived deprivation of care of the conservatively treated group.

Although in this study it was found impractical to continue this trial it may be more appropriate to design a trial comparing conservative treatment of these fractures in a nursing home or geriatric ward environment with operative treatment on an orthopaedic ward.

An area that still remains controversial is whether a Thompson hemiarthoplasty should be used with or without cement. A trial was conducted comparing cemented and uncemented Thompson hemiarthroplasty (3.5). The short term result was more predictable with a cemented prosthesis, with less patients suffering thigh pain if the prosthesis was cemented. Although the results of uncemented arthroplasty are inferior in the short term there still remains the questions as to whether there is any difference in long term results, which will be answered by a long term review of the patients entered into this trial.

Although many methods of internal fixation of intracapsular proximal femoral fractures are used by UK surgeons, the most commonly used methods are either multiple cancellous screws or a sliding screw and plate. A trial was conducted comparing these two methods of fixation (3.6). Although there were no differences in failure rate between the two devices multiple cannulated screws were more difficult to use and were associated with postoperative subtrochanteric fractures.

This study has shown that acceptable results can be obtained from internal fixation of intracapsular proximal femoral fractures. What is has not been investigated in this study is whether the different devices are associated with different rates of avascular necrosis. A long term review of the patients that were included in this study will help to answer this question.

This study not addressed the issue of whether it is better to replace or fix the femoral head. This question will only be answered by a study comparing the best method of fixation with the best method of replacement, neither of which are yet known.

The study of intracapsular pressure following intracapsular proximal femoral fracture (3.7) has shown that high levels of intracapsular pressure are found, most particularly in undisplaced fractures. The levels of intracapsular pressure are theoretically high enough to obstruct femoral head blood flow.

It has been shown, using intraosseous pressure,(3.8) that aspiration of these haemarthroses improves femoral head blood flow. If this is to reduce avascular necrosis the aspiration should be performed as soon as possible following fracture, before osteocyte death has occurred.

The question remains as to whether early aspiration of the hip following intracapsular proximal femoral fracture reduces the failure rate from internal fixation. Only a prospective randomised trial comparing early aspiration with no aspiration will answer this question.

This collection of studies around the subject of intracapsular proximal femoral fractures has tried to address problems of diagnosis and management by means of prospective trials. Wherever possible, when comparing two different methods of management, these trials have been randomised.

Although more questions have been raised than answered it is only by the prospective randomised trials that an element of scientific fact can begin to influence clinical management decisions.

5. General Summary

3.1 Orthopaedic surgeons in the United Kingdom do not have a consensus as to the best way to manage intracapsular proximal femoral fractures.

3.2 Elderly people with pain in the hip following trauma and a normal initial radiograph have a low incidence of proximal femoral fracture.

3.3 Computerised tomography has shown new facets to the morphology of proximal femoral fractures, most particularly that some apparently new fractures may be old.

3.4 Conservative treatment of displaced intracapsular proximal femoral fractures in the elderly demented patient is not a practical method of treatment.

3.5 Uncemented Thompson hemiarthroplasty produces a short term result which is inferior to a cemented prosthesis.

3.6 There are no differences in failure rate between multiple cannulated screws and a sliding screw plate when treating intracapsular proximal femoral fractures, but multiple cannulated screws are more difficult to use and are associated with postoperative subtrochanteric fractures.

3.7 High levels of intracapsular pressure are found in the hip following intracapsular proximal femoral fracture. These levels are highest in undisplaced fractures.

3.8 Aspiration of the haemarthrosis in the hip following intracapsular proximal femoral fracture improves the blood flow to the femoral head.

Appendices

Appendix 1 Postal questionnaire.

WHAT IS YOUR MOST COMMON METHOD OF TREATMENT FOR **DISPLACED** SUBCAPITAL FRACTURES IN PATIENTS IN THE FOLLOWING AGE GROUPS

1 **UNDER 70 YEARS OF AGE**

Manipulation and pinning ☐

Replacement ☐

2 **BETWEEN 70-80 YEARS OF AGE**

Manipulation and pinning ☐

Replacement ☐

3 **OVER 80 YEARS OF AGE**

Manipulation and pinning ☐

Replacement ☐

4 WHEN "PINNING" A DISPLACED SUBCAPITAL FRACTURE WHICH METHOD OF FIXATION DO YOU MOST OFTEN USE

a) Knowles Pins ☐

b) Howse Screws ☐

c) Garden Screws ☐

d) Cannulated Screws (Richards, AO) ☐

e) Sliding screw/plate (DHS,AHS) ☐

f) Other ☐

if answer is d, e or f please indicate method used

____

5 WHEN YOU FEEL PROSTHETIC REPLACEMENT IS INDICATED FOR SUBCAPITAL FRACTURES IN ELDERLY PATIENTS WHICH PROSTHESIS DO YOU MOST OFTEN USE

a) Thompson ☐

b) Austin Moore ☐

c) Bipolar Hemiarthroplasty ☐

d) Total Hip Replacement ☐

e) Other ☐

if answer is c,d,or e please indicate type of prosthesis used

____

6 WHEN USING THIS PROSTHESIS IN THESE CICUMSTANCES DO YOU USE BONE CEMENT __?

a) Always ☐

b) Usually ☐

c) Sometimes ☐

d) Rarely ☐

e) Never ☐

if answer is c, or d please specify indications for use

____

7 **WHAT SURGICAL APPROACH DO YOU USE TO PERFORM ARTHROPLASTY IN THESE CIRCUMSTANCES**

a) **Antero-lateral** ☐

b) **Posterior** ☐

c) **Hardinge** ☐

d) **Charnley** ☐

e) **Other** ☐

if answer is e please indicate approach used

____

Thank you for your co-operarion in this study.

Appendix 2 Patient information sheet

SUBCAPITAL FEMORAL NECK FRACTURES ;

GENERAL PATIENT INFORMATION

As has been explained to you have suffered a break (fracture) of the main hip bone. This is a break that almost always requires an operation. There are two sorts of break around the hip, the sort that you have suffered can sometimes be slow to join and may lead to arthritis.

