REVIEW OF LITERATURE
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Fractures of femoral neck, though known from time immemorial have always been posing challenge to orthopaedic surgeons because of the problems of non-union and avascular necrosis irrespective of the method of treatment. Volumes and volumes are available but still there is no unanimity over the most successful method of treatment. Anatomical reduction, impaction and rigid internal fixation are considered to be the pre-requisites for union of the femoral neck fractures.

Even if the fracture unites, the vascularity of the femoral head can not be predicted upon and avascular necrosis of the femoral head takes place in about 10 to 15% of cases.

To overcome the problem of avascular necrosis, Helstadius (1942) came with the idea of muscle pedicle bone grafting. Impressed with this idea, workers (Judet, 1962; Meyers and Harvey, 1974) used this principle of muscle pedicle bone grafting with internal fixation in treatment of femoral neck fractures.

Anatomy of fracture neck femur -

Proximal femur consists of femoral head, neck, greater trochanter and lesser trochanter and is covered by
periosteum beneath synovium but periosteum does not have cambium layer, which is essential for callus formation after fracture as shown by Banks (1964).

At the base of femoral neck and at the level of capsular attachment, there is an extra-capsular arterial ring of arteries from which ascending cervical branches arise along the neck, around its circumference, as shown by Trueta and Harrison (1953). These arteries at the Junction between articular cartilage of head and bony surface of neck, forms subsynovial anastomotic ring, known as circulus articulari vasculosus of Hunter; also give rise to metaphyseal and epiphyseal branches and within epiphysis, there is no anastomosis between sinusoidal termination of epiphyseal arteries before secondary centre of ossification appear.

Chung (1956) stated that vascular patterns which are established at the time of birth does not change throughout life. Vessels within the bone do not cross between epiphysis and metaphysis until the closure of epiphyseal plate.

Trueta (1957) described vascular pattern of femoral head as follows -

At birth -

Vessels of ligamentum teres are insignificant and supply only the limited area of head about the fovea
with vessels radiating outward like a laural leaf. Major supply of femoral head is by ascending cervical arteries (metaphyseal and lateral epiphyseal arteries of trueta).

**Infantile (4 months to 4 years)** -

At 4 months main blood supply of femoral head is from ascending cervical arteries but after 4 months vertical metaphyseal vessels decreases in size and number and provide little blood supply but the lateral epiphyseal vessels play major role for vascularity of head.

**Intermediate (3-7 years)** -

As the epiphyseal plate is a firm barrier between the epiphysis and metaphysis, the lateral epiphyseal vessels are the main source of blood supply.

**Pre-adolescent (9 - 10 years)** -

After 7 years ligamentum teres vessels become more prominent and extend deeper into epiphysis and anastomose with lateral epiphyseal vessels known as medial metaphyseal vessels.

**Adolescent period** -

Lateral epiphyseal vessels are the main source of blood supply with increasing prominence of ligamentum teres vessels.
As the period of skeletal maturity and epiphyseal fusion approaches, the metaphyseal arteries anastomose with terminal branches of medullary nutrient artery but they can not be traced upward into the femoral neck as discrete trunks.

Crock (1965) described that after epiphyseal fusion, epiphyseal and metaphyseal vessels effectively anastomose with each other at the surface of femoral neck.

Epiphyseal plate of bone is a firm barrier for anastomosis between vessels supplying the epiphysis and metaphysis until skeletal maturity, when two vascular systems blend. Main arterial supply of the proximal femur is derived from the branches of extra-capsular arterial ring and subsynovial intra-articular ring of the femoral neck.

Chung (1956) said that arteries running in the ligamentum teres of the head of the femur supplement the blood supply of the head.

**Classification of the fracture neck femur**

Pauwel (1935) classified the femoral neck fracture on the basis of angle of inclination of fracture line across the neck. With type I being more horizontal and type III more vertical.
Pauwel type I - includes the femoral neck fractures where the fracture line is almost horizontal (angle of inclination less than 30°), any shearing force causes impaction and chances of union are best.

Type II - Fracture line is oblique, angle of inclination being between 30 - 70°, needs internal fixation to prevent distraction at fracture site.

