DOI: https://doi.org/10.4038/tsljos.v10i1.34

The evolution of fracture neck of femur treatment

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Sri Lankan Journal of Orthopeadic
2023 : 08 : 6-16

The incidence of Fracture neck of the femur(FNF), is considered to be reaching almost epidemic proportions among the elderly population. In 1990, the estimated FNFs were 1.26 million,; 2.6 million cases are anticipated by 2025, and 4.5 million, by 2050 (1). Regardless of the patient's fitness for surgery, this is one of the very few fractures that almost always need surgical intervention. When it comes to the treatment of FNF, there is a saying in orthopaedics that the person most unsuited for surgery is the one who needs the surgery the most. Despite the advances in surgery over the last 100 years, these fractures still pose a challenge today.

This article examines the evolution of FNF treatment.

The earliest evidence…

There is no documented evidence of hip fractures in the ancient Indian, Greek, Roman or Egyptian medical literature, The Edwin Smith and Eber's papyri are the oldest medical records; and though they explained treatment methods of a variety of fractures, they do not categorically mention hip fractures(2). French surgeons, Alexis Boyer (1757 – 1833) and François Malgaigne (1806 – 1865) mention that Hippocrates had a notion of hip fractures and their 'need' for immobilization(3). Roman physician Gallen (Claudius Galenus 129AD- 216AD) noted that upper thigh fracture immobilization was explained by Hippocrates. Gallen developed a fracture table (Fig 1.1), based on the ideaology of Hippocrates.

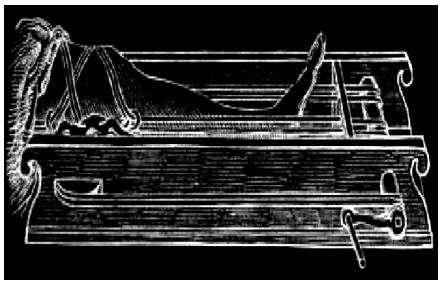

Fig 1.1 : Gallen's illustration of his technique Original illustration (4)

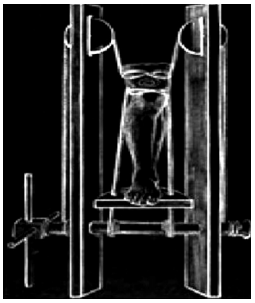

Fig 1.2 : Ambroise Pare technique.

The first documented evidence of treatment of a hip fracture was in the time of king Charles IV, who was the emperor to the territories of Rome and Bohemia.Roman and Bohemia territory. He died due to complications of a hip fracture in 1378(5).

13th century onwards- Developing methods of traction

Towards the end of the 13th century, Italian physician Theodore explained the method of traction advocated by Avicenna. He described a method of hanging a weight on to the foot over a pully to provide pain relief and maintain limb length while the fracture healed.

15th century onwards- The Development of methods of traction

From the 15th century to the late 18th century, different techniques of external immobilization were introduced (3).

French military surgeon Ambroise Pare (1510-1590) explained various braces and immobilization techniques (Fig 1.2) for FNF fractures in his thesis of "Works of Ambroise Pare"(3). Later on, Morgagni (1682-1731), Heister (1683-1758) and Ruysch (1638-1731) explained the pathology of hip fracture by autopsy studies.

Fabricius Hildanus (1537-1619) introduced the 'belt of Hildanus', which consisted of one tight metal one belt above the knee and another at the ankle. A traction device was attached to it which applied traction to keep the leg in extension. Hildanus used the principle of extension and counter traction for the first time. Lawrence Heister (1683-1758) popularized this technique and explained it in his book "A General System of Surgery" in 1750.

In 1780 Benjamin Gooch further developed this technique with the application of two metal rods to the thigh belt which was referred to as "Gooch's machine". He modified the Hidanus belt with two adjustable screws at the ankle belt to achieve distraction(3).

Jean Louis Petit(1674-1750) used the same principle with linen straps for the thigh belt and ankle belt, rather than metal ones for immobilization. Till the mid-17th century, the hip fracture immobilization principle was the extension and counter traction theory.

Percival Pott an English surgeon from London (1714-1788) and one of the founders of modern orthopaedic surgery explained a different mechanism for hip fracture immobilization. He explained the process of semiflexion of the hip to relax the muscles and balance the forces of fracture fragments at the site of the fracture.

Pott's method did not become popular as his theory of semiflexion and muscle balance was not accepted in that era. Desault (1744-1795) raised objections to this method and developed a new splint called the Desault splint which extended from foot to groin. Desault's wife suffered a hip fracture and was immobilized with Desault's splint and died from pneumonia as a complication of this method of treatment. Deasault's splint was criticized for causing pressure necrosis on counter traction touch points.

