REVIEW OF TAPERED FEMORAL STEM FIXATION

IN CEMENTED TOTAL HIP REPLACEMENTS

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A dissertation submitted to the Tamil Nadu Dr.M.G.R. Medical University in partial fulfillment of the requirement for the award of M.S. Branch II (Orthopaedic Surgery) degree March 2006-2008

CERTIFICATE

This is to certify that this dissertation titled **"REVIEW OF TAPERED FEMORAL STEM FIXATION IN CEMENTED TOTAL HIP REPLACEMENTS"** is a bonafide work done by **Dr. K. VIGNESH PRASAD,** in the Department of Orthopaedic Surgery, Christian Medical College and Hospital, Vellore in partial fulfillment of the rules and regulations of the Tamil Nadu Dr. M.G.R. Medical University for the award of M.S. Degree (Branch-II) Orthopaedic Surgery under the supervision and guidance of **Prof. ALFRED JOB DANIEL** during the period of his post-graduate study from March 2006 to February 2008.

This consolidated report presented herein is based on bonafide cases, studied by the candidate himself.

Prof. Alfred Job Daniel
D.Ortho., M.S.Ortho.
Professor of Orthopaedics
Department of Orthopaedic Surgery
Christian Medical College & Hospital
Vellore.

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Prof. Vrisha Madhuri
D.Ortho., M.S.Ortho., M.Ch.Ortho.(L'Pool)
Professor & Head
Department of Orthopaedic Surgery
Christian Medical College & Hospital
Vellore.

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AIMS AND OBJECTIVES

The aims and objectives of the study are

- To retrospectively analyse all cases of double-tapered (Exeter Universal) and triple-tapered (C-stem) femoral stem cemented Total Hip Replacements done in our Department from November 2000 to February 2007.
- To analyse the functional outcome of patients in both groups.
- To analyse the initial post-operative and follow-up radiographs of patients with Exeter & C-stem Total Hip Replacements and compare them with respect to radiological parameters.
- To measure the subsidence of the femoral stem in the cement mantle in comparable digital radiographs of both groups by a computer-aided manual method.
- To analyse the subsidence of the femoral stem of the two groups at identical follow-up periods.

INTRODUCTION

The Hip joint is a ball and socket type of synovial joint. It is a major weight-bearing joint and is subjected to high physiologic loads. Hence, it is one of the commonest joints in the human body to develop arthrosis, and consequently Total Hip Replacement (THR) or Total Hip Arthroplasty (THA) is a very commonly performed Orthopaedic procedure worldwide.

Hip arthroplasty has its origin in the early nineteenth century, when Anthony White performed the first Excision arthroplasty of the hip at the Westminster Hospital in London in 1821.[1] It has evolved so much from then onwards to its present state.

The real success of Total Hip Replacement surgery started with the introduction of the Low Friction Arthroplasty (LFA) by John Charnley in 1962. Ever since then, there has enormous change in this field with the development of newer prosthetic designs with insight into the biomechanics of the artificial joint, newer bearing surfaces, newer surgical techniques and approaches, newer varieties of cement and cementing techniques and uncemented prosthesis. Resurfacing arthroplasties which were tried and abandoned in the last century are making a comeback.

This study analyses two types of cemented femoral stem designs widely used in total hip replacement surgery in the present scenario.

HISTORICAL REVIEW

1840	-Carnochan, New York used wooden block between the damaged ends of hip joint[2]
1860	-Auguste Stanislas Verneuil, Paris performed the first soft tissue hip interposition[1]
1890	-Gluck introduced an Ivory ball and socket joint fixed to bone with Nickel-plated screws[1]
1919	-Delbet used Rubber femoral head for femoral neck fractures[2]
1925	-Marius N Smith Peterson, Boston introduced the Mold arthroplasty[1]
1936	-Vitallium, an alloy of cobalt-chromium introduced
1938	-Philip Wiles - first Total Hip Arthroplasty with a metal-on-metal prosthesis made of stainless steel[2]
1939	-Bohlman and Austin T.Moore used a 12-inch long Vitallium femoral head prosthesis in a patient with Giant Cell Tumour of the proximal femur[3]
1939	-Frederick R. Thompson of New York – Thompson prosthesis[2]
1946	-Judet brothers designed the Acrylic short stemmed prosthesis[4]
1946	-Edward J. Haboush, New York used “Fast setting Dental acrylic” to glue prosthesis to bone[1]
1950	-Sven Kiaer introduced bone cement[2]

1952 -Gaenslen introduced metallic acetabular cup used for acetabular cup arthroplasty with reshaped femoral head[2]

1955 -McBride introduced metallic acetabular cup used along with Thompson prosthesis[2]

1957 -Urist - Vitallium acetabular socket used along with Thompson femoral prosthesis[5]

1957 - Aufranc reported 1000 cup arthroplasties performed at the Massachusetts General Hospital[2]

1958 -John Charnley develops Low Friction Arthroplasty (LFA) using Polytetrafluoroethylene (PTFE)[2]

1962 -Sir John Charnley - The first cemented metal-on-polyethylene hip replacement at the Wrightington Hospital in England using cemented high-density polyethylene (UHMWPE) socket and monoblock cemented femoral stem with head size of 22.225 mm. The stem was polished and manufactured out of EN58J stainless steel.[6,7]

1963 -McKee and Watson-Farrar - Metal-on-metal articulation with a modified Thompson femoral head prosthesis and a chrome-cobalt metal socket fixed with cement.[8]

1963 -Stanmore hip developed - Department of Biomedical Engineering, Institute of Orthopaedics, Stanmore. Femoral component made of cast cobalt-chromium- molybdenum alloy (Alivium) with a 25 mm or 35 mm diameter head and the acetabular component is made of high molecular weight RCH 1000 polyethylene.

1964 -Ring prosthesis – Acetabular cup with a long threaded stem and a modified Moore's prosthesis as femoral stem[9]

1969 -Ling and Lee introduced the collarless polished double tapered Exeter stem (Stryker, Newbury, UK)

1970 -Pierre Boutin used alumina cup and alumina ceramic head attached to a metal stem

1970 -Stanmore hip modified to matte stem

1972 -Stanmore hip again modified to narrow smooth, straight stem with a 25-mm head and an ultra-high molecular weight polyethylene cup

1972 -Pierre Boutin - Femoral component entirely made of ceramic[2]

1972 -Alumina ceramic heads articulating with UHMWPE in Japan[2]

1980 -Silane cross-linked HDPE – Wrightington Hospital[2]

1992 -Sedel introduced a new Alumina ceramic-on-ceramic design[2]

1995 -Muller – Cobalt chrome alloy pairings

REVIEW OF LITERATURE

EVOLUTION OF TOTAL HIP REPLACEMENT

Sir John Charnley in 1958 pursued methods of replacing both the femoral head and the acetabulum of the hip joint and he developed a concept of low friction arthroplasty (LFA) after analysing animal joint lubrication.[2] He realized that a cartilage substitute was necessary in order to allow artificial joints to function at extremely low friction levels as seen in nature. He first used Teflon shells on the surface of the femoral head and acetabular components. The rapid failure of Teflon parts led to the development of a new design with a small diameter metallic femoral head attached to acrylic-fixed stem, which articulated with a thick walled Teflon shell. This new design failed quickly due to poor wear characteristics and also led to generation of huge amount of wear debris. These wear debris promoted massive inflammatory reactions in the joints.[2]

This led to the development of a socket made of High Molecular Weight Polyethylene (HMWPE) with wear properties that was 500 to 1000 times better than Teflon and in 1962, Charnley finalized his total hip design - the cemented high-density polyethylene socket and the monoblock cemented femoral stem with head size of 22.225 mm. This was polished and manufactured out of EN58J stainless steel. There have been five changes in the standard ‘Charnley’ stem since these first-generation flat-back stems.[10] There have also been various other prosthetic designs evolved from the Charnley hip.

EVOLUTION OF THE EXETER HIP[11]

The Exeter Hip was developed jointly at the Princess Elizabeth Orthopaedic Hospital and the Department of Engineering Science of the University of Exeter in 1969 and early 1970. It was introduced in to clinical practice at the Princess Elizabeth Hospital in November 1970.