In Leicester we have a special interest in this break and we are looking into ways of improving its treatment using different types of operation. The type of treatment we will advise for your break is, we believe, the best for your individual case. Professor P J Gregg is in charge of this work and a surgeon (Mr W M Harper) has been appointed to perform the work at the Leicester Royal Infirmary. Mr Harper will see you individually and disscuss your treatment. The decision to enter into the trial is yours and we will explain to you exactly what the plan is for your managemement. It must be emphasised that all treatments we propose are the most modern and our aim is to speed up your recovery and get you back home as soon as possible.

To give some general information if your break requires an operation this will be performed as soon as possible after your admission (usually two to three days). Before your operation blood tests and x-rays will be performed to help in treatment. In some cases we may wish to perform special tests to help in your treatment, this will be fully disscuussed with you.

After your operation you are usually allowed to sit out of bed on the day after operation and begin walking two days after. It is usual to begin walking with a frame or sticks and do not be disappointed if progress appears to be slow, this is a major break and full recovery can take some months. To start with you are helped to walk by a physiotherapist and the nurses and they will help and reasure you.

Before being discharged from hospital (usually in about two to three weeks although sometimes longer) we ensure that you are able to cope at home. The nurses will ask if there is someone to help and if extra help is required. An occupational therapist will usually also see you.

Some people may require a period of recuperation before going home and often a doctor concerned with the care of the more elderly patient will be asked to see you to arrange this.

Throughout your stay in hospital you will be treated by a team of nurses and doctors whose aim is to help you, please feel free to ask any questions you may have.

After discharge from hospital you will be followed up in the fracture clinic of the Leicester Royal Infirmary in a special clinic for patients with hip fractures.

We hope that you will cooperate with this very important work.

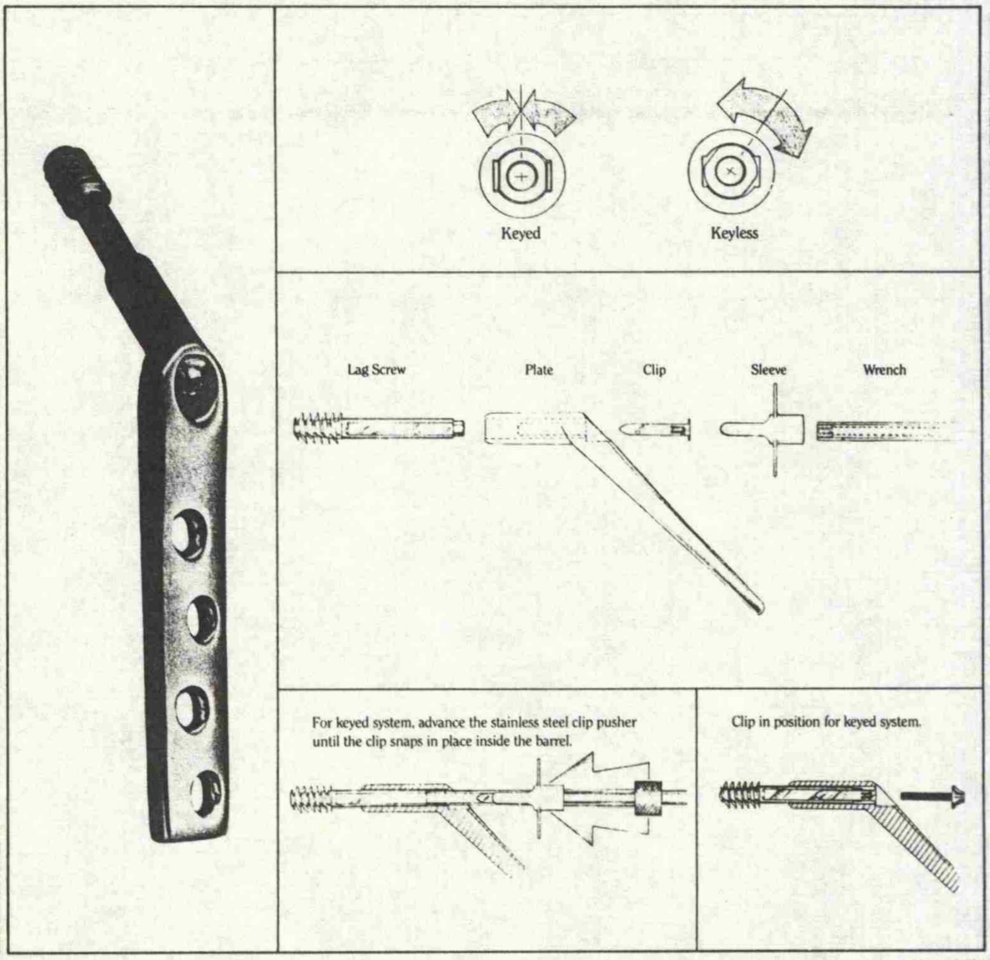
Appendix 3 Details from Ambi hip screw technique manual.

the tool:

Richards offers this new version of the Compression Hip Screw that allows the surgeon to choose a "keyed" or "keyless" system at time of surgery. The new design features the simplicity of technique of the keyless, with the positional security of a keyed system, when desired.

An improved insertion wrench facilitates assembly of the plate and lag screw, helping to reduce surgery time. Major components of the system are cannulated, which permit the surgeon to do the procedure over the guide wire until the compression step.

The plate is designed for greater strength at the plate/barrel juncture and features autocompression slots to accommodate the hex drive 4.5mm diameter bone screw. The thread design of the lag screw provides additional purchase. The compression screw has a hexagonal drive which accepts the same screwdriver used to insert the 4.5mm bone screw. Plate, lag screw, clip and compressing screw are made of Richards Certified Stainless Steel (ASTM F-138).