Type III - Fracture line is almost vertical and angle of inclination is 70° or more and have got worst prognosis.

Boyd & George (1948) and Boyd & Salvatore (1964) evaluated that rate of avascular necrosis and non-union could not be correlated with increasing angle of the fracture. They observed that Pauwel's type I fractures (impacted type) treated by internal fixation, none developed non-union and none become displaced but 13% ultimately developed avascular necrosis. Type II fractures, treated by internal fixation, developed non-union in 12% and avascular necrosis in 33% and of type III fractures treated by internal fixation, non-union occur only in 8% with avascular necrosis in 30%.

It thus appear that broader fracture surfaces of Pauwel's type III, fracture tend to unite radially, provided that shearing forces are sufficiently negotiated.
Garden (1961), Kleinerman and Marcuson (1970) were also of the view that it is very difficult to know the exact angle of fracture across the femoral neck from the routine antero-posterior roentgenogram. They suggested that Pauwels' classification based on the roentgenographic shadow of fracture line, can be altered very well by rotation of distal fragment, that is in one position of rotation, fracture may appear Pauwels' type I and in other position Pauwels' type III.

Garden (1961) classified the femoral neck fractures by radiographic appearance on the basis of the degree of displacement. This classification is helpful in treatment decision and he classified them into four groups:

**Type I** - Incomplete fracture with head tilted in postero-lateral direction.

**Type II** - Undisplaced complete fracture.

**Type III** - Complete fracture with partial displacement.

**Type IV** - Complete fracture with full displacement and both proximal and distal fragment have no contact.

According to this classification type III & IV fractures have maximum chances of complications.
Singh, Nagarth and Mani (1970) considered the quality of bone of the patients. Many patients with femoral neck fracture have markedly porotic bone. The quality of fixation and stresses which can be tolerated post-operatively are related to the severity of porosis.

Singh's index which denotes the quality of bone, is based on trabecular pattern of proximal femur.

Group 6 - Normal trabecular pattern with primary compression and tension trabeculae and secondary compression trabeculae.

Grade 5 - Decrease in secondary trabecular pattern and Wart's triangle become prominent.

Grade 4 - Secondary trabecular pattern is absent and primary trabecular pattern decreased.

Grade 3 - A break occurs in tension trabeculae.

Grade 2 - Loss of primary trabeculae is complete and there is a marked reduction in compression trabeculae.

Grade 1 - Only a few compression trabeculae seen.

This grading shows that fixation is proportional to grade, higher the grade better the fixation. Grade 3 and below indicate significant osteoporosis.
These grades should be determined when considering internal fixation and whether or not weight bearing will be tolerated in post-operative period.

Vascular supply in femoral neck fracture -

Chandler (1940) described limited anastomosis between the intra-osseous vessels in the femoral head and lateral and medial epiphyseal vessels and limited anastomosis of the branches of the lateral epiphyseal artery with one and the other. He stated that venous occlusion is second important factor and parallel to the degree of arterial damages. He also compared the pattern of intra-osseous arteries in femoral head with avascular area seen in bisected specimen with partial avascular necrosis which indicate that the configuration of the avascular areas coincides with how much of the arterial supply is interrupted and occluded. He also reported that venous interruption and occlusion are also important factors for avascular necrosis.

Smith (1959) showed that the vessels of ligamentum teres of femoral head obstructed in two rotational malposition of the head (i) clockwise rotation round the antero-posterior axis (valgus deformity) and (ii) rotation in either direction round the longitudinal axis of the neck. These vessels becoming more and more responsible for vascular supply of the femoral head with advancing age.
Soto-Hall & co-workers (1963) suggested that with an intact capsule, the haemarthrosis due to fracture may produce a tamponade effect, that will occlude retinacular vessels. In addition, internal rotation of hip increases the intracapsular pressure of the hip joint. Maintenance of internal rotation of hip for one or two hours may increase the vascular damage by increasing the pressure probably.