Benjamin Bell (1796) developed a double inclined traction device to immobilize upper thigh fractures.

Delpech (1777-1832) French surgeon further modified the Bell's device. He introduced a double plane inclined bed to treat upper thigh fractures: the "Bed of Delpech".

18th Century onwards- A better understanding of fracture patterns.

In the late18th century, Sir Astley Paston Cooper (1768-1841), the legendary British surgeon, in his book "A treatise on dislocations and on fractures of the joint" described the first classification of hip fractures.

In the same era Irish surgeon Abraham Colles (1773-1843) published the first study describing impacted hip fractures with drawings of per trochanteric fractures in 1818.

In 1819, Sir Astley Cooper in his book of "Surgical Essays" explained intracapsular and extracapsular fractures and the reasons for non-union of hip fractures (5).

Cooper's concept of 'conservative management' was criticized by his colleagues namely Dupuytren, Boyer, Malgaigne, Charles Bell and Henry Earle. They argued an active involvement should be performed in immobilization in the view of achieving osseous healing.

Bell's method was introduced to the French surgeons by Dupuytren (1777-1835) who was a military surgeon and renowned as Napoleon Bonapart's surgeon. French surgeons used pillows and cushions to incline the proximal thigh. Within a short time of it coming into use it was recognized that this mechanism could displace the fracture,

Philip Physick (1768-1867) further modified the Desault's splint by introducing a counter traction band to the axilla. The splint was from the foot to the groin and the counter traction band was from the groin to the axilla.

Hutchinson modified Physick's splint by keeping a wooden block in the inner side of the traction splint to prevent pressure ulcers in the foot, which was a common complication of Physick's splint.

Dupuytren (1777-1835) elaborated that hip fractures usually occur in elderly women with osteoporosis. And he emphasized that keeping the leg without traction immobilization can result in the shortening of the

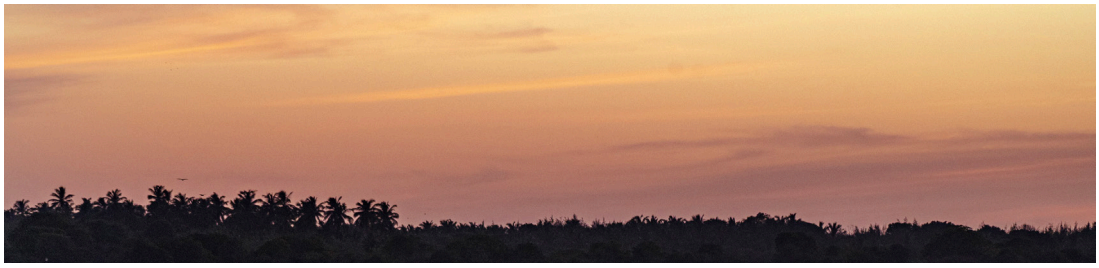

Fig 1.3: Belloq' machine(3).

Fig 1.4 : Boyer's technique: Original illustration (6).

affected limb. He explained the way of reducing the fracture to prevent shortening and kept a pillow under the knee to facilitate the healing of fractures. Hutchison's method was like Sir Astley Cooper's method. Belloq (1732-1807) introduced a machine with a jack to stabilize the foot in extension (fig 1.3).

Boyer (1757-1833) further developed Belloq's machine (fig 1.4). But these mechanical methods did not get popular due to the complexity of the mechanism and the high cost of production.

Bruninghausen explained the possibility of keeping the foot in internal rotation to prevent the external rotation of the hip fracture.

In 1823 Henry Earle published a book on hip fractures and illustrated his fracture bed.

Velpeau (1841) explained a method of using a dextrin coated splint around the leg and hip to immobilize the leg. He was the first to describe the use of dextrin coated Whitman's "Plaster of Paris" spica to immobilize the hip and leg.

R.W. Smith, in 1847, also categorized and classified hip fractures into intracapsular and extracapsular fractures which was similar to the Astley Cooper's classification.

In 1860 Hamilton further developed Hagedorn's splint which was already modified by Gibson, which consisted of a wooden footboard to rest both feet and a well-padded axillary support for counter traction. In 1861, Gurdon Buck introduced an extension apparatus called "Buck's extension unit".

In 1867 Nathan. R. Smith explained the possibility of using an anterior suspensory band to keep the hip and knee in semiflexion as described originally by Sir Astley Cooper.

The famous "Thomas's splint" was developed by Hugh Owen Thomas in 1888(3) it consists of a proximal oblique iron ring to which two iorn bars are attached which extend distally to end like the letter"V". The oblique shape of the proximal ring facilitates the fixation to the hip crease. The foot is fastened to the distal end of the iron rod to keep traction. Ridlon a student of Hugh Owen Thomas popularizes this splint. Thomas named this splint the "Thomas-Ridlon splint" (fig 1.5). It is still in use for femur fracture immobilization.