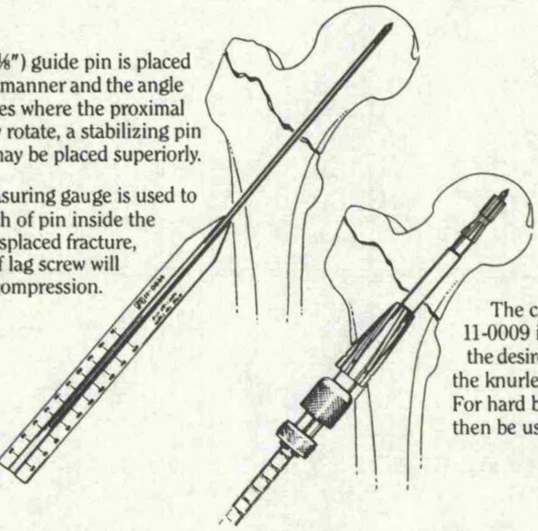


the technique:

NOTA BENE: The technique description herein is made available to the health care professional to illustrate a suggested treatment for the uncomplicated procedure. In the final analysis, the preferred treatment is that which addresses the needs of the specific patient.

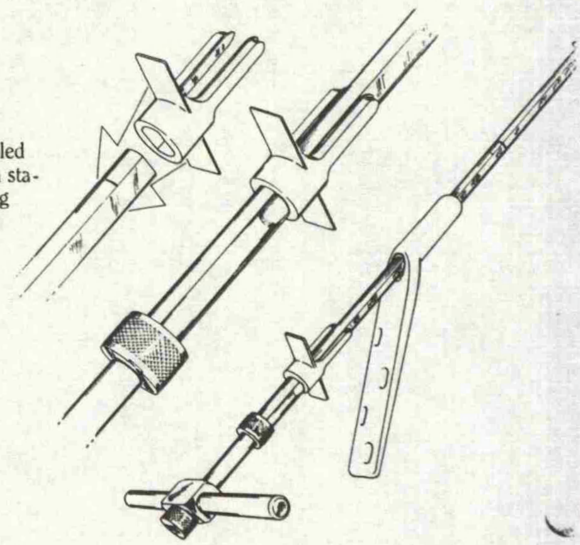
The 3.2mm (⅛″) guide pin is placed in the usual manner and the angle confirmed. In cases where the proximal fragment may rotate, a stabilizing pin may be placed superiorly.

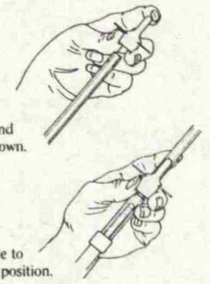
The direct measuring gauge is used to indicate the length of pin inside the femur. For a nondisplaced fracture, the same length of lag screw will allow 5mm of compression.



The combination reamer 11-0009 is set with the Screw Lok to the desired length and reamed until the knurled ring contacts the femur. For hard bone, the tap (11-0014) may then be used.

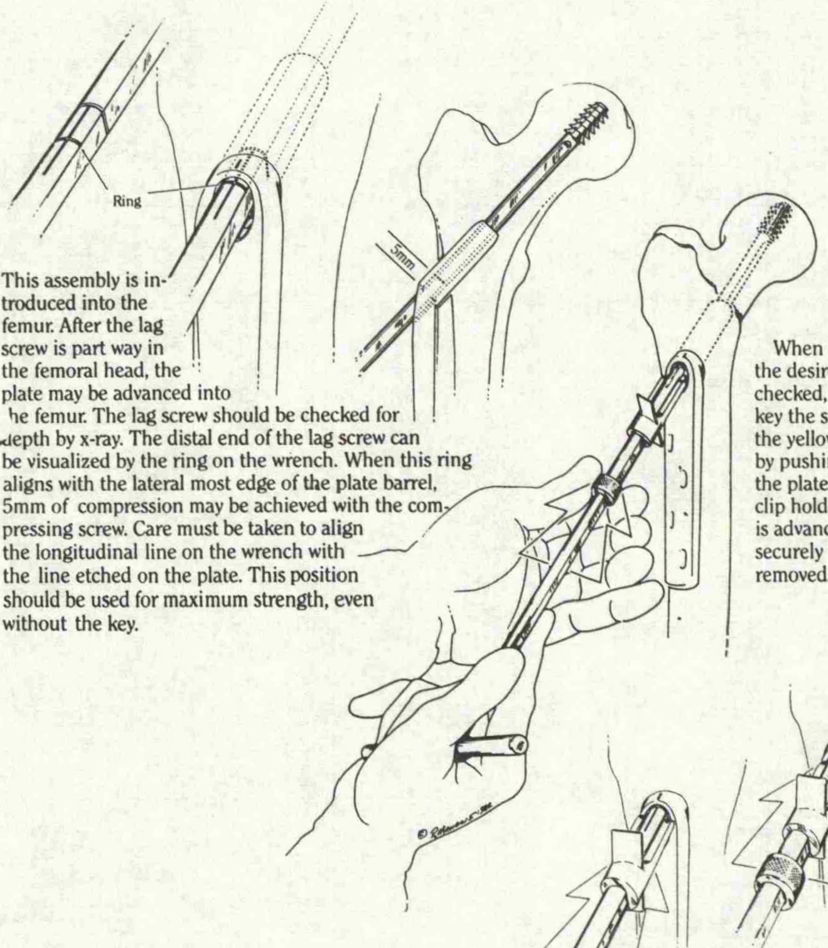
The clip, plate and lag screw are assembled on to the wrench (11-0022) and the wrench stabilizer screwed into the distal end of the lag screw for security.