FEMORAL STEM GEOMETRY

A double-taper shape was adopted for the stem because it was believed that this would represent the optimal shape for the extrusion of acrylic cement dough into the endosteal surface of the femur during stem insertion. The taper was carried right up to the base of the neck on the anterior and posterior surfaces of the stem. The stem was originally made available in two sizes known as standard and lightweight.

The original Exeter stems were manufactured from the rather ductile stainless steel EN58J (also used for the original polished flat-back Charnley stem).

The optimum head size was debated and a compromise between the 41mm head of the McKee-Farrar stem and the 22.5mm head of the Charnley LFA was adopted with a head size of 29.75mm.

ACETABULAR CUP GEOMETRY

The cup was manufactured from ultra-high molecular weight polyethylene. As a 29.75mm head diameter had been selected, the problem arose of how to obtain a thick layer of polyethylene in the projected wear path of the head without going to an excessively large outside diameter of cup. This was addressed by making the inside of the cup eccentric with respect to the outside, a design feature later recognised as inappropriate and changed in 1988. The vertical skirt on the lateral aspect of the face of the cup was intended to protect against dislocation, and in practice, was usually placed posterolaterally rather than superior by rotating the cup posteriorly through 30-45 degrees in the long axis of the cup introducer before insertion. This defeated the object of the eccentricity because it brought a thin layer of polyethylene into part of the projected wear path of the femoral head. Guides on the introducer helped to orientate the cup appropriately in abduction and anteversion.

EVOLUTION OF THE FEMORAL STEM

By 1974, it had become clear that a stronger stem was needed with more sizes. A new range of stems was introduced at the beginning of 1976, slightly heavier in section than the original polished stems but incorporating the same basic geometry. A minor change was that the anterior and posterior surfaces of the upper fourth of these stems were parallel to each other and not tapered up to the base of the neck, as with the original polished stems.

The new stem range was manufactured from 316L stainless steel for which there was no standard that required a polished surface. Since polishing a stem was expensive, the new stems had a matt-surface which was two orders of magnitude rougher than the original polished stems in surface roughness terms. No significance was attached to this change at that time. From 1983 onwards, all Exeter stems were manufactured from the high nitrogen stainless steel REX 73413 under the proprietary name ‘Orthinox’. This material had a high fatigue strength and low corrosion and is still being used.

MATT Vs POLISHED STEMS

The incidence of stem fracture was virtually abolished with the matt-surfaced stems, but there gradually emerged the paradoxical finding of a significant increase in the incidence of focal femoral lysis and aseptic loosening in comparison with the original polished stems. Of the 180 matt stems inserted at the Princess Elizabeth Hospital in 1980, 10% had been revised for aseptic loosening by 10 years. This revision rate for aseptic stem loosening was almost four times higher than that found with the original polished stems over 20 years.

By 1985, it had become clear that the polished surface should be re-introduced and so the monoblock Orthinox matt-surfaced stems were manufactured with a polished surface. They entered into clinical practice in 1986.

SUBSIDENCE OF THE FEMORAL STEM

With the steadily increasing length of follow-up of the original polished Exeter stems, it eventually became apparent that the phenomenon of subsidence of the polished stems within the cement was of importance functionally and biomechanically. It was therefore necessary to ensure that the new polished stems should not be ‘end-bearing’ in the cement and thus inhibit such subsidence. The old metal centralisers sometimes ‘held up’ the original polished stems and so they were abandoned and replaced by an hollow centraliser, initially manufactured from ultra-high molecular weight polyethylene and later from pre-polymerised PMMA, that ensured that the stem tip would not be end-bearing in the cement.

EXETER UNIVERSAL SERIES

The monoblock polished stems were succeeded in 1988 by the Exeter Universal series that has been in use ever since. The parallel anterior & posterior surfaces of the monoblock 316L & Orthinox stems were changed to restore the taper up to the base of the neck, as with the original EN58J polished stems. The upper end of the stem was also stiffened slightly by adding metal to the shoulder (Figure 1). Modularity was introduced with interchangeable head sizes, the 26mm diameter head becoming the size most commonly used. Rasps were introduced for femoral canal preparation, together with an improved femoral introducer.

Since 1988, the available range of stem sizes and offsets has been gradually extended, though the basic double taper geometry has remained unchanged. To address the problem of loss of femoral diaphyseal bone stock in revision surgery, longer stems were introduced. The spigot at the head-neck junction was changed to the V40 design to allow the use of a ceramic bearing combination in 2001.

EVOLUTION OF THE ACETABULAR CUP

The original cup design was unchanged until 1988, though metal backing was introduced in 1984. The eccentric design of the original cup was subsequently shown to be unsound and changed to a more conventional concentric design in 1988 when the Exeter Universal stems were introduced. Further theoretical analysis suggested that the biomechanical basis for metal-backing was unsound and it also became apparent that the metal back was responsible for increased particulate debris formation and loosening and so the metal back was abandoned in 1990.

EVOLUTION OF THE EXETER CEMENTING TECHNIQUE

The technique of using cement was gradually refined between 1970 and 1980 based on two in vitro studies that had been carried out in Exeter. These showed that by a using a combination of exposure of strong cancellous bone in the femur, thorough pressure washing of the bone surface followed by the subsequent plugging & retrograde filling of the femur with reduced viscosity cement dough and ‘closed cavity’ pressurisation of the femoral canal, a fourfold increase in the shear strength of the cement-bone interface is produced. The clinical application of such methods was flawed initially by failure to appreciate the potentially damaging effects of bleeding at the cement-bone interface.

These effects in conjunction with an extensive laboratory simulation study formed the basis for the femoral cementing technique that has been in use in Exeter since 1984. This concentrates on the retrograde insertion of reduced viscosity cement dough into a thoroughly clean and distally plugged medullary canal, followed by prolonged pressurisation of the cavity using a gun and proximal seal, the delayed insertion of a pre-warmed stem and the subsequent pressurisation of the proximal end of the canal using a seal around the stem that is retained until polymerisation.

INTRODUCTION OF TRIPLE TAPERED STEMS

Wroblewski introduced a new collarless and polished stem with a third taper in an attempt to achieve greater stability and to improve fixation in 1993. The triple-tapered C-stem (DePuy International, Leeds,UK) had evolved from the double-tapered concept.

It has tapers in the anteroposterior and mediolateral planes and a third taper from the wide lateral to the narrow medial planes (Figure 2). It was hypothesized that this would provide more rigid fixation and minimize subsidence to within the limits of cement creep. Moreover, the third taper was designed to improve loading of the proximal femoral neck, therefore maintaining bone quality and avoiding stress shielding.[12] Early results have been promising with reports of apparent improvement in the bone-cement interface in 20% of hips, with the cancellous bone taking on a denser appearance.[13]

BIOMECHANICS OF FEMORAL STEM GEOMETRY

The femoral stem of a cemented THR can be described to consist of a rod inside two tubes, the inner of which is of cement and the outer of bone. In engineering terms, this combination can be considered either as a composite beam or as a loaded taper.[10]

COMPOSITE BEAM

To act as a composite beam, there must be perfect bonding at the stem-to-cement interface and the cement must provide good support. In these conditions the strain in the stem and the cement is identical at the interface at all times and stress in the cement can only be relieved when the interface ruptures. The development of radiolucency is presumed to indicate that this interface is damaged and that the construct is then at risk of failure. Finite-element analysis of the composite beam predicts that the stiffer component will carry the greater share of the load. So, much of the physiological load on the head of the prosthesis is transmitted through the metal stem to its tip and then to the cement and bone below it. These forces will thus bypass the proximal femur and lead to loss of proximal bone stock and resorption of the calcar.[10]

TAPER SLIP

The taper-slip principle depends on shortening or subsidence in order to obtain and maintain a tight fit.[10] This means that the taper should be polished and that the cement should allow some subsidence. The system is then held together by the resultants from axial forces and the greater the load, the tighter is the fit of the taper. When there is subsidence, radial compressive forces are created in the adjacent cement, and transferred to bone as hoop stress.