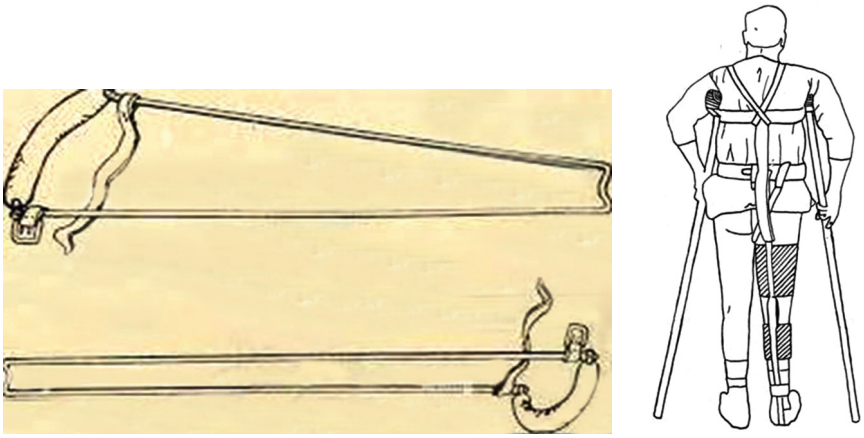

Fig 1.5: Thomas- Ridlon splint

Scudder modified the Thomas- Ridlon splint by adding the Senn's lateral pressure pad over the greater trochanter (fig 1.6).

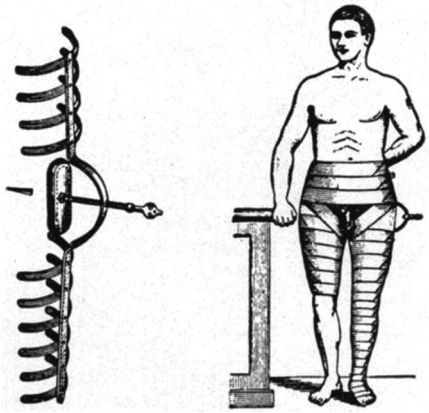

Fig 1.6: Senn's device with lateral pressure over the greater trochanter, with external fixation (3)

In 1891 an anatomical method of immobilization was introduced with longitudinal and lateral traction by C.R. Ruth. This was called the Maxwell-Ruth method.

At the beginning of the 20th century newer concepts were developed for hip fracture immobilization. The most remarkable method was explained by a New York surgeon, Royal Whitman in 1904. He introduced a plaster of Paris spica abduction splint for FNF fracture immobilization. This was popularized all over the world and got a reputation as the standard method of hip fracture immobilization. The object of his spica was to restore the anatomical alignment of the hip(3). The application of Whitman plaster spica (fig 1.7) was performed under general anesthesia on a special table that had a pelvic support. In 1910 Cotton further elaborated on Whitman's method and he noted that after reducing the fracture, impaction of fracture would deliver better results.

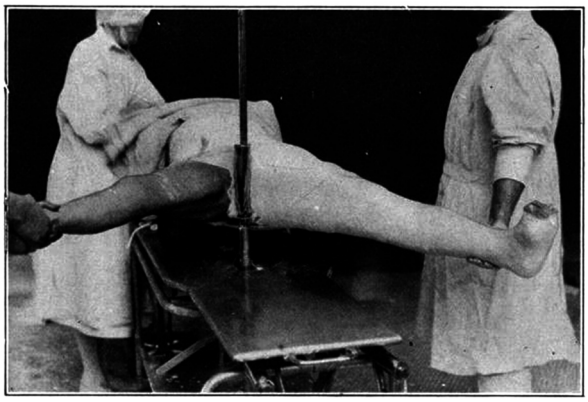

Fig 1.7: Whitman plaster spica, Original illustration (7)

The Royal Whitman method was modified by Leadbetter, who introduced perpendicular traction with the thigh flexed to a right angle, abduction, and internal rotation. At the beginning of the 20th century Kleinberg (1936) further improved the Whitman technique by early mobilization with supported weight bearing.

In1930 the American Orthopaedic Association appointed a commission to evaluate the outcome of Whitman's technique. The commission reported that bony union was only present in 50% of the cases and that the rest of the fractures was healed by fibrous union.

By this time the concept of internal fixation of hip fractures was becoming a topic among the European and American surgeons.

Despite various concepts and appliances developed by the surgeons to treat hip fractures, the general acceptance among the public was very poor and the overall management of hip fracture was gloomy. Sir Astley Cooper described this in his own words "Baffled in our various attempts at curing these hip fractures and finding the life of patients occasionally sacrificed under the trials made to unite them" (2).