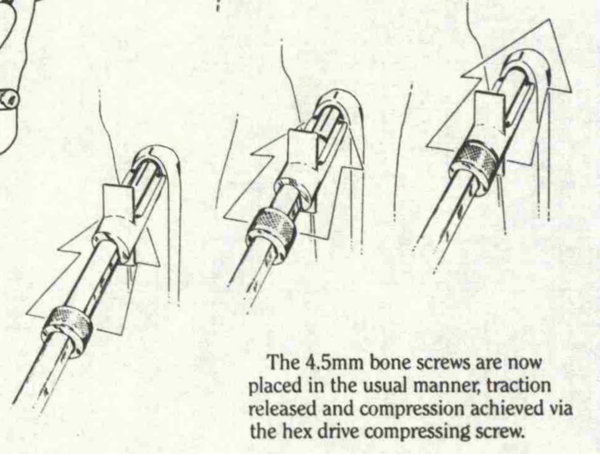
Hold clip and holder as shown.

Slide to seated position.



This assembly is introduced into the femur. After the lag screw is part way in the femoral head, the plate may be advanced into the femur. The lag screw should be checked for depth by x-ray. The distal end of the lag screw can be visualized by the ring on the wrench. When this ring aligns with the lateral most edge of the plate barrel, 5mm of compression may be achieved with the compressing screw. Care must be taken to align the longitudinal line on the wrench with the line etched on the plate. This position should be used for maximum strength, even without the key.

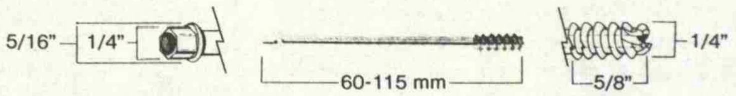
When the lag screw is positioned to the desired depth, the alignment is checked, and the surgeon has chosen to key the system, the metal clip (within the yellow plastic magazine) is advanced by pushing the knurled knob toward the plate. As the fingers of the plastic clip holder contact the plate, the clip is advanced into the barrel and snapped securely in place. The wrench is then removed.



The 4.5mm bone screws are now placed in the usual manner, traction released and compression achieved via the hex drive compressing screw.

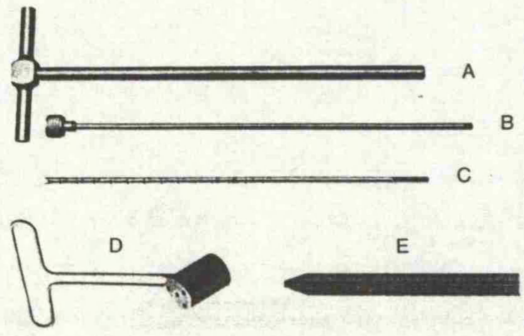
Appendix 4 Details from the cannulated hip screw technique manual.

CANNULATED HIP PIN



FEATURES

The stainless steel (ASTM F 138) pin has a self-tapping blunt tip with triflanged cutting edges. It is cannulated for use with a standard 3/32-inch guide wire and has three reverse cutting flutes to facilitate pin removal. The pin has a 1/4-inch hexagonal head with a threaded recessed socket for controlled insertion and removal with the insertion wrench. The pin is available in lengths of 60 to 115 mm (in 5-mm increments). Also available are a cannulated insertion wrench (A) and a wrench stabilizer for ease of removal (B); a reamer (C) and a pin guide (D) for making parallel holes; and a direct measuring gauge (E).



GENERAL OPERATIVE TECHNIQUES

by John P. Lyden, M.D.
Assoc. Prof. of Surgery (Orthopaedics)
Cornell University Medical Center
New York City, New York

Free-Hand Technique

Place the patient in the supine position, and prepare and drape the operative hip in the usual manner for surgery. Reduce the fracture and verify full correction radiographically. Then, with a stab incision down to the bone, open the skin, fascia and muscle over the lateral femur. Make a hole in the lateral cortex of the femur with a 3/16-inch diameter trocar-pointed Steinmann pin. This cortical aperture should be 40 to 50 mm below the crest of the greater trochanter (or opposite the middle of the lesser trochanter) to allow hip pin placement at 135° (Fig. 1). (A more valgus pin angle may be used, if desired.)

Next, introduce a 3/32-inch tip threaded guide wire across the fracture into an acceptable position and depth in the femoral head (the tip should engage subchondral bone) (Fig. 2). If this is poorly positioned, withdraw and reinsert the guide wire parallel to the femoral neck and central in the head. If more than one pin is used, the second and/or third pin should be parallel to the first with their threads not touching. Either a linear or triangular configuration is acceptable.

Use a direct measuring gauge to determine the length of the pin required (Fig. 3) or merely place a second free guide wire along the initial one to measure the length.

FIG. 1

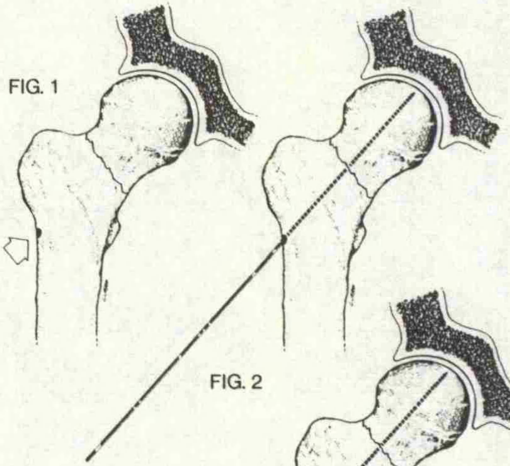


FIG. 2

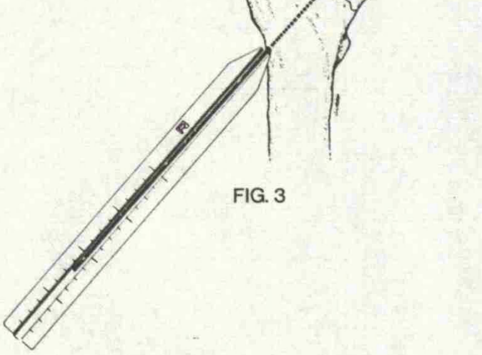


FIG. 3

Then connect the wrench to the pin of the appropriate length by means of the threaded wrench stabilizer (Fig. 4). Insert the cannulated hip pin over the guide pin into the hip (Fig. 5). The flutes of the cannulated pin will cut through the cortical and cancellous bone until the bevelled shoulder seats on the lateral cortex. The fracture can then be compressed at the discretion of the surgeon.