The fundamental engineering implication of these theories is that a perfectly bonded stem-to-cement interface cannot allow any stress relaxation until this interface has ruptured. In a taper system, stress relaxation can take place when the load is reduced, as during sleep, while the taper maintains the strain.[10]

The good long-term outcomes for the first-generation flat-back Charnley and the polished Exeter stems can be attributed to the taper-slip principle. Both stems have designs and surfaces that allow subsidence. In an anteroposterior view, the tapers of the flat-back Charnley stem and the smallest Exeter stem are nearly identical, although the Exeter is also tapered in the lateral view. The other requirement is that the cement used allows such movement. In the early years of both designs, finger-packing was used which was unable to prevent subsidence, while the more recent Exeter technique provides a hollow centraliser below the tip of the stem.

Cyclical loading during activity must generate compressive and hoop stress in the cement and bone, with periods of stress relaxation during relative unloading, as in sleep. This cycle continues throughout the service life of the stem and may help to account for the satisfactory state of the proximal femoral bone in the Exeter series.[10]

The survival rates for the third-generation dorsal flanged Charnley stems were lower despite the use of modern cementing techniques with lavage, medullary plugging, cement guns and cement pressurisation. Such techniques are essential to meet the requirements for a good composite beam, but the later generations of Charnley stems have a satin finish, which may not bond adequately to cement. This is another requirement for success of the composite beam. Stronger cement is preferred when subsidence is prevented by a dorsal flange, as in the Charnley stem.

In an ideal composite beam, the strain is identical on both sides of the stem-to-cement interface. Since the stress-strain behaviour of metal and cement is very different, the demand on this interface must be excessive. Any mixture of the two systems is likely to cause problems. With the use of 'matt-finish' Exeter stems, excessive metallic debris was generated by the subsidence, necessary in a taper-slip system.

A taper-slip system may appear to be on the verge of failure when assessed by the standards for a composite beam, but once it has subsided it can establish a new stable position. The criteria for radiological failure of a composite beam cannot be applied to a loaded taper-slip system.[10]

CEMENTING TECHNIQUE AND ITS EVOLUTION

The overall technique of cementing total hip replacement has evolved from first-generation to third-generation techniques.[14] The literature supports improved outcomes in cemented total hip replacement with improvements in cementing techniques.[14] Major improvements between these generations have been stratified in terms of bone preparation, cement preparation, and cement delivery (Table 1).

MIGRATION OF THE FEMORAL STEM

The migration of cemented femoral components is a complex combination of rotation and translation in three dimensions. It may take place at the interface between the cement and bone or the cement and implant, or it may be the result of creep in the cement. The site of the migration is important since it influences the mechanism by which failure occurs.[15] Migration at the cement-bone interface may interfere with fixation. The significance of migration at the cement-implant interface depends on whether the implant is designed to subside within the cement mantle or not.

Weber and Charnley in 1975 noted ". . .that the prosthesis will subside and take up a new, lower position in the tapered cavity, where the load will be transmitted evenly over the whole surface of the cement. Once this has been achieved a new situation of stability and symptomless function exists."[16] In this new situation of stability, the implant is able to resist longitudinal and torsional loads. The ability to resist torsional loads is important because these are a potential cause of failure.[17] Despite Weber and Charnley's observations, it generally has been perceived that subsidence is synonymous with loosening.[18]

With satisfactory implants, migration is rapid initially and then slows. In those which are going to fail early, rapid migration continues after the initial phase.[15] It is therefore generally believed that designs of implants which have high mean rates of migration are likely to give unsatisfactory long-term function.

Kobayashi et al[19] have recommended that implants migrating more than 0.4 mm at two years should not be used because they are likely to have a high failure rate. This recommendation was based on studies of implants that have not been designed to migrate within the cement and may not be appropriate for implants such as the Exeter. Subsidence of the stem of more than 2 mm within 2 years after implantation is correlated with a significantly higher probability of implant failure in later years.

It is generally believed that some femoral stems, such as the Charnley Elite do not sink within the cement mantle whereas others, such as the Exeter do. The Charnley Elite was developed from the Charnley. It has a small collar, and in some cases a flange, to help to compress the cement and to prevent the implant migrating within it. The surface has a 'vaquasheen' finish, which is matt. It is possible that these modifications have rendered the implant less able to resist torsional loads. The Exeter has a smooth polished, collarless tapered stem which allows it to subside within the cement.

The Exeter has rapid early distal migration associated with slight collapse into valgus and slow posterior migration of the head. In contrast, the Charnley Elite has rapid early posterior migration of the head with slight distal migration. After the first year, the migration of both implants slows, but the patterns remain similar.[18]

Alfaro-Adrian et al[18] has shown that the pattern or direction of migration changed with time and that this change in pattern is larger than the change in rate. This difference suggests that different mechanisms underlie the migration at different periods.

The rapid early migration is probably caused by resorption of the bone layer which has been injured by surgical trauma and the heat of polymerisation of PMMA cement. This migration occurs at the cement-bone interface and is limited by the extent of bone damage.

The direction of migration during the first postoperative year was a combination of internal rotation and varus tilt, with the largest migration at the head in a medial, distal and posterior direction. The posterior migration is explained by the posterior component of the joint contact force, which is particularly large during stair-climbing, straight-leg raising and rising from a chair. The medial element of migration, when the joint contact force is usually distal or distal and lateral, can be explained by our finding that the tip is the point with the least migration. The implant is therefore most securely fixed near the tip and will tend to rotate about this point. As a result vertical components of the joint contact force will tend to cause the component to tilt into varus and the head to migrate medially.

After the first year when the initial settling is complete, the implants tend to migrate slowly distally. This is the only direction in which they can migrate without substantial bone loss and probably results from a combination of creep in the cement allowing the implant to sink within its mantle and the gradual remodelling of bone and fibrous tissues around the cement. Some authors have stated that Exeter stems continue to migrate during their entire life span because of its collarless, tapered, polished design but at a very, minimal rate.

Radio Stereometric analysis (RSA) can be used to measure the mgration of an implant relative to bone in 3 dimensions with an accuracy of a few tenths of a millimeter. RSA has been used to establish a relationship between early migration and late loosening in THA. Distal migration does not correlate with failure.[20] Instead, posterior head migration probably is the best predictor of loosening. Implants with very high posterior head migration, defined as > 2 SD from the mean, are particularly likely to fail.[18]

Cement used in THA may differ with respect to viscosity. Although the advantage of lower viscosity cements would be better cement penetration and better bone interlock, studies show increased revision rates in some low-viscosity total hip studies. Controversy exists on the relation between viscosity and cement penetration into bone. Peculiarly, all cements pass through various phases of increasing viscosity during polymerization, which will be mainly determined by room temperature.

Most authors have shown that thin cement mantles and defects are associated with increased failure rates. Complete non-uniform cement mantles with a minimum thickness of about 3 mm are associated with good biomechanical and clinical results.[14] Some, however, show that canal-filling stems with thin and often incomplete cement mantles have good long-term results as well.[21] Peak stresses increase once the thickness of the cement is below 1 mm, which will then cause fragmentation of the mantle, leading to failure.

RADIOGRAPHIC ASSESSMENT OF CEMENTED THR

ASSESSMENT OF CEMENTING TECHNIQUE

Barrack, Mulroy and Harris[22] described a system to grade the radiographic appearance of the cementing on the immediate postoperative radiograph in all the 14 zones of Gruen. The four grades are

Grade A is defined as complete filling of the medullary cavity by cement, so-called "white-out" at the cement-bone interface.

Grade B as the presence of slight radiolucency at the interface between the bone and cement.

Grade C as radiolucency involving 50 to 99% of the cement-bone interface, or a defective or incomplete cement mantle of any size, with metal against bone.

Grade D as radiolucency involving 100% of the cement-bone interface in any projection, or a failure to fill the canal with cement such that the distal tip of the prosthesis is not covered.

Postoperative and follow-up radiographs were reviewed for "loosening" and they assessed the relation of the cementing technique to implant loosening.