Deyerle in 1965 stated that in the more avascular cases blood vessel buds must grow into the head of femur from fracture and periosteum. The vulnerable point in fracture during first 6 months is not the head but the fracture line. The growing vessels must be protected until union occurs. Any motion at fracture site, particularly piston-like shearing and rotational motion, damages these blood vessels and causes hyperemic decalcification of the fracture line. This hyperemic decalcification causes shortening of the neck and additional loss of fixation with disruption of the fracture. The damaged blood vessels lay down an area of fibrotic scar tissue that prevents additional blood vessels to grow across the fracture line. This may lead to collapse of reduction, non-union or avascular necrosis.

Frangakis (1966) stated that damage to extra-osseous vessels, mainly lateral epiphyseal vessels is directly related to displacement of the fracture and
communion in postero-superior cortex which ultimately leads to increased incidence of avascular necrosis. He also described that femoral head suspended from the acetabulum by the ligamentum teres which is subjected to rotational malposition in three planes - the vertical plane, the antero-posterior and the long axis of the neck of the femur. Residual displacement of the femoral head in one of these planes may obstruct remaining blood supply as initial displacement damage the epiphyseal vessels and it is one of the main cause of avascular necrosis of femoral head.

On the contrary, Netter (1953) & Crock (1967) showed that interruption of extra-osseous vessels alone did not significantly jeopardize the blood supply of head, because femoral head is also supplied by branches of metaphyseal and retinacular intra-medullary vessels, interrupted at the level of fracture.

William & Stephen et al (1974) in their study and previously reported series, considered avascular necrosis only when it occurred in association with united fracture. They stated that when an intra-capsular fracture occurs, the blood supply of the femoral head may be damaged either by the displacement or by some other factor. Once this occurs, the healing process is associated with revascularization of the necrotic head. They believe that
no method of reduction and internal fixation will reduce the incidence of avascular necrosis below 11% found in 101 cases of undisplaced femoral neck fractures and in 15% of 135 united displaced intra-capsular femoral neck fractures in their series in the follow-up of 6 months to 1 year duration. The incidence may increase with further follow-up. They also supported the view of Hecaroll (1953) that incidence of avascular necrosis does not decrease with early surgery even within one or two days after the fracture.

Barnes et al (1976) stated that posterior displacement of the head with intact joint capsula and synovium and blood within the capsule under some pressure tends to collapse the synovial vessels. The longer the vessels remain collapsed, higher are the chances of thrombosis and delay in revascularization process of the head. Synovial fluid constantly bathing the fracture surfaces are less responsive to normal endosteal healing process of the fracture. With all above factors, revascularization of head is delayed.

Anderson in 1979 stated that vascular damage caused by femoral neck fracture is the major factor in avascular necrosis of the femoral head. In impacted and non-displaced fracture damage occurs to intra-osseous vessels at fracture site whereas displaced fracture leads to varying degree of damage to retinacular vessels, in addition to intra-osseous vessels. Additional vascular
damage is also produced at the time of reduction but it is more when head is displaced or rotated.

The relationship of avascular necrosis with alignment of fracture fragment after reduction -

After the union of fracture avascular necrosis usually presents as segmental collapse of the femoral head. This collapse is definite indication of avascular necrosis but there are other changes as well, indicative of avascular necrosis of the femoral head.

Barnes (1962) claimed in his study that ischemic necrosis cannot be excluded on radiological grounds before twenty four months. This is true if recognition is based on structural changes in capital fragment. However, other signs manifest earlier, which are reliable but not constant. He found flatening of the weight bearing area of head to be an early radiological sign while in others condensation or collapse was the early feature of avascular necrosis.

Bunata et al (1959) suggests that a valgus reduction increases the percentage of avascular necrosis, if the valgus is sufficient to allow the parallel trabeculae in the head of the femur (as an extended line) to fall medial to the femoral shaft. Extreme valgus reduction should be avoided and varus reduction is not acceptable.
Garden in 1966 proposed an index for acceptable reduction using the trabecular pattern alignment as viewed in both antero-posterior and lateral roentgenographic planes. This has been referred to "Garden alignment index". In antero-posterior view, the angle formed by the central axis of the medial trabecular system in the head fragment and medial cortex of the femoral shaft should measure not smaller than $160^\circ$ and not greater than $180^\circ$.