After the first pin is in satisfactory position, additional pins may be inserted. The number of pins chosen depends on the stability of the fracture, the quality of bone, and the adequacy of pin placement. I prefer two pins for impacted fractures or slipped capital femoral epiphyses, and three for displaced fractures that are reduced during surgery. Subsequent pins may be inserted with or without the initial guide wire protruding to act as an insertion guide for subsequent pins. The second pin may go in freehand by first using a 3/16 -inch Steinmann pin, then a guide wire, and then a subsequent cannulated pin. Alternatively, if the necessary length of subsequent pins is assured, follow the initial pin with a 3/16-inch Steinmann pin to create a femoral hole, and then insert the subsequent cannulated pins directly without the intermediate guide wire stage (Fig. 6A).

Alignment Guide Technique

To use the parallel pin guide, place the guide over the protruding initial guide wire. With additional 3/32-inch guide wires, mark the bone with the tip of the guide, remove the pin guide, and with a 3/16-inch trocar-pointed Steinmann pin, create a second lateral femoral hole. Reattach the pin guide and insert the second guide wire (Fig. 6B). By this method, two or three parallel guide wires and their respective pins can be inserted. This pin guide technique is difficult when done percutaneously, and is better done through a standard lateral incision down to the femoral cortex to avoid problems with intervening fascia and muscle.

With good radiographic control (I use a biplane image intensifier with memory), this technique can be done percutaneously with satisfactory parallelism and will achieve good results.

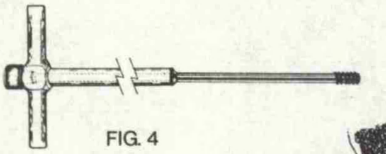


FIG. 4

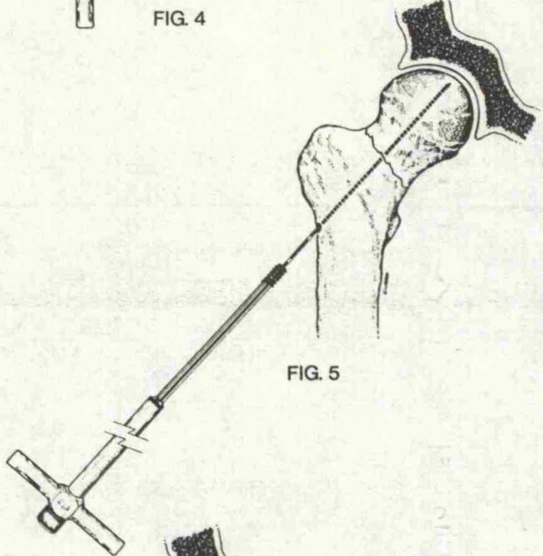


FIG. 5

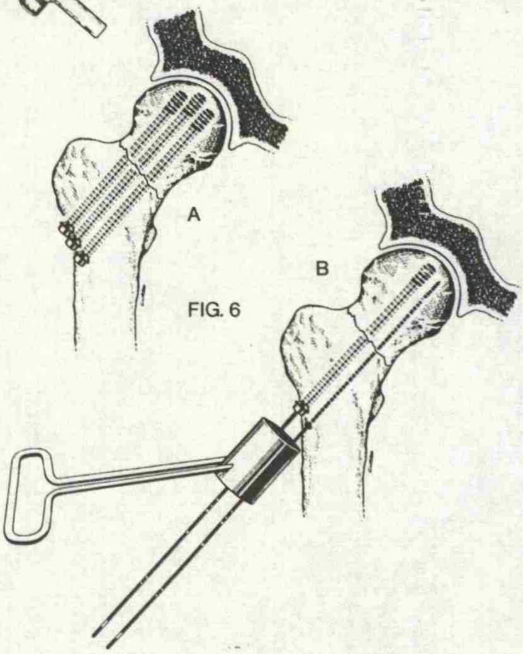


FIG. 6

Appendix 5 Technical details of the Gould P50 pressure transducer.

I. GENERAL DESCRIPTION

The Gould Model P50 Transducer is a direct pressure sensing instrument that provides stability, simplicity of operation, and rugged construction. It has the additional advantage of being small and lightweight so that it may be mounted directly on the patient near the measurement site. This eliminates the requirement for lengthy tubing and results in improved waveform fidelity, convenience of use and enhanced patient comfort.

The Model P50 is electrically isolated both externally and internally. The external ceramic case and the internal insulation of the sensing element assure patient safety and protect the transducer from electrical damage from defibrillators and electrocautery equipment.

A. Principle of Operation

The heart of the Model P50 Pressure Transducer is a silicon chip onto which the strain elements of a Wheatstone Bridge electrical measurement circuit are diffused. When all resistance legs of the circuit are in balance, and an excitation voltage is applied across the circuit, electrical output of the circuit is zero. The silicon chip is linked mechanically to the metal diaphragm of the transducer. When the diaphragm is deflected by the positive or negative pressure of the fluid being measured, the silicon chip is stressed. This stress causes an unbalance in the resistances of the Wheatstone Bridge circuit proportional to the pressure applied. An unbalance of the resistances in the circuit causes a proportional electrical output. The circuit then delivers an electrical output proportional to the pressure applied.

The transducer is connected through the cable to a pressure monitor or recording device. The shielded cable is attached to the case through a liquid-tight seal that permits immersion of the transducer case for cleaning, chemical disinfection or sterilization (see pg. 8). The transducer case is vented through the cable so that measurements are always referenced to atmospheric pressure.