'Definite' loosening was defined as migration, or a change in position of the stem or the cement. This included fracture or bending of the stem, fracture of the cement, the appearance of a radiolucent line at the cement-stem interface not present on the immediate postoperative radiograph, and a shift in the position of the cement mantle relative to the femur.

Radiographs that showed a continuous (100%) radiolucent line at the cement-bone interface without evidence of migration were graded as
'probably' loose.

If a radiolucent zone was present that was not complete, but involved between 50% and 99% of the interface, the component was classified as 'possibly' loose.

They had no hips with Grade C or Grade D cementing. The reduced loosening rates in their study were attributed to the introduction of improved cementing techniques and better stem designs.

ANALYSIS OF THE CEMENT MANTLE IN THR

Ebramzadeh[23] et al have done an analysis of the long-term radiographic results of the cement mantle in total hip arthroplasty. They assessed various factors in the immediate & follow-up postoperative radiographs. The thickness of the proximal medial part of the cement mantle was measured on the AP post-operative radiographs as the distance from the endosteal edge of the proximal femoral cut to the medial border of the prosthesis. The hips were categorized into four groups, according to the width of the cement mantle:

Less than two millimeters thick, two to five millimeters thick, five to ten millimeters thick, and more than ten millimeters thick.

Total hip replacements with a proximal medial cement mantle thicker than ten millimetres were at a greater risk for progressive loosening of the femoral component, fracture of the cement, and radiolucent lines about the femoral stem-cement or bone-cement interface than those with a cement mantle that was two to five millimeters or five to ten millimetres thick. Similarly, total hip replacements with a cement mantle that was five to ten millimeters thick were at a greater risk for radiolucent lines at the femoral bone-cement interface than those that had a two to five millimeter-thick mantle.

But, total hip replacements with a cement mantle that was five to ten millimeters thick were at a lower risk for cortical hypertrophy than those with a cement mantle that was less than two millimeters thick or that was two to five millimeters thick.

The filling of the distal part of the canal by the femoral stem was recorded as the ratio of the width of the stem to the width of the canal, measured seven centimeters distal to the collar of the stem. The hips were divided into two groups on the basis of the canal fill ratio:
more than 50 percent and 50 percent or less.

Stems that filled more than half of the canal were at a significantly lower risk for progressive loosening, fracture of the cement, and the development of radiolucent lines at the stem-cement interface and bone-cement interface. However, the femoral components that filled more than half of the canal were at a significantly higher risk for calcar resorption and cortical hypertrophy.

The orientation of the stem was recorded as the angle between the axis of the distal portion of the stem and the axis of the femoral shaft. The hips were divided into five groups according to the orientation of the stem:

neutral (a stem-shaft angle between 0 and 3 degrees), slight valgus or varus angulation (a stem-shaft angle of 3 to 5 degrees), and valgus or varus angulation (a stem-shaft angle of more than 5 degrees).

Stems that were oriented in neutral, in slight varus (5 degrees or less), or in slight valgus had similar radiographic behaviour. Stems that had been implanted in more than 5 degrees of varus were at a significantly higher risk for progressive loosening, fracture of the cement, and the development of radiolucent lines at the stem-cement and bone-cement interfaces than those implanted in neutral or valgus (more than 5 degrees). Varus stems performed poorly independently of the thickness of the cement mantle, possibly because of the increased loading of the cement or of the bone in the critical proximal medial and distal lateral regions.

Brian Jewett[24] has stated that stem geometry has less effect on the success of cemented THA than does stem surface finish. They compared four polished cemented stem designs and found no substantial difference between them. The surface finish of cemented femoral stems has undergone intense scrutiny over the past two decades.

Ong et al suggested four types of roughened stem failures:

bone-cement loosening, stem-cement debonding, progressive focal osteolysis, and stem fracture. All patients with rough stem failures in his study had extensive femoral bone damage. Polished stem failures showed minimal bone damage compared with rough stem failures. Also, patients with polished stem failures seemed to function well for a long period of time with their loose stems.

ECTOPIC BONE FORMATION

Ectopic bone formation following Total Hip Replacement is a recognized complication. Charnley stated that a notable degree of ectopic ossification is seen in 5 per cent of hips not previously operated on.[25] Harris noted myositis ossificans in 14 per cent of his patients but stated that only 3 per cent had significant interference with motion.[25]

Brooker[25] devised a classification system for ectopic ossification following THR based on his study at the Johns Hopkins Hospital on supine AP roentgenograms of the hip taken with a fixed tube-to-plate distance of 101.6 centimeters.

Class I: Islands of bone within the soft tissues about the hip.

Class II: Bone spurs from the pelvis or proximal end of the femur, leaving at least one centimeter between opposing bone surfaces.

Class III: Bone spurs from the pelvis or proximal end of the femur, reducing the space between opposing bone surfaces to less than one centimetre.

Class IV: Apparent bony ankylosis of the hip.

He stated that patients with previous procedures have a much higher incidence of ectopic ossification and that though patients have ectopic ossification after THR, they do not necessarily have poor functional results.

FAILURE OF POLISHED CEMENTED STEMS

Gruen at al[26] performed a retrospective sequential radiographic evaluation of total hip replacements to identify real and potential modes of failure as an aid to classifying the loosening of cemented femoral components. Looseness is defined as a radiographic interpretation of change in the mechanical integrity of the load carrying cemented femoral component, specifically, fractured acrylic cement and an interface gap such as a radiolucent zone at the stem-cement or at the cement-bone interface.

The proximal femur was delineated into 7 zones for the detailed review of the anteroposterior radiographs of the cemented femoral component**.** The radiographs were then evaluated chronologically to assess loosening as manifested by progressive changes in the width or length of radiolucent zones, appearance of sclerotic bone reaction, widening of the acrylic cement fracture gap, additional fragmentation of the cement, gross movement of the femoral component, and stem fracture.

The loosening was described by one of 4 modes of failure. It must be emphasized that the term failure signifies a deviation from the stable femoral component where there is adequate fixation at each interface (i.e., no radiolucent zones) and intact material integrity. It does not necessarily represent clinical failure where the hip becomes symptomatic due to pain, and possibly restricted function, muscle power and range of motion. The four modes of failure are

Mode I - Pistoning behaviour

I A - Stem within cement

I B - Stem within bone

Mode II - Medial midstem pivot

Mode III - Calcar pivot

Mode IV - Bending cantilever fatigue

The radiolucent zone at the cement-bone interface was the predominant evidence of radiographically defined looseness in this study. The immediate postoperative evidence of radiolucent zones at the cement-bone interface is indicative of inadequate penetration of cement into cancellous bone, as with relatively late insertion of the cement or inadequate removal of residual fibrous membrane.

Gruen also indicated a 14.4% incidence of progressive loosening from considerations of initial cement fixation and the subsequent radiological evidence of loosening. The higher number of acrylic fractures on the lateral (tensile) side compared to the medial (compressive) side is attributed to the relatively weak tensile and brittle characteristics of acrylic cement.

Mode I B is the most common mode of loosening where the acrylic encapsulated stem migrates distally within the intramedullary canal. Mode IV is a serious phenomenon, since its proximal loosening of the femoral component with rigid distal fixation usually precedes fractures of the stem.

MATERIALS AND METHODS

This study is a retrospective analysis of all polished double-tapered Exeter Universal (Stryker Howmedica Osteonics) and triple-tapered C-stem (DePuy International) femoral stem cemented total hip arthroplasties done in the Department of Orthopaedics, Christian Medical College, Vellore between November 2000 and February 2007.

All patients who had primary or revision cemented total hip replacement with the above femoral stems were included in the study.

EXCLUSION CRITERIA

1. Patients who had revision long-stemmed prostheses.
2. Patients who had hybrid total hip replacement with the above femoral stems.
3. Patients who had metal-on-metal arthroplasty with the above stems.

PATIENT DEMOGRAPHICS

EXETER GROUP

The Exeter group had 83 patients. 19 patients had bilateral hip replacements, making a total of 102 hips. The mean age of this group was 42.3 years (range, 17 to 66 years), and there were 55 men (66.3%) and 28 (33.7%) women. 55 hips (53.9%) were right-sided and 47 hips (46.1%) were left sided. The patient demographics of both groups are shown in Table 2.