Mid-19th Century- The beginning of fracture fixation

The era of internal fixation began in 1858, when Bernhard Rudolf Konrad von Langenbeck performed the first internal fixation of a hip fracture. He opened the fracture site and fixed the greater trochanter to the neck and femoral head by passing two fine gimlets (nail with a topper). But the comorbidities of old age and wound infection resulted in failure. Autopsy revealed the fracture fixation as being stable but the nails had penetrated into the hip joint(5). During this era there was no concept of aseptic surgery.

The concept of aseptic surgery was introduced about 30 years later in 1890. In 1878, Franz Koenig presented a paper on internal fixation of hip fracture. He described a successful percutaneous fixation of a hip fracture with a gimlet, under aseptic conditions which had given a good outcome with fracture healing. Koenig's surgery seems to be the first successful internal fixation of fracture neck of femur. From 1878, there were adoptions of many surgical methods and instruments to fix hip fractures.

American surgeons Murphy and Beckman, Scottish surgeon MacLennan used ordinary nails and screws with different success rates. In 1878, Trendelenberg and Lister, in 1880 used the same nail technique as Koening.

In addition to the fixation with nails, they utilized the Buck's traction apparatus or Whitman plasters to achieve the reduction and maintain it. Koeing and Trendelenberg advised suture of the bone with silver wire.

Swiss born American surgeon Julius Nicolas Senn (Nicolaysen 1844-1908) described the significance of healing and with restoration of the anatomy of hip to near normality. Senn did some animal experiments on fracture fixation. Senn published 13 cases of fresh fractures treated with a 15cm steel spike percutaneously inserted, 5cm below the tip of greater trochanter. The head of the steel spike was outside the skin and was immobilized with a plaster spica for eight to ten weeks without weight bearing.

In 1891 Dollinger a German surgeon, published a report on an openly reduced and internally fixed extracapsular fracture which healed successfully. He had fixed the fracture with silver wires. Dollinger seems to be the first one who had performed an open reduction of an extra capsular fracture.

Theodor Kocher (1841-1917), a Swiss surgeon who was a student of Langenbeck, did experimental studies on proximal femoral fractures and presented a classification of proximal femoral fractures. It is the first classification of proximal femoral fractures and proposed names for individual fractures. These terms are still being use : pertrochanteric fractures, intertrochanteric fractures, and sub trochanteric fractures(8).

In 1900 a German surgeon Borchard presented a paper at the German Surgical Association and noted the advantages of the operative technique of Senn. In the same publication he acknowledged, two Russian surgeons namely: the Derjushinski and Michalkin, who operated on non-healing hip fractures with dissection of fibrous tissues followed by fixation with silver wires(9). These had a good outcome with the fractures healed. In 1898 Clayton Parkhill (1860-1902) suggested the possibility of external fixation of an intracapsular fracture.

The first internal fixation with an anterior approach to the hip was performed by an American surgeon Gwilyn G. Davis in1900. He had performed an arthrotomy with an anterior approach and fixed the fracture with two steel pins.

In 1898 an American surgeon Arthur J. Gillette, explained the possibility of hip fracture fixation using bone or an ivory peg. It was the first case of internal fixation with an ivory peg. During this era the significance of lateral compression of the hip fracture for fracture healing was emphasized. R.H. Sayre published that he had achieved lateral compression with a gimlet and two nuts outside the skin.

During the pre-Xray era the reduction and fixation of fractures (and dislocations) was not accurate due to the inability to visualize the fracture. All fracture reductions were done along imaginary planes based on anatomical landmarks, identified by palpation.

The new revolution of internal fixation and fracture reduction began with the invention of X-ray in 1895 by W.C. Rontgen, which was available for clinical use by 1896.

In 1905 a surgeon from Piladelphia Augustus Wilson (1853-1919) published a fixation of an intracapsular fracture with German silver spike wires and checked the position with radiographs. It is the first documented evidence of per intra operative use of X-rays in hip fracture fixation.

Pierre Delbet , French surgeon in 1907 was the first to use the metal screws to fix hip fractures. He used 6 mm thick heavy worm screws, about 7cm to 9cm in length. He inserted them percutaneously 1.5 cm below the tip of the greater trochanter. The construct of the worm screw imparted a compressive force on the fracture site. After the surgery he applied 15 to 20 pounds of skin traction to the foot for about two weeks then immobilized the patient with a walking splint for about one month. Later in 1910, he developed a targeting device to aim the screw which was referred to as a "Delbet cannon"(fig 1.8). He is the first surgeon who used a target device to insert the screw. He fixed fractures with thick heavy worm screws and bone pegs from the fibula. Delbet further classified the proximal femoral fractures, which was independent from the coexisting classification of that era. It was called the "Delbet-Collona" classification which is still used in the classification of proximal femoral fractures in children(5).