B. Features of the Model P50

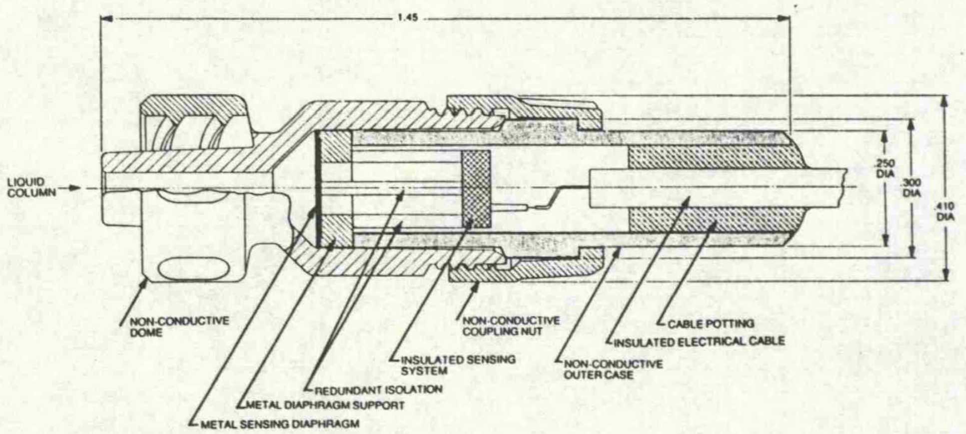
A pressure range of −50 to +300 mmHg makes the transducer useful for a wide variety of physiological pressure measurements. In addition to arterial blood pressure, the excellent stability of the instrument in the lower pressure ranges makes it ideal for central venous, pulmonary artery, pulmonary wedge and left atrial pressure measurements.

The Model P50's miniature size makes it convenient for mounting the transducer directly on the patient near the measurement site. This offers improved system response and waveform fidelity due to decreased tubing requirements. The miniature size is also ideal for intracranial pressure monitoring.

The Model P50 has been designed expressly to withstand the high voltages generated during electrocautery and defibrillation (withstands 10,000 volts DC). It also withstands overpressures up to 10,000 mmHg.

The internally isolated sensor and nonconductive case protect the patient against inadvertent electrical shock under all operating conditions.

Principles of Isolation, Model P50 Transducer



II. DOMES

The dome is a chamber for the liquid that transmits pressure to the sensing diaphragm of the transducer. It is made of transparent plastic to facilitate the detection and removal of bubbles since even minute bubbles can degrade the frequency response of the pressure monitoring system.

A. Disposable Diaphragm Domes for Model P50 Transducers

Sterile, pyrogen free disposable diaphragm domes are furnished in individual packages. The diaphragm of the dome provides a sterile barrier between the transducer sensing diaphragm and the liquid filled chamber of the dome. It also provides an extra degree of electrical isolation. Certified tests have demonstrated that the 5 mil thick silicone rubber diaphragm of this dome acts as a complete barrier to the transit of gram positive and gram negative bacteria, spores, fungi and viruses from a contaminated transducer diaphragm for up to 14 days.

- The diaphragm of each dome is 100% leak-tested at 8 psi (414 mmHg).
- The domes are packaged in easy-to-use tear-open containers and are sterilized by ethylene oxide.
- Disposable diaphragm domes save wear and tear on the transducer and reduce the need for disinfection or sterilization in conjunction with proper sterile technique. They also minimize transducer damage caused by overzealous cleaning and mishandling.
- Available with Rotating Luer Lok fittings.

Since the ports of the three way stopcocks of the monitoring system may become contaminated during prolonged use, it is recommended that the sterile disposable diaphragm dome and other components of the system be replaced routinely in accordance with hospital policy. These domes should NEVER be reused, since cleaning and sterilization may damage the diaphragm.

If a sterile diaphragm dome is used with aseptic technique, the transducer may be reused without sterilization. Accumulation of microorganisms on the transducer diaphragm and surface, however, increases the risk of contamination of all disposable components of the disposable monitoring system through accidental nonsterile technique. High level disinfection of the transducer is therefore advised. Ethylene oxide gas or gluteraldehyde sterilization of the transducer is required when it is necessary to have a sterile transducer in certain applications. (See Cleaning and Sterilization on page 8. See, also, references on page 9.)

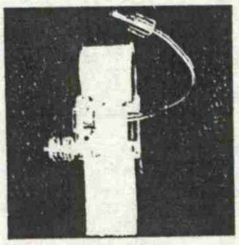
B. *CritiFlo*™ Flow/Flush Domes for Model P50 Transducers

The *CritiFlo* dome is a uniquely designed disposable diaphragm dome which incorporates a continuous flow and manual flush capability in a single device. It minimizes bulk, is less awkward to use, reduces the number of connections in the system, and provides for simple two finger operation. The flush mechanism of the *CritiFlo* dome also has an overpressure relief capability. When pressures within the system exceed approximately 1500 mmHg, an overpressure relief valve releases the pressure back toward the infusion system. This virtually eliminates transducer damage caused by overpressurization.

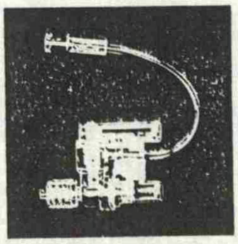
C. Standard Reusable Domes for Model P50 Transducers

The standard reusable domes are made of nonconductive, nonpyrogenic polycarbonate. Their clear design simplifies detection and elimination of air bubbles. These domes are available with a Luer Lok fitting and are reusable after proper cleaning and sterilization.