Avascular necrosis of the femoral head with secondary arthritis of the hip joint was the most common indication for surgery (19.3%) in this group.

C-STEM GROUP

The C-stem group had 117 patients. 36 patients had bilateral hip replacements, making a total of 153 hips. The mean age of this group was 46.3 years (range, 18 to 72 years), and there were 58 men (49.6%) and 59 (50.4%) women. There were 70 hips on the right side (45.8%) and 83 hips on the left side (54.2%).

Chronic arthritis of the hip joint secondary to ankylosing spondylitis was the most common indication for surgery (19.7%) in this group. The indications for total hip replacement in both groups are shown in Table 3.

OPERATIVE PROCEDURE

All patients had been admitted preoperatively and evaluated with proper documentation of the history and clinical findings including the range of motion in the admission records. All the Exeter total hip arthroplasties were performed by a single arthroplasty surgeon except for one patient. They were all done in lateral position using the 'Omega approach' of Learmonth. The C-stem total hip arthroplasties were performed by four arthroplasty surgeons who have vast experience in joint replacement. They were done in either supine or lateral position.

The approaches used were

1. Posterior Moore approach in lateral position
2. Lateral Omega approach of Learmonth in lateral position
3. Modified Hardinge Lateral approach in supine/lateral position
4. Lateral approach with trochanteric osteotomy in lateral position

All patients were administered pre-operative intravenous antibiotics. All patients had cementation with second-generation cementing technique. Wounds were closed with suction drains. An abduction pillow was placed between the legs in the operating room before transfer. Beginning on the night of surgery, all patients received mechanical prophylaxis for thromboembolism in the form of ankle-pump exercises, calf muscle squeezing and sequential compression device. All patients followed a physical therapy regimen beginning on the first postoperative day, while in bed including isometric knee extension and hip abduction exercises. Drains were removed two days after surgery and radiographs taken. Intravenous antibiotics were continued at least till drain removal and then changed to oral antibiotics depending on the surgeon's preference. Full weight-bearing ambulation with bilateral axillary crutches was started after x-rays. Patients with bilateral total hip replacements were initially ambulated full weight-bearing with a walker and gradually progressed to crutch walking.

ASSESSMENT OF FUNCTIONAL OUTCOME

The functional outcome of patients in both groups was assessed using the Harris Hip Score (HHS). The domains included in the Harris Hip Score are

- Pain – 44 points
- Function – 47 points
    - Gait – 33 points
    - Activities of daily living (ADL) – 14 points
- Absence of deformity – 4 points
- Range of motion – 5 points

A score of 90-100 is considered as excellent, 80-89 good, 70-79 fair and below 70 poor.

10 patients with 11 hips in the Exeter group and 13 patients with 20 hips in the C-stem group who came for follow-up between August 2007 and November 2007 were examined and the Harris Hip Score Proforma was filled with the pre-operative details made out from the hospital records.

The mean age of patients in the Exeter group was 45.40 years with a range from 19-66 years. The mean follow-up duration was 19.7 months (range, 7-49 months).

The mean age of patients in the C-stem group was 45.69 years with a range from 19-65 years. The mean follow-up duration was 20.4 months (range, 5-52 months) (Tables 4 and 5).

The pre-operative and post-operative Harris Hip Scores were analysed and compared between the two groups. The pre and post-operative pain and function scores were also individually analysed. The clinical photographs of patients of both groups are shown in Figures 3 and 4.

RADIOGRAPHIC ASSESSMENT

All patients in both groups have had anteroposterior and lateral radiographs taken on the third postoperative day after drain removal. They also had radiographs taken at all follow-up visits. The anteroposterior (AP) view of the pelvis was taken with the patient lying down supine with both feet internally rotated to 15 degrees, so that the great toes touch each other and with the X-ray tube at a distance of 100 centimeters from the bucky. The X-ray tube was centered to show the entire prosthetic joint including the radio-opaque tip of the cement restrictor. The radiographs were retrieved for study from PACS using the GE Centricity software, Version 2.1. The availability of the radiographs for the study was 100%.

ASSESSMENT OF INITIAL POSTOPERATIVE RADIOGRAPHS

The initial postoperative anteroposterior radiographs were assessed for the cementing technique and the orientation of the femoral stem. A total of 102 Exeter hips in 83 patients and 153 C-stem hips in 117 patients had the initial assessment, making a total of 255 hips.

CEMENTING TECHNIQUE

The cementing technique as described by Barrack et al was assessed in the 7 Gruen zones and graded.

The cementing technique was analysed and compared between the two groups and its effect on the appearance of radiographic loosening as manifested by radiolucencies in the follow-up radiographs was analysed.

ORIENTATION OF THE FEMORAL STEM

The orientation of the femoral stem was recorded as the angle between the axis of the distal portion of the stem and the axis of the femoral shaft in the anteroposterior radiograph. The hips were divided into three groups according to the orientation of the stem:

neutral (a stem-shaft angle between 0 and 5 degrees), valgus angulation (a stem-shaft angle of more than 5 degrees valgus), and varus angulation (a stem-shaft angle of more than 5 degrees varus). The femoral stem orientation was also compared between the two groups.

ASSESSMENT OF FOLLOW-UP RADIOGRAPHS

The follow-up radiographs were assessed for proximal medial femoral resorption, ectopic ossification, distal cortical hypertrophy around the stem, endosteal cavitation around the stem, fractures of the cement mantle, subsidence of the femoral stem and the appearance of radiolucencies. The parameters were statistically analysed and compared.

58 of 102 Exeter hips (56.9%) and 98 of 153 C-stem hips (64%) had at least one follow-up radiograph.

PROXIMAL FEMORAL RESORPTION

Proximal femoral resorption or stress shielding was defined in the follow-up anteroposterior radiographs using the criteria described by Engh et al.[20,27]

First degree - slight rounding of the proximal-medial edge of the cut femoral neck

Second degree - rounding of the proximal-medial aspect combined with loss of the medial cortical density to the level of the lesser trochanter

Third degree - extensive resorption of cortical bone with involvement of the anterior cortex at the level of the lesser trochanter and the medial cortex below the lesser trochanter

Fourth degree - resorption extends into the diaphysis

ECTOPIC BONE FORMATION

Ectopic bone formation around the hip was assessed in the follow-up anteroposterior radiographs using the classification system devised by Brooker et al, which has been previously described.

SUBSIDENCE OF THE FEMORAL STEM

Subsidence of the femoral stem within the cement mantle can be measured by various methods as described by Sutherland et al, Ianotti et al and Malchau et al[28] by measuring the distance between two landmarks in successive radiographs. In the Sutherland method, the bone landmark was the tip of the greater trochanter and the prosthetic landmark was the femoral head center.[29] Ianotti used the most inferior part of the lesser trochanter and the prosthetic stem shoulder as the bone and prosthetic landmarks.[29] In the Malchau method, the landmarks were the medial tip of the lesser trochanter and the femoral head center.[28] Malpositioning during successive radiographs can cause errors in measurement with these methods.

The subsidence of the femoral stem in our study was calculated by comparing the change in distance between the distal tip of the stem and the inferior pole of the cement restrictor in successive, comparable anteroposterior radiographs. All radiographs were digitalized and adjustment for magnification was calculated on the basis of the known diameter of the prosthetic head (28 mm). This was done by a computer-assisted method using the GE Centricity software. Patients who had incomparable radiographs were excluded from the subsidence study. Patients who had radiographs not showing the inferior pole of the cement restrictor were also excluded. Patients were divided into groups with radiographs at 4,6,9,12,15 and 24 months respectively, with a margin of +/-10 days.

Of the 58 Exeter hips which had at least one follow-up radiograph, measurement of subsidence was possible only in 40 hips. 13 Exeter hips were excluded because their radiographs did not show the cement restrictor in one or all postoperative radiographs. 5 hips were excluded because they had incomparable radiographs.