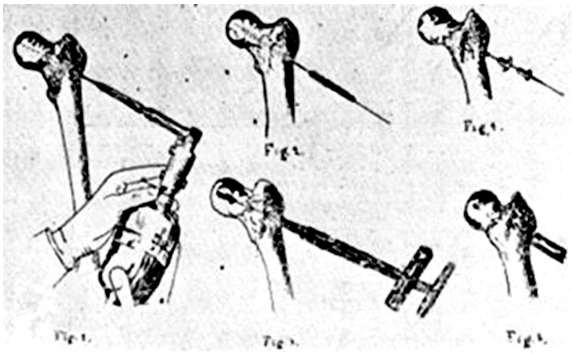

Fig 1.8: Delbet Targeting device(3)

During this era discussions were focused on using alternative methods for FNF fixation. Hahn in 1909 was the first surgeon who used an autogenous tibial bone graft as a bone peg to fix the hip fracture. Fred Houdlett Able in 1912 further elaborated about the autogenous bone graft as a peg to fix hip fractures. In 1914 during the annual congress of the German orthopaedic Society, Able presented his paper which discussed the surgical difficulties with hip fractures.

Able, Henderson and Campbell used intramedullary bone pegs and bone grafts to treat non healing hip fractures. In 1916 Vittorio Putti, an Italian surgeon further developed the fixation of hip fractures with screws with successful results.

Early 20th Century- The development of modern traction systems

Bradford in 1919, explained a method of immobilization with an external splint which allowes mobilization. An Australian surgeon Hamilton Russell explained a method similar method to Buck's traction device (Fig 1.9). This is known as "Russell Traction device"(3).

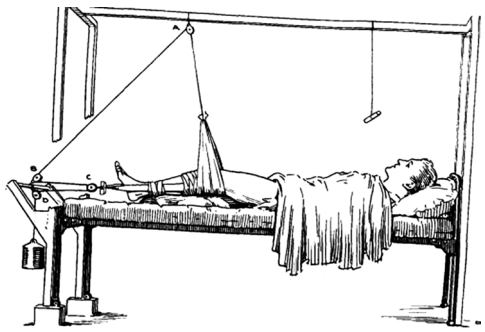

Fig 1.9: Russell Traction, original illustration (Russell, 1987).

American surgeon, Roger Anderson in 1932 introduced the concept of skeletal traction as a better method of applying traction. The skeletal traction was applied to the distal tibia with a non-rotating plaster of Paris boot (Fig 1.10).

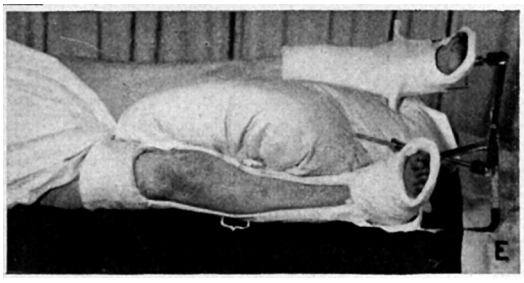

Fig 1.10: Anderson's skeletal traction device Original illustration (10)

Early to Mid 20th Century- The impact of radiology and asepsis on fracture treatment

In 1932 Ellis Jones published his case of hip fractures fixed with autogenous fibular bone graft (fig1.11) which had successful outcomes.

Ellis's followers Davison, Smith, Mayo, Nordenbos and Kelvington practiced this method with good results.

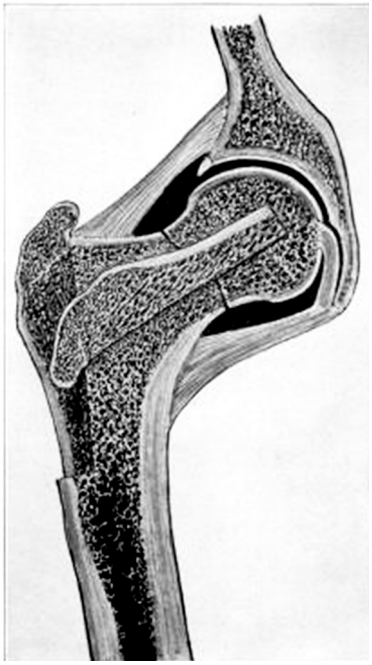

Fig 1.11: Ellis Jones trochanteric transplantation of fibular bone graft, Original illustrations (3)

Unlike in the early era of the 19th century, presence of X-ray had given the opportunity in the accuracy of fracture reduction. The awareness of the concept of aseptic surgery and aseptic techniques had reduced the number of post operative infections.