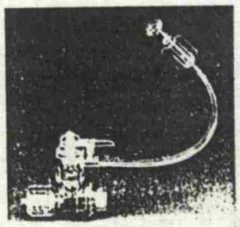
P50 Transducer Dome Selection Chart



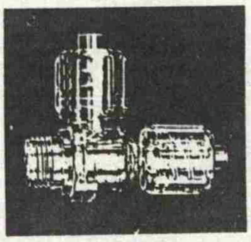
TA1017SM
CritiFlo™ Disposable Dome



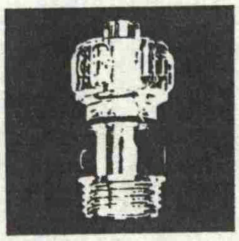
TA1017M
CritiFlo™ Disposable Dome



TA1017
CritiFlo™ Disposable Dome



TA1019
Disposable Diaphragm Dome



TA1002
Reusable Dome

III. SET UP

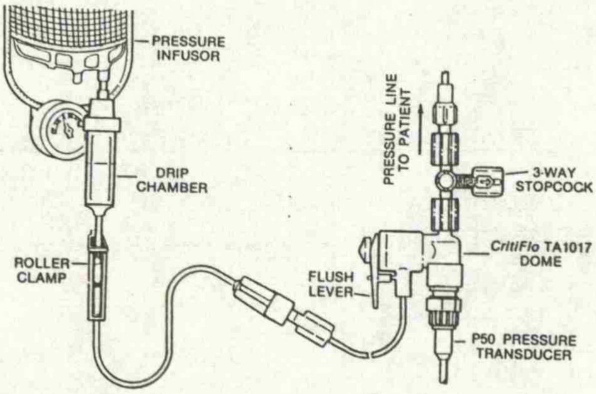
Physiological pressure is transmitted from the patient to the transducer by way of a sterile solution. Commonly used solutions are 0.9% normal saline, or lactated Ringers. These solutions are generally heparinized. In addition to transmitting pressure, the solution prevents clotting of the line.

Gould manufactures several sterile, preassembled monitoring kit configurations which provide the disposable "plumbing" required between the transducer and patient.

There are a variety of ways to set up the disposable plumbing between the patient and the transducer. Therefore, no attempt will be made here to give specific instructions. Refer to the instructions that accompany the pressure monitoring kit or components you are using. A typical set-up is shown here only as an example.

General Instructions for Attaching *CritiFlo*™ Domes

1. Remove protective dome from transducer. Be sure transducer is clean. (See page 8.)



2. Connect the electrical connector on the cable of the transducer to the monitor. The Model P50 requires 2 minutes to "warm up".

3. Prepare a sterile flush solution of 0.9% normal saline or equivalent electrolytes in a non vented plastic container by adding a heparin mixture prescribed by a physician (usually 1 to 2 units of aqueous heparin per cc of solution).

4. Insert a microdrip (minidrip) I.V. administration set into the flush solution container.

5. With the roller clamp closed, squeeze the solution bag slightly to force solution into the drip chamber (fluid level should be ⅓ full because the level will increase when the solution bag is pressurized).

6. Slowly fill the tubing in the infusion line by opening the roller clamp.

7. Insert the solution bag into the pressure infusor.

8. Hang the pressure infusor and bag on an I.V. pole.

9. Select and assemble the disposable stopcocks, pressure tubing and *CritiFlo*™ dome as required by your specific set up.

10. Attach the filled infusion line to the female Luer fitting on the 4 inch tubing of the *CritiFlo* dome.

11. Open the system to air through the side port of the stopcock or at the end of the pressure line.

12. Holding the dome as shown below (Figure 1), open the roller clamp on the infusion line and gently activate the flush lever to allow the back chamber to fill (*CritiFlo* must be lower than bag of infusion solution for the dome and set up to fill under gravity).

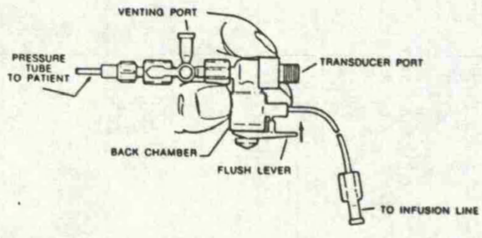


Figure 1

NOTE: If infusion solution is under pressure, flush lever should not be activated until solution has filled tubing and back chamber.

13. Once the back chamber has filled, activate the flush lever and manipulate the unit to fill the remainder of the system. Manipulate and/or gently tap the setup as required to aid in the elimination of air bubbles.

NOTE: Tapping should be done only with the presence of bubbles and not as a routine procedure.

14. Pressurize solution source to 300 mmHg. At this pressure and using a microdrip administration set, the *CritiFlo* dome will provide a continuous infusion of approximately 2 to 4 cc/hour (2 to 4 drops/min.).

Appendix 6 Technical details of the transducer and amplifier.