Subsidence could be measured only in 64 of the 98 C-stem hips which had at least one follow-up radiograph, excluding 34 hips. 22 hips were excluded because their radiographs did not show the cement restrictor in one or all postoperative radiographs. 12 C-stem hips were excluded because they had incomparable radiographs.

The subsidence of the femoral stem was analysed and compared between the two groups at identical follow-up periods.

RADIOLUCENCIES

The presence of radiolucent lines in the cement-bone or the cement-stem interface was assessed in all the seven Gruen zones in the anteroposterior radiographs, as was the presence of any femoral endosteolysis, distal cortical hypertrophy or cement mantle fractures. Radiolucency was defined as the presence of a radiolucent line adjacent to a sclerotic line.[26] The presence of radiolucencies was compared and analysed between the two groups.

Statistical analysis of all data was done using the SPSS 11.0 for Windows software.

RESULTS

RADIOGRAPHIC FOLLOW-UP

EXETER GROUP

The mean duration during the last radiographic follow-up was 16.65 months with a range of 3-60 months. 58 of 102 Exeter hips had at least one follow-up radiograph. 15 hips had radiographs with more than 2 years follow-up. The longest radiographic follow-up was 5 years.

C-STEM GROUP

The mean duration during the last radiographic follow-up was 16.81 months with a range of 2-84 months. 98 of 153 C-stem hips had at least one follow-up radiograph. 24 hips had radiographs with more than 2 years follow-up. The longest radiographic follow-up in this group was 7 years.

COMPLICATIONS

EXETER GROUP

There were no perioperative deaths in the Exeter group. 1 patient who underwent bilateral total hip replacement developed deep vein thrombosis with Pulmonary Embolism on the second post-operative day and had to be shifted to the Surgical

Intensive Care Unit (SICU). She was anticoagulated and ventilated in the SICU and subsequently she also had a tracheostomy. She recovered completely after 30 days and was discharged home with no further complications. There were 3 dislocations. One was managed with closed reduction and derotation boot for 6 weeks. The other two had excessive acetabular cup anteversion and the cup had to be revised at ten days. There was 1 posterolateral subluxation which was managed with a derotation boot for 6 weeks. There were no cases of recurrent dislocations.

There were 3 cases of superficial wound infection that were managed with appropriate antibiotics without further complications. Two patients encountered deep infections and management comprised intravenous antibiotics and multiple intraarticular washouts and debridement with antibiotic-cement beads implantation. Fortunately, no patient required removal of the prosthesis caused by persistent infection till date. There were 2 cases of common peroneal nerve palsy and 1 case of sciatic nerve palsy and all three had fully recovered at the time of their first follow-up. 3 patients had intraoperative trochanteric fractures. Two required no intervention and one required cerclage wiring and all three had healed at the time of their first follow-up.

2 cases had cortical breach during reaming and subsequent cement extrusion from the medullary canal. One of the two patients with cortical breach presented with a periprosthetic fracture five months after surgery. She had a Vancouver B1 periprosthetic fracture and was treated with open reduction and internal fixation with a 10-holed Broad DCP. She went on to heal uneventfully and was successfully ambulated after 3 months

(Figure 5).

C-STEM GROUP

One patient died in the immediate post-operative period, the cause of which was not identified. 1 patient had cerebro vascular accident in the immediate postoperative period, probably due to peri-operative hypotension and ischaemia. There were no cases of Pulmonary Embolism in the C-stem group. There were 2 dislocations. One was managed with closed reduction and pantaloon cast for 6 weeks. The other required open reduction and was put on a derotation boot for 6 weeks postoperatively. There were no cases of recurrent dislocations.

There were 4 cases of superficial wound infection that were managed with appropriate antibiotics without further complications. Five patients encountered deep infections and management comprised intravenous antibiotics and multiple intraarticular washouts and debridement with antibiotic-cement beads implantation. One patient has been advised implant removal and revision surgery due to persistent infection. There was 1 case of femoral nerve palsy which had completely recovered at first follow-up. Six patients had intraoperative trochanteric fractures. Two required no intervention and four required cerclage wiring and three had healed at the time of their first follow-up. The other three were lost to follow-up.

5 hips had cortical breach during reaming and subsequent cement extrusion from the medullary canal. One of the five had a minimally displaced Vancouver B1

periprosthetic fracture detected in the immediate postoperative radiograph and was kept in bed rest for 3 months, during which the fracture healed uneventfully. Another patient with cortical breach had a periprosthetic fracture as a result of a fall, five months after surgery. He had a Vancouver B1 periprosthetic fracture and had been put on traction with Thomas splint elsewhere and came here three months after the fall. The fracture had malunited by then and the patient had no problems (Figure 6).

One patient had a periprosthetic fracture as a result of fall, while climbing stairs 14 months after surgery. She had a Vancouver B2 periprosthetic fracture and underwent revision to a long-stemmed prosthesis supplemented by internal fixation with a Dynamic Compression Plate (DCP) and stainless steel wires. She was kept in bed rest and was gradually ambulated after 4 months, when the fracture showed signs of healing. One patient who underwent bilateral total hip replacement had gross femoral component malpositioning with partial extramedullary placement of both stems, detected in the immediate postoperative radiograph. She underwent bilateral revision three days later. The complications in both groups are shown in Table 6.

ANALYSIS OF FUNCTIONAL OUTCOME BY HARRIS HIP SCORE

10 patients with 11 hips in the Exeter group and 13 patients with 20 hips in the C-stem group were analysed for functional outcome. Preoperatively, the average Harris Hip score in the Exeter and C-stem groups was 40.6 (range, 34 to 46) and 38.3 (range, 28 to 43), respectively. At the time of follow-up, the average Harris Hip score in the

Exeter group was 88.2, an improvement of 47.6 points. This improvement was comparable with the C-stem group, which had an increase of 47.9 points, with an average score of 86.2 (Table 7).

The mean Harris Hip Score in both groups improved from 39.1 preoperatively to 86.9 postoperatively, with an average improvement of 47.8 points.

In the Exeter group, 6 had excellent and 5 had a good outcome. 5 hips had excellent, 13 had good and 2 had fair outcome in the C-stem group.

The clinical results were further subanalysed to assess the degree of improvement of pain and function separately (Table 8). Statistical analysis by the Levene's test and t-test showed no significant difference between the two groups with respect to improvement of pain, function or total Harris Hip Scores with a p value of > 0.05 (Table 9).

RADIOLOGICAL RESULTS

CEMENTING TECHNIQUE

Of the 102 hips in the Exeter group, the cement mantle was graded as A in 76.5%, B in 12.7% and C in 10.8%. There were no hips of grade D in this group. The cement mantle was graded as A in 62.1%, B in 30.1%, C in 6.5% and D in 1.3% of the 153 C-stem hips (Table 10).

Statistical analysis by the Chi-square test showed a significant difference between the two groups with respect to cementing technique with a p value of 0.006 (Table 11).

ORIENTATION OF THE FEMORAL STEM

Alignment was satisfactory in 101 Exeter hips (99%), with only 1 hip showing greater than 5 degrees of valgus angulation. No Exeter hip was oriented in more than 5 degrees of varus. Alignment was deemed satisfactory in 145 of the 153 C-stem hips (94.8%), with 7 hips (4.6%) showing greater than 5 degrees of varus angulation. One hip (0.7%) was oriented in more than 5 degrees valgus (Table 12).

Chi-square test showed no significant difference between the two groups with respect to femoral stem orientation with a p value of 0.088 (Table 13).

PROXIMAL FEMORAL RESORPTION

First-degree resorption of the proximal femur was noted in 7of the 58 Exeter hips (12.1%) with second-degree resorption in 5 hips (8.6%). None of the hips in the Exeter group showed third-degree or fourth-degree resorption.

First-degree resorption of the proximal femur was seen in 5 of the 98 C-stem hips (5.1%) with second-degree resorption in 2 hips (2%). None of the C-stem hips showed third-degree or fourth-degree resorption (Table 14).

Chi-square test showed that the C-stem group had a better proximal femoral bone stock with a p value of 0.037 which was statistically significant (Table 15).