An angle smaller than $160^\circ$ denotes unacceptable varus reduction and angle more than $180^\circ$ indicates severe valgus reduction, which increase the risk of avascular necrosis and non-union. On the lateral view, Garden alignment index should again be within $20^\circ$ of normal $180^\circ$ straight line along neck. If this angle is more than $20^\circ$, the femoral head is anteverted or retroverted, then an unstable anatomic reduction is present and chances of non-union and avascular necrosis may increase.

Frangakis (1966) also stated about the accuracy of reduction. He stated that valgus malposition was assessed by measuring in antero-posterior radiographs of hip by Garden alignment index. An angle of $165^\circ$ was considered to be the normal relation between head and neck in this plane and was taken as neutral position. Anything above this angle was measured as the degree of malposition. Fixation in more than $20^\circ$ valgus malposition has a catastrophic effect on the viability of the head.
On the contrary, Wm Minar Deyerle (1965) recommended valgus reduction and described the advantage of valgus reduction. Valgus reduction shortens the neck and decreases the lever arm of proximal fragment which decreases the amount of motion at fracture site. The distal fragment is placed under the proximal fragment and provides a bony support that converts the oblique fracture line to one of contact compression. The irregular surfaces of fragments invaginated into each others provide point of fixation.

However, Barnes et al (1976) reported 29% incidence of late segmental collapse in 240 cases of united femoral neck fractures in women which were internally fixed with Gaden angle greater than 180° but this incidence decreased to 25% in 223 united femoral neck fractures in women when fractures were fixed internally with Gaden angle less than 180°. Acceptance of a varus reduction does not seem to influence the incidence of union. Although a slight degree of varus may be acceptable in some fractures treated by internal fixation. No fracture which was impacted in varus progressed to union in a series of impacted fractures and varus reduction has been almost equally overwhelming to those internally fixed.

Frangakis said that rotation in horizontal plane (the normal angle between centre lines of head and neck in lateral view is 180°) have no significant effect on the
incidence of ischemic necrosis. He also stated that strenuous and careless manipulation may cause further damage to blood vessels already done by the original injury which is a high price for perfect reduction.

The variety of factors contributing to the problems of non-union and late segmental collapse has been grouped by Lowell, J.B. in 1966 as follows:

1. The radiographs and their interpretation,
2. Gentleness of reduction,
3. Accepted position of reduction,
4. Posterior neck comminution,
5. The choice of fixation device.

Treatment of femoral neck fracture -

Fractures of the femoral neck have always presented great challenge to orthopaedic surgeons and remain in many ways even today, the unsolved fracture as far as treatment and result is concerned. Adequate reduction, impaction and rigid internal fixation constitute an essential part in solving this fracture.

Von Langenbeck (1850) was first who did internal fixation in cases of femoral neck fracture. Nicolasyen (1897) and Hey Groves (1916) used various materials for internal fixation but because of incompatibility or material failure, the process of internal fixation fell
into some disrepute. Whitman (1904) after the introduction of roentgenograms suggested careful closed reduction followed by hip spica immobilization. This produced few satisfactory union but higher morbidity and mortality.

Smith Peterson (1931) is credited for reviving and popularising the procedure of internal fixation for femoral neck fractures by introducing triflanged nail and reported lower rate of mortality and morbidity from 75% to 25% and increasing the rate of union from 30% to 70%.

The revival in the treatment of fracture neck femur by internal fixation was made practical by -

(i) development of efficient apparatus for internal fixation,

(ii) The development of non-electrolyte metals after the experimental work of Venable, Stuck and Beach (1937).

(iii) The projection of more efficient roentgenographic control.

In young patients where anatomical restoration of femoral head and neck is not possible, treatment by osteotomy and osteosynthesis is often advocated. Several types of osteotomy have been described (Mc Murray, 1936; Reich, 1941; Blount, 1943; Leadbetter, 1944). These operations help to stabilize the hip but union of the
fracture does not always occur and sometimes hip remains painful and function is unsatisfactory (Hermann, 1945; Reynolds & Totto, 1951; Dickson, 1953; Stewart & Well, 1956).