GOULD Transducer Preamplifier

SPECIFICATIONS	Preamplifier Only	Preamplifier in a Gould 2000 Series Recorder
Measurement Range (Using a four active-arm bridge)	100 microvolts full scale to 5 volts full scale	100 microvolts full scale to 5 volts full scale
Maximum Sensitivity	For transducers of 50 microvolts per volt per cm Hg to 250 microvolts per volt per cm Hg (100 - 3000 ohms)	For transducers of 50 microvolts per volt per cm Hg to 250 microvolts per volts per cm Hg (100 - 3000 ohms)
Attenuator Steps	10, 25, 50, 100, 250 and 500 units full scale and Off	10, 25, 50, 100, 250 and 500 units full scale and Off
Attenuator Inaccuracy	±0.5% of calibrated step	±0.5% of calibrated step
Calibrate Vernier	Provides calibrated sensitivity adjustment from 50 microvolts per volt to 250 microvolts per volt.	Provides calibrated sensitivity adjustment from 50 microvolts per volt to 250 microvolts per volt.
Input Circuit	Differential	Differential
Input Impedance	50 kilohms	50 kilohms
Common Mode Rejection		
Inputs to Common with 350-ohm unbalance	Greater than 60 dB on most sensitive range	Greater than 60 dB on most sensitive range
60 Hz at 350-ohm unbalance	Greater than 100 dB on most sensitive range	Greater than 100 dB on most sensitive range
Maximum Allowable Input Voltage	50 volts dc or peak ac across input terminals 500 volts dc or peak ac from common to chassis	50 volts dc or peak ac across input terminals 500 volts dc or peak ac from common to chassis
Zero Line Instability (After 15-min. warm-up; at 250 μV full scale sensitivity)	±0.5% of full scale for 24 hours ±1.0% of full scale per °C ±0.2% of full scale for 10% line change	±0.6% of full scale for 24 hours ±1.2% of full scale per °C ±0.3% of full scale for 10% line change
Gain Instability (After 15-min. warm-up; at 250 μV full scale sensitivity)	±0.05% of reading for 24 hours ±0.1% of reading per °C ±0.1% of reading for 10% line change	±0.15% of reading for 24 hours ±0.8% of reading per °C ±0.6% of reading for 10% line change
Amplifier Output		
Recorder Output Voltage	±5.0 volts into 2 kilohms or greater	
Output Impedance	Less than 5 ohms	
Non-Linearity	±0.1% of full scale	±0.45% of full scale
Noise (dc to 100 Hz at 250 μV full scale sensitivity)	Less than 2% referred to input with a 350-ohm source	Less than 2% of full scale peak-to-peak
Display Output	10 volts into 2 kilohms or greater in x10 position 1 volt into 2 kilohms or greater in x1 position	
Tape Output	±5.0 volts into 2 kilohms or greater	
Frequency Response		
Direct Mode	dc to 100 Hz ±0.5% Less than 3 dB down at 1 kHz	See Recorder specifications
Mean (Average) Model	3 dB down at 0.05 Hz ±10%	3 dB down at 0.05 Hz ±10%
Filter Rolloff	12 dB/octave or 40 dB/decade	12 dB/octave or 40 dB/decade
Optional Filter	1-pole: 3 dB down at 24 Hz ±10% 2-pole: 6 dB down at 24 Hz ±10%	1-pole: 3 dB down at 24 Hz ±10% 2-pole: 6 dB down at 24 Hz ±10%
Calibrated Zero Suppression		
Ranges	±100 units, ±1000 units and Off	±100 units, ±1000 units and Off
Resolution	±0.1% of full suppression range	±0.1% of full suppression range
Non-Linearity	±0.3% of full suppression range	±0.3% of full suppression range
Inaccuracy (at 25°C and nominal line)	±0.5% of full suppression range	±0.5% of full suppression range
Stability (After 15-min. warm-up)		
With Time	±0.2% per week	±0.2% per week
With Temperature	±0.05% per °C	±0.05% per °C
With Line	±0.02% for 10% line change	±0.02% for 10% line change
Noise	±0.05% of suppression range	±0.05% of suppression range
Bridge Excitation		
Voltage	5 volts dc ±4% balance to common; polarity internally switched	5 volts dc ±4% balance to common; polarity internally switched
Noise	0.1% peak-to-peak from dc to 1 kHz	0.1% peak-to-peak from dc to 1 kHz
Stability (After 15-min. warm-up)		
With Time	±0.05% per 24 hours	±0.05% per 24 hours
With Temperature	±0.05% per °C	±0.05% per °C
With Line	±0.02% for ±10% line change	±0.02% for ±10% line change
Operating Temperature	0°C to +50°C (+32°F to +122°F)	0°C to +50°C (+32°F to +122°F)
Storage Temperature	−40°C to +70°C (−40°F to +158°F)	−40°C to +70°C (−40°F to +158°F)
Humidity	95% at +30°C (+86°F) non-condensing	95% at +30°C (+86°F) non-condensing
Vibration and Shock	Best commercial practice	Best commercial practice
Power Input		
DC Voltage	±15 Vdc ±4% at 100 milliamperes	See Recorder specifications
Line and Load Regulation	±0.5%	
Ripple	5 millivolts rms maximum	
Weight (Amplifier only)	3.6 pounds (1.5 kg)	3.6 pounds (1.5 kg)
Dimensions (Amplifier only)	6.1 i[illegible] H x 2.2 in. W x 13 in. D (15.[illegible] m H x 5.5 cm W x 33 cm D) Depth dimension includes attenuator knob and chassis mounted connector	6.1 in. H x 2.2 in. W x 13 in. D (15.3 cm H x 5.5 cm W x 33 cm D) Depth dimension includes attenuator knob and chassis mounted connector
Signal Input Connector	Multi-pin mating connector supplied with each Amplifier (Model 11-5407-50)	Multi-pin mating connector supplied with each Amplifier (Model 11-5407-50)

Gould Inc., Instruments Division
3631 Perkins Avenue, Cleveland, Ohio 44114
Telephone (216) 361-3315 TWX 810-421-8580

GOULD
Electronics & Electrical Products

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Printed in U.S.A.

Appendix 7 Technical details of the intraosseous pressure probe.

gaeltec

PRESSURE TRANSDUCER
TEST REPORT

Serial No. L0477 **Type** 16CT/6F/SS

Bridge Resistance: 1.504 KΩ

Test Excitation Voltage: 5 V

Test Temperature Limits: 13 °C to 50 °C

Full Scale Pressure Range 0 to 300mmHg

Sensitivity: 5uv/v/mmHg

Max. Linearity Error: ±0.6 % FS

Max. Hysteresis Error: 0.2 % FS

Temperature Coefficient of Zero: 0.03 % FS/C°

Temperature Coefficient of Sensitivity: -0.04 %/C°

Insulation Leakage Current at 240V rms: 9.9 μA rms

Connector Type: **LEMO 2306**

Positive Supply: Pin No. 4

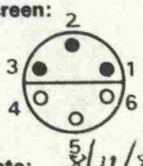
Negative Supply: Pin No. 1

Positive Output: Pin No. 3

Passive Output: Pin No. 2

Calibrate: Pin No. –

Screen: Pin No. –



PIN CONNECTIONS VIEWED **FROM** TRANSDUCER.

Date: 8/12/89. **Sig:** [signature]

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