ECTOPIC BONE FORMATION

Of the 58 Exeter hips, 5 hips showed grade 1 ectopic ossification, 4 showed grade 2, and 2 hips showed grade 3 ectopic ossification. No Exeter hip had bony ankylosis.

Ectopic ossification was graded as grade 1 in 6 of the 98 C-stem hips, grade 2 in 6 hips, and grade 3 in 2 hips. None of the C-stem hips had grade 4 ectopic ossification (Table 16).

There was no statistically significant difference between the two groups with a p value of 0.865 (Table 17).

CEMENT MANTLE FRACTURES

1 Exeter hip and 2 C-stem hips showed cement mantle fractures. There was no significant difference between the two groups with respect to cement mantle fractures with a p value of 0.689 (Tables 18 and 19).

DISTAL CORTICAL HYPERTROPHY

5 of 98 C-stem hips (5.1%) and 1 of 58 Exeter hips (1.7%) showed distal cortical hypertrophy in the follow-up radiographs. Hips which had pre-existing distal cortical

hypertrophy due to various reasons were excluded from the study (Table 20).

Chi-square analysis of data showed no significant difference between the two groups with a p value of 0.275 (Table 21).

ENDOSTEAL CAVITATION OR LYSIS

Localised endosteal femoral lysis is defined by Sporer et al[30] as any non-linear radiolucency of more than five millimeters in width at the cement-bone interface. None of the hips in either group showed femoral endosteal lysis.

RADIOLUCENCIES

55 of the 58 Exeter hips (94.8%) showed no radiolucent lines in the follow-up radiographs. One hip showed radiolucency in zone 1, one in zones 1 and 7, and one hip in zones 1-7. All three hips had radiolucencies at the cement-bone interface. No hip was considered at risk of aseptic loosening in this group. The hip which showed radiolucencies in all zones was a case of septic loosening and was advised staged revision.

There were no radiolucent lines in the follow-up radiographs of 91 C-stem hips (92.9%). Four hips showed radiolucency in zone 1, two in zones 1 and 7, and one hip in zones 1-7. Five of the seven hips had radiolucencies at the cement-bone interface and two hips had lucencies in zones 1 and 7 at the implant-cement interface. These two hips were considered at risk of aseptic loosening in this group. The C-stem hip which showed radiolucencies in all zones was due to infection and was advised staged revision.

Chi-square test showed p value for the above data as 0.848, which suggested that there was no significant difference between the two groups (Tables 22 and 23).

SUBSIDENCE OF THE FEMORAL STEM

The mean subsidence of the femoral stem in the Exeter group at 1 year was 1.28 mm and the mean subsidence in the C-stem group was 0.82 mm at 1 year. At 2 years, the mean subsidence of the two groups was 1.44 and 1.17 mm respectively. Only one C-stem hip, considered to be at risk of aseptic loosening had a subsidence of 3.93 mm at 3 years. All other hips had a subsidence of less than 2 mm at all periods.

The subsidence of the femoral stem in both groups at various periods of time is shown in Tables 24, 25 and 26.

DISCUSSION

Cemented total hip replacement is one of the safest and most successful operations in orthopaedic surgery, providing excellent results in restoration of hip function and patient satisfaction. This is evidenced by the ongoing success of the Exeter Universal femoral stem since its introduction in the 1970s. Recent long-term follow-up studies of the Exeter Universal stem have shown excellent clinical performance of the prosthesis, with low rates of mechanical failure and complications such as excessive subsidence, endosteolysis and radiolucencies.[31,32,33] The success of the double-tapered design led to the development of the triple-tapered design (C-stem). We, in this study have used well-recognized assessment techniques to standardize the clinical and radiological evaluation to allow easier analysis and comparison between the two prostheses.

COMPLICATIONS

Olwen Williams[34] in his study of 1100 total hip replacements showed that the risk of dislocation was estimated to be 2.7%, of which about one-third required an open reduction. Other complications in his study were perioperative fracture (1.0%), sciatic nerve palsy (0.1%), cerebrovascular accident (0.3%), pulmonary embolism (0.8%) and deep infection (1%). Jonas Franklin[35] reported nerve injury rate of 1.1% and a dislocation rate of 5% with Exeter hips and he has stated that the infection rate in most series of total hip arthroplasty is 1-3%. The complication rate in our study is comparable to most other studies with dislocation seen in 1.9%, deep infection in 2.74% and nerve palsy in 1.56% of patients.

CLINICAL RESULTS

The clinical results of both groups in our study are in the accepted range for successful outcome after total hip replacement. Comparison with the Harris hip scores in several published series using contemporary cementing techniques and also with uncemented prostheses is favourable. The mean Harris Hip Score in both groups in our study improved from 39.1 preoperatively to 86.9 postoperatively, with an improvement of 47.8 points. K.H. Chiu[36] showed that the average preoperative Harris Hip Score in his study of Exeter arthroplasty in small femurs was 39.8 and that at the last follow-up visit was 82.3.

Justin Sherfey[37] showed that the Harris Hip Scores improved from an average of 40 preoperatively to 84 at the last follow-up in his study of Exeter hips, which is comparable with our study.

Preoperatively, the average Harris Hip score in the Exeter and C-stem groups in our study was 40.6 (range, 34 to 46) and 38.3 (range, 28 to 43), respectively. At the time of follow-up, the average Harris Hip score in the Exeter group was 88.2, an improvement of 47.6 points. This improvement was comparable with the C-stem group, which had an increase of 47.9 points, with an average score of 86.2. There was no significant difference between the two groups.

The results are comparable to the study by Eugene Ek,[12] who showed that the average preoperative Harris Hip score in the Exeter and C-Stem groups was 40 and 43 respectively. The postoperative Harris Hip score in the two groups was 85 and 88 respectively, with an improvement of 45 points in both groups.

RADIOLOGIC RESULTS

CEMENTING TECHNIQUE

Of the 102 hips in the Exeter group, the cement mantle was graded as A in 76.5%, B in 12.7% and C in 10.8%. There were no hips of grade D in this group (Figures 7,8 and 9). The cement mantle was graded as A in 62.1%, B in 30.1%, C in 6.5% and D in 1.3% of the 153 C-stem hips (Figure 10).

Eugene Ek[12] in his comparative study of Exeter and C-stem showed that the cement mantle was graded as A in 36.5%, B in 56.6%, and C in 6.9% of his Exeter hips. The cement mantle was graded as A in 45.7%, B in 46.3%, and C in 8.0% of the C-stem hips.

Hook[31] in his study of 142 Exeter hips has showed that Barrack grade A was seen in 63 hips (72%), grade B in none, grade C in 21 hips (24%) and grade D in four hips (4%).

Our study showed a much better cementing technique, with 67.8% of hips graded as Barrack A. There was also a statistically significant difference in the cementing technique, with the Exeter group showing more grade A hips than the C-stem group. This may be due to the fact that the surgeon who uses the Exeter implant tends to oversize the femoral stem in most cases, leading to better cement penetration of cancellous bone and “white out”. But oversizing of stems can also lead to incomplete cement mantles as shown by the higher number of Grade C hips in the Exeter group compared to the C-stem group.

The number of grade C hips in our Exeter group is still very much lower than most other studies which shows that adequate mantles can routinely be achieved even with larger stems as long as care is taken to remove enough cancellous bone and to align the stem properly.

Chiu et al[36,38] from their experience with the Exeter stem in Chinese patients with small femora, showed that there was early loosening in a population in which oversizing of the stem was common, with a resultant incomplete cement mantle and high rates of failure. These incomplete mantles can be avoided by downsizing the implant from the last broach used as long as there are adequate smaller sizes available to allow this. Scheerlinck et al[39] confirmed that cement mantles were less likely to be deficient when the stems were downsized from the broach, although they felt that support for the larger stems was good because of excellent penetration of the cancellous bone and the more secure support afforded by the cortical bone.

Downsizing actually reduces subsidence of the stem with polished tapers. This can probably explain the lower subsidence of the stem in the C-stem group compared to the Exeter group, where we routinely oversize femoral stems. Also, the slightly higher subsidence in the Exeter group is still very much within the permissible limits and gives very good clinical and radiological results.