William Thomas Green Morton (1819-1868), who is considered as the father of modern anesthesia, introduced the newer modes of anesthesia, which facilitated the FNF treatments.

The newer generation of orthopedic surgeons in both Europe and America was working out strategies to achieve good outcomes for hip fractures. Lambotte in 1913 explained fixation using two screws.

The strategy of hip fracture treatment totally changed when the Boston surgeon Marius Smith Peterson (1886-1953) introduced his three flanged nail (fig 1.12). He published initially published his three flanged nail initially, in 1914(3).

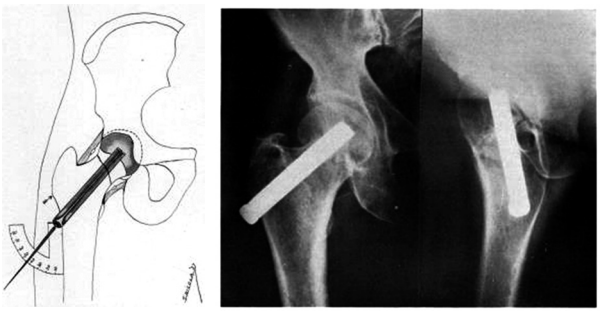

Fig 1.12: Smith-Peterson initial technique of nail fixation. It was inserted blindly, one inch below the greater trochanter in at an angle of 45°(3).

Post operatively, the patient was immobilized with a five-pound traction for three to four weeks. After four weeks, the patient was mobilized with a 10° to 15° abduction splint which was removed for physiotherapy. Henderson in 1937 explained the difficulties with of the Smith -Peterson nail. During the same era Sven Johansson (180-1959) from Sweden introduced a new drilling method of the head of the femur through the femoral neck under X-ray guidance (fig 1.13).

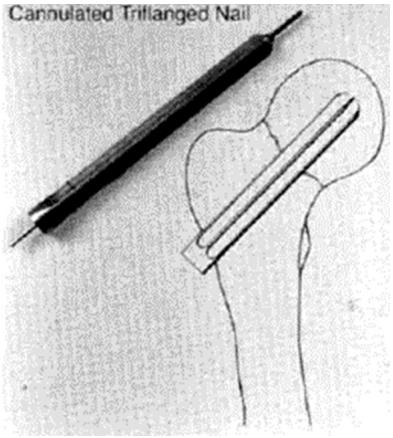

Fig 1.13: Johansson cannulated triflanged nail. Original illustration (11).

Johanson in 1932 and Wescott in 1934 further developed this method into a cannulated drilling system and system insertion of a triflanged nail over the guide wire. Subsequently Smith Peterson modified

his method to a closed reduction, drilling of the femoral head and triflanged nail fixation with intraoperative X-ray guidance. In 1937 Henderson presented a paper on his surgical technique with cannulated drilling and lag screw fixation with a washer (fig 1.14) which achieved a fracture healing rate of 86% (11).

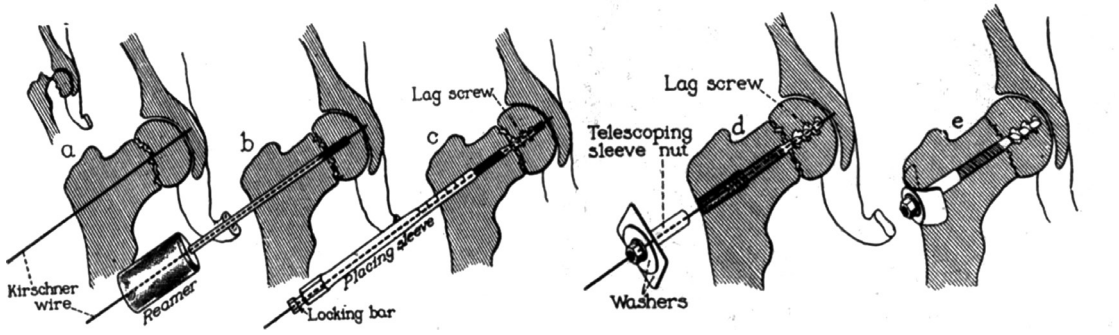

Fig 1.14: Henderson surgical technique(12) .

Using a similar surgical technique Eyre- Brook and Pridie used a modified nail which facilitated easy extraction and reported a 60% union rate (12). Inability to maintain the fracture reduction, nail backout from the insertion point, joint penetration and inability to maintain lateral stability were the major issues with the Smith-Peterson nail technique (11).

Wescott's modification of the Smith Peterson nail, Leadbetter's closed fracture reduction technique, and Sven Johanson' cannulated drilling with intraoperative X-ray facility, had given a new hope for hip fracture management in the 3rd and 4th decade of the 20th century with better outcomes.