Osteosynthesis of the femoral neck fracture using a tibial or a fibular graft and Smith-peterson nail (King, 1939) have been advised for the patient where fracture was less than three months old, provided that the femoral head was vascular and not much of the neck has been absorbed. Dickson (1953) said that sometimes insertion of cortical graft across the fracture site disimpacts or angulates the head which in turn lead to unsatisfactory healing and non-union.

These procedures were not good for Garden type III & IV fractures and total failure rate including non-union and subsequent avascular necrosis was 70.9% in displaced fractures as shown by Frangakis in 1966.

Inclan (1946) and Patrick (1944) also published their results of Smith-Peterson nailing and fibular grafting, reporting 10% to 15% of non-union and avascular necrosis.

There is lot of confusion and controversy regarding the treatment of femoral neck fracture, especially in comparison with primary prosthetic replacement and internal fixation and if internally fixed then over method of internal fixation. Recently emphasis is given to
preserve the head because viable head work definitely better than prosthesis. Over it Bracey (1977) commented that those fractures if reduced accurately, definitely did better.

Keeping the above problem in mind, many workers devised various methods of treatment from time to time for femoral neck fractures with the general agreement that anatomical reduction, impaction and rigid internal fixation of displaced femoral neck fractures are the basic requirements for treatment of fracture neck femur.

The workers have used different methods of internal fixation such as Trunnaged nail by Smith-Peterson (1931), Austin Moore pins, Knowel's pins, Henery screw, Henderson lag screw, sliding nails of Hugh. More recently other type of apparatus such as cross screw of Garden (1964), Triangle fixation by Smyth (1964), Deyerle's apparatus which consist of multiple threaded pins and a plate attached to lateral side of the femoral shaft (1965), compression collapsable appliances by Calandruccio & Richards; posterior bone grafting combined with internal fixation by Meyers (1974) and Percutaneous multiple pin fixation by Neufied (1973), Arnold (1984) & many others.

Deyerle observed that area of neck is of critical importance because large portion of the blood supply to heal the fracture and maintain the viability of head must come through this area. The area of the neck is 1/4 inch
in diameter. Each 3/8 inch pin takes up 1% of its cross section while a cannulated triflanged nail takes up 6% of the neck area, the equivalent of 6 3/8 inch pins. Two 1/4 inch lag screws take up 8% of the area of the neck. 7 pins take 7% area. The recommended fixation in neck fracture is 7 pins. 7% of the area of the neck is not a very great sacrifice to obtain absolute fixation and thereby to avoid further trauma to the budding young blood vessels that must grow across the fracture.

With a triflanged nail, it is comparable to brakes applied to the axle while with multiple peripheral pins, it can be likened to brakes applied to the peripheral drum. The stress is applied to a large surface area of trabeculae over or 1 inch area with peripheral pins and is applied to a small 7/6 inch area with triflanged nail or any nail of comparable size. The 6 peripheral pins have 2-3 to 4 times the leverage of triflanged nail.

He also compared the resistance to motion by triflanged nail to Smith-Peterson nail and he found that resistance to motion with seven pins fixation would be 20 times that with a triflanged nail. He also concluded that fixation is directly related to surface area of contact and the dispersal of the area of contact.

He also summarises the importance of absolute fixation (rigid fixation) as follows -
1. Repeated trauma of fracture surface is avoided.

2. Repeated inflammatory reaction at the fracture site with decalcification of the neck and fibrosis of the fracture surfaces that may block revascularization.

3. Fracture unites sooner and thus the femoral head is less likely to become avascular.

In Deyerle's initial series of 75 fractures, he reported avascular necrosis in 3% and no non-union, but Metz et al in 1970 reported in 63 patients with displaced femoral neck fracture treated by Deyerle's method, found that union occurred in 94% and avascular necrosis in 6%.

Chapman et al (1975) and Ryan associates (1979) however found higher incidence of non-union and avascular necrosis.

With the recent advance in knowledge of injuries and diseases of hip and especially with great increase in the incidence of bony union following pinning and wiring of fresh fractures as aseptic or avascular necrosis of the head of the femur has come to be recognized as one of the most important and perplexing problems which confront the orthopaedic surgeons.