The major issues raised with the above surgical techniques were the lateral compression instability, unable inability to maintain the fracture reduction and screw penetration into the hip joint.

During this era surgeons tried to achieve lateral compression stability by introducing different types of lag screws. Henderson 1939, Putti 1940, Godoy-Moreira 1940, and Lippmann 1939 introduced different types of lag screws. A Spring-loaded lag-screw was introduced by MacAusland in 1945.

Thornton introduced a slide plate (fig 1.15) to the fixation(11). It gave lateral stability for the fracture. The nail plate was secured with an interlocking screw at the lateral nail plate junction.

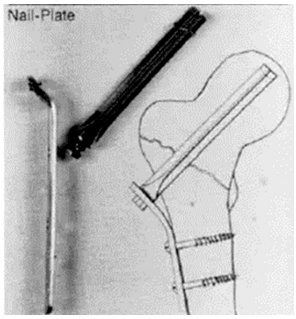

Fig.1.15: Thoronton nail with lateral plate
Original illustration (11)

Jewett in 1941 designed a device with a fixed nail and plate (fig 1.16). It was done by adding a side plate to the triflanged nail. He designed this plate for per trochanteric fractures.

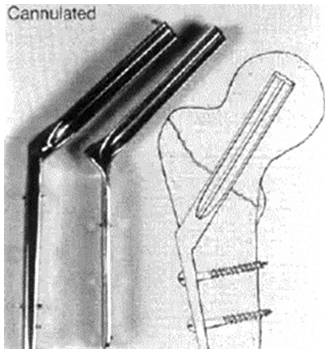

Fig.1.16. Jewett Nail, The first fixed angle blade
Original illustration(11).

In his paper he mentioned that he had achieved 80% healing with a good reduction (11). The issue was that as the fixed one-piece nail plate device was rigid, it increased the incidence of screw penetration into the hip joint. Also, the device did not facilitate fracture

fragment impaction. Failures of fixed angled nail plate lead to the development of lateral sleeve plate and screw with a spring loading mechanism to facilitate fracture healing(11). Sliding nail plate devices were later introduced and they facilitated the controlled impaction of the fracture.

In 1934 Robert Danis first designed a dynamic implant (fig 1.17) for stabilization of femoral neck fractures.

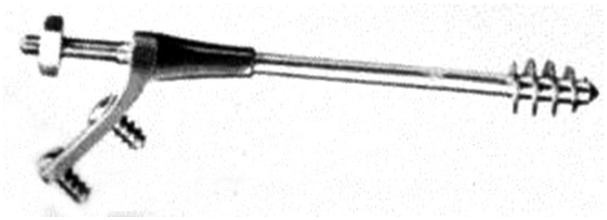

Fig1.17: Danis compression hip screw(9).

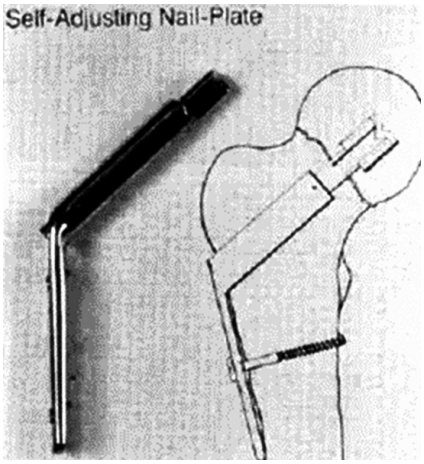

Fig.1.18: Paugh nail plate with self-adjusting screw

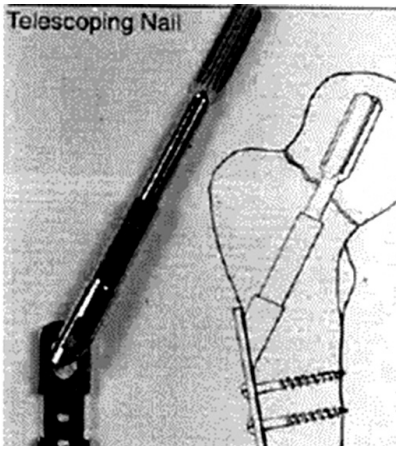

Fig. 1.19: Massie sliding telescoping nail. Original Illustration(11).

Mid-20th Century – The development of the sliding screw

Paugh introduced a sliding device with a keyed barrel (fig 1.18) to prevent rotation of the screw and a fixed angle plate of 135°. He reported a successful healing rate of 73%. Fielding reported a 90% healing rate with the same device. Massie developed a 150° fixed angle sliding plate (fig 1.19), and reported a 33% healing rate(11).

The sliding nail plate next evolved into the sliding hip screw with large diameter lag screws. The larger diameter lag screw design gave the advantage of better fixation of osteoporotic bone and a less traumatic insertion.