Fracture of the neck of femur unites early if head remains alive. This is because there is callus
formation from the end of each fragment when the head survives but only from the end of distal fragment when proximal or head fragment dies.

To overcome the problem of poor vascularity, Helstadius (1942) came up with the idea of muscle pedicle grafting with its vascularity intact. Stuck (1944), Francel (1952), Hartley (1954) and Davis (1958) showed survival of the bone portion of the muscle pedicle grafts in animal experiments.

Baadsgaard and Medgyesi (1965) showed that pedicle cancellous grafts in rabbits survived with numerous vessels present deep in the bone graft from the periosteum. Medgyesi (1968) reported that in pedicled cortical bone grafts majority of the osteocytes perished but the blood supply and osteogenic ability of the bone persisted. He also stated that for the viability of pedicle graft, following factors play role -

1. Graft should be handled atraumatically,

2. No torsion of pedicle,

3. There should be no flexion and extension.

Stuck and Hinchey (1944) reported improved circulation in the femoral head in osteo-arthritic hip after transplanting a muscle pedicle graft into the neck of the femur in humans.
Davis and Taylor (1952) in their experimental study on dogs showed that if the muscle pedicle was of sufficient width, not too long and not stretched or twisted, periosteal attachment of the muscle to the bone was retained, the cut surface of attached bone graft continued to bleed and in all favourable condition a cancellous bone graft retains its viability when it is transplanted with a muscle belly pedicle which leaves its periosteal blood supply intact in comparison to the cancellous grafts transplanted without pedicle.

Frankel & Derine (1962) reported that autogenous muscle pedicle graft of the gluteus medius and vastus lateralis in dogs were capable of restoring the blood supply to the femoral heads which had been made avascular experimentally.

Launois & Judet (1963) described a similar experiment in dogs, which was carried out by means of an autogenous muscle pedicle bone graft of the quadratus femoris muscle. In 1962 Judet reported a clinical use of muscle pedicle graft of the quadratus femoris muscle as a means of improving the blood supply of head fragment in displaced femoral neck fractures.

In a retrospective study of 250 displaced subcapital fractures treated at the Los Angeles County University of Southern California Medical Centre from 1960 to 1965, an incidence of non-union in 35% of the cases and
late segmental collapse in 32% of the cases was found. A significant improvement in these results was noted following introduction of the muscle pedicle graft procedure. In 144 cases treated since July 1971 with a standardized technique reveals that the rate of union is 95% and late segmental collapse has occurred in 5% of the cases that united. It is impressive that in this series, all but one of 23 patients in the young adult group under the age of 40 have united and to date there has been no radiologic evidence of late segmental collapse. The latter result is a remarkable achievement considering the discouraging reports in the literature on the treatment of displaced subcapital femoral neck fractures in patients under the age of 40.

Meyers and Harvey (1974) reported that muscle pedicle bone grafting procedure gives encouraging results in old and delayed or non-union of fracture neck femur.

Nine year later, Baksi (1983) reported encouraging results in the treatment of post traumatic avascular necrosis of the femoral head whether the fracture was united or not. Later same author (Baksi, 1986) did internal fixation of un-united fracture of femoral neck combined with muscle pedicle bone grafting and evaluated encouraging results.

The posterior bone graft (muscle pedicle) was improved the incidence of union and lowered the rate of late segmental collapse. The muscle pedicle graft improves
the blood supply to the head fragment when it is impaired, thus reducing the incidence of late segmental collapse. A higher rate of union is a result of better fixation and restoration of continuity to the posterior comminuted portion of the neck since a posterior intra-capsular approach is required to carry out the procedure.

In addition to providing a source of blood to the head fragment when the fracture interrupts the blood supply either totally or sub-totally, the operation has many advantages.

Since it is necessary to approach the fracture site posteriorly and intra-capsularly, direct visualization of the posterior neck of the femur is obtained. A more accurate reduction of fracture can be realized under direct view. Iliac bone chips and chips from greater trochanter can be added to fill the defect in the posterior neck of the femur, which has been found in 70% of the fractures. Improved fracture stability is provided by the pedicle graft. The latter acts as a neutralization force since it is fixed to the posterior surface of the neck which is compression side of the fracture.