In 1941, the American Academy of Orthopaedic Surgeons (AAOS) recommended the use of Tiffin's nails for internal fixation. The sliding fixation device was developed and the Dynamic Hip Screw (DHS) was introduced in the 1950s and 1960s, by Pugh and Massie (11). Kuntscher, Zickle, Grosse, Kempf, Russel, and Taylor developed sliding hip screws with an Intra Medullary Nail (IMN)(13).

The first intra medullary implant for trochanteric fractures was developed by the Ernst Pohl in the early 1940's and was called a "Y-nail "(fig 1.20)"(9).

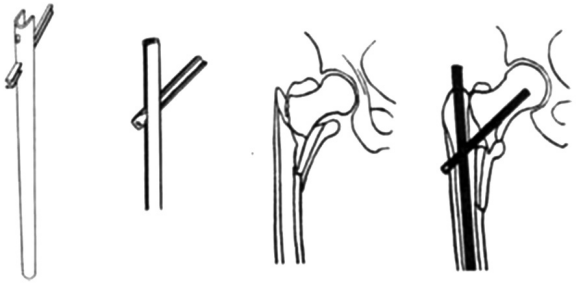

Fig 1.20: Y-nail

In 1951, Ernst Pohl with Gerhard Küntscher developed the first clinically successful sliding hip screw (fig 1.21) by further development of the Robert Danis dynamic screw. This implant was constructed with a dynamic screw and a two-hole plate with a 135 degrees fixed angled blade. They patented this sliding hip screw device in Germany in 1951, and it was recognized in America in 1952. In 1955 Schumpelick and Jantzen published their first clinical experiences of Pohl's sliding hip screw device (Bartoníček & Rammelt, 2014).

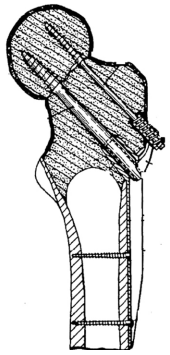

Fig 1.21: Ernst Pohl nail developed in 1951(9).

Pohl's implant was commercialized as "Richards classic hip screw" towards the end of 1951 by Richards company. This implant was manufactured on a commercial scale with 135 degrees and 150 degrees fixed angled plates(9).

In 1955, Willis L. Pugh developed a similar construct with a 120-degree fixed angled blade with a tri-flanged nail instead of a lag screw. In 1957 John Charnley introduced a dynamic sliding screw with a 120 degrees fixed angled barrel with a plate (fig 1.22). In this implant Charnley had addressed the issues with fracture impaction, lateral buttress stability and the large diameter screw to hold the osteoporotic bone.

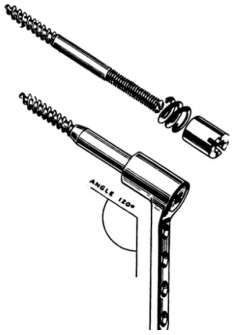

Fig 1.22: John Charnley's device(14).

Even though Charnley's device seemed to be better than the available devices, AO/ASIF foundation was not much interested in Charnley's device. AO/ASIF recommendation was a fixed angled blade plate (Jewett nail or AO 1300 angled blade plate). In Europe around the 1960's in Europe, it was becoming evident that the fixed angled blade was not a successful option for hip fracture fixation. The fixed angled blade plate was associated with a high incidence of biomechanical failures. Due to the high incidence of biomechanical failures, alternative non-anatomical reconstructions were proposed.

In 1967 Dimon JH and Hughston JC formulated a theory of non-anatomical reconstruction of trochanteric fractures with resection of the comminuted fracture segments, medial translation of the femoral shaft with and stabilization in valgus. This reduction got popularized as the Dimon and Huston method of proximal fracture fixation during the latter part of 1960's. But with the passage of time complications and bio-mechanical failures were recognized.

A condyle-cephalic technique by Ender's was introduced around the 1970's. Initially it was recognized but with time the failures with this system also became evident, and its popularity faded away.

Late 20th Century onwards - Establishment of the current methods of fixation

By understanding the complications and biomechanical failures with other devices, surgeons around the world went back to using the dynamic hip screw (DHS). By the 1980's the DHS became the standard implant for extracapsular femoral neck fracture fixation. The AO/ASIF recognized the advantages of DHS and they introduced the AO version of the DHS implant with a trochanteric stabilization plate.

Around the 1990's intramedullary nailing devices were introduced for extracapsular fractures.

Today our understanding of hip fractures has evolved considerably from what it was 50 years ago. Still there is a considerable debate about the choice of implant for extra capsular fractures .

Irrespective of technological advances, a promising treatment for extracapsular fracture is yet to come.

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