FEMORAL STEM ORIENTATION

Russotti et al[40] noted that varus or valgus positioning of the femoral stem and less than two centimetres of cement extending past the tip of the femoral stem were significantly associated with new or progressive radiolucent lines about the femoral stem, which shows the significance of alignment.

Alignment was satisfactory in 101 Exeter hips (99%), with only 1 hip showing greater than 5 degrees of valgus angulation. Alignment was deemed satisfactory in 145 of the 153 C-stem hips (94.8%), with 8 hips showing malalignment (Figure 11). Eugene Ek,[12] in his series showed that alignment was satisfactory in 94.1% of Exeter hips and 93.8% of C-stem hips. Though there was not any statistically significant difference in femoral stem orientation between the two groups, the much satisfactory alignment in the Exeter group can be attributed to the use of larger stems.

PROXIMAL FEMORAL RESORPTION

91.4% of Exeter hips and 98% of C-stem hips had no changes or first-degree changes, which according to Engh et al,[27] are equivalent to little or no stress shielding. Our study showed that the C-stem group had a better proximal femoral bone stock, which was statistically significant with a p value of 0.037. This is comparable with most studies which have showed that the triple-taper design leads to greater compressive loading of the proximal medial femur and better bone stock. Figure 12 and 13 show second degree proximal femoral resorption in both groups.

Wroblewski et al[13] from their first 7 years of experience with the C-Stem, reported on progressive improvement in proximal bone quality in 20% of their sample, with cancellous bone taking on a denser appearance.

However, this improvement in the femoral calcar is unlikely to be expected in all patients. The design of the C-Stem requires it to be loaded to a certain level for it to transfer enough force to the cement-bone interface. This is possible in active patients with good bone quality and good function. Therefore, this may be a problem in patients with increased age, infirmity, disability, and declining function. The shorter follow-up of our study may explain the reason for not seeing any improvement of femoral calcar in our study.

ECTOPIC BONE FORMATION

11 of the 156 hips (7.1%) in both groups showed class I ectopic ossification. 10 hips (6.4%) and 4 hips (2.6%) showed class II and class III ectopic ossification respectively at a mean follow-up of 17 months (Figure 14-19). Our results are much better than Brooker's original series[25] of 100 total hip replacements, where he graded ectopic ossification as class I in 7%, class II in 5%, class III in 7% and class IV in 2% at 6 months.

CEMENT MANTLE FRACTURES

1 Exeter hip and 2 C-stem hips had cement mantle fractures, when they had periprosthetic fractures. There were no isolated cement mantle fractures in the follow-up radiographs of both groups. Williams et al[33] in his study of 325 Exeter hips showed cement mantle fracture in 1 hip and Eugene Ek[12] showed cement mantle fracture in 1 of his 200 C-stem hips.

DISTAL CORTICAL HYPERTROPHY

5 of 98 C-stem hips (5.1%) and 1 of 58 Exeter hips (1.7%) showed distal cortical hypertrophy in the follow-up radiographs (Figure 20 and 21), making a total of 6 of 156 hips (3.8%). This is comparable with other studies. Williams et al[33] showed that diaphyseal hypertrophy was present in 5% of his patients with Exeter Universal stems. This compares with 30% diaphyseal hypertrophy in the original Exeter polished stems at follow-up of five to ten years. The reduction in diaphyseal hypertrophy in the Universal series was due to better cement filling of the proximal third of the femur than in the original series. This also confirms that both the prostheses designs are not “end-bearing” and have optimal load sharing properties.

RADIOLUCENCIES

2 hips in the Exeter group and 6 hips in the C-stem group (excluding one case of septic loosening in each group) showed radiolucent lines, mainly in zones 1 and 7

(Figure 22-26). Hook[31] in his review of 88 Exeter stems followed for ten years, noted radiolucent lines in one or more zones at the cement-bone interface in nine hips (10.2%). Williams et al[33] showed radiolucent lines in 18 of his 200 Exeter hips (9%), which is also significantly higher than our study (5.1%). The much better outcome in our study may be due to the shorter follow-up.

Eugene Ek[12] showed no significant difference between Exeter and C-stem groups, which is similar to our study.

The generally accepted definitions of ‘definite loosening’, ‘probable loosening’ and ‘possible loosening’ cannot be reasonably applied to the polished Exeter & C-stem stems. According to these definitions, any visible migration of the component is defined as ‘definite loosening’. This would mean that every hip in this series was ‘definitely loose’, a clearly untenable suggestion. Only two C-stem hips (1.28%) in the entire series, which showed gross change in position of the stem were considered to be at risk of aseptic loosening. These two hips were revision hips, which had been revised due to partial extramedullary placement of the femoral stem.

SUBSIDENCE OF THE FEMORAL STEM

Early subsidence rates have been used to predict stem failure. However, in such studies, stem migration is measured as the overall movement of the stem in relation to bone. Therefore, a distinction must be made between early subsidence within the cement mantle, which is advantageous in a tapered prosthesis, and movement between the cement and bone, which is associated with implant failure.

Radiostereometric analysis (RSA) is the gold standard for measuring implant migration. This technique involves the implantation of tantalum marker beads into the bone around the prosthesis. Migration is measured using 2 radiographs of the hip taken simultaneously at different angles, with the subject placed in front of a specialized calibration cage. The relative positions of the implant, bone, and cage markers are analyzed using sophisticated software to give a 3-dimensional migration measurement. Although RSA is accurate and precise, it requires specialized equipment, is time consuming, and can be used only prospectively in subjects with marker beads.[29]

Several simple methods have been described for measuring migration directly from plain radiographs without specialized equipment. These measurements can be applied retrospectively but give a 2-dimensional representation of migration and can be subject to large errors. Inaccuracy and poor precision of direct plain radiographic measurements may arise because of preanalytical or analytical errors. Preanalytical errors include variations in patient positioning and rotation, film centering, and focus-to-film distance between radiographs, resulting in factitious migration measurements. Analytical errors include interobserver variation and experience. Inaccurate pencil marking and the limited resolution of a hand-held ruler also may be sources of analytical variability.[29]

Many sophisticated computerized techniques have been developed for measuring migration from routine radiographs with the aim of improving precision and accuracy.

Use of digitized radiographs and specialized analysis software also improve precision.

The EBRA study[29] for migration suggests that measures taken to optimize radiographic standardization in the clinical setting, where time taken, cost, repeated radiographic exposure, and the frequent change of radiographic staff are important issues, may be limited. As such, the direction for improving the utility of migration measurements made from plain radiographs may be directed more effectively toward improvement in the analysis of routine radiographs using digital technology, appropriate measurement landmarks and by excluding noncomparable radiographs.

The slightly higher subsidence in the Exeter group in our study is still within permissible limits. Also, the subsidence stabilises at around 2 years, so that the implant achieves a new stable position and gives good long-term clinical and radiological results.

CONCLUSION

The cemented collarless polished tapered stem gives very good clinical and radiological results. The stem does migrate, but the migration (early subsidence) takes place at the stem-cement interface, which is advantageous in a tapered prosthesis. The Exeter Universal stem has been a benchmark for cemented THA, exhibiting excellent long-term results for survivorship. From this present study, we can see that from early results, the C-Stem and Exeter Universal femoral components performed equally well clinically and are also comparable on radiological analysis. Therefore, there is a potential to translate the promising early results of the C-Stem into the future and expect similar long-term success.

LIMITATIONS OF THE STUDY

1. Our study is not a prospective study.
2. The functional outcome assessment in our study is done on a small group of patients who came for follow-up during this year. They may not be representative of the entire group of patients.
3. Our method of measuring subsidence may not be as accurate and precise as radiostereometric analysis, which is the gold standard.
4. The measurement of subsidence was not done in all patients because of noncomparable radiographs in many patients.
5. The measurement of subsidence was not done at identical periods in all patients. Instead, patients who had radiographs at identical periods were grouped and their subsidence measured and analysed.

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ANNEXURE

Table 1: Cementing technique – Generations

GENERATION	CEMENT MIXING	CANAL PREPARATION	CEMENT DELIVERY	CENTRALISATION
FIRST	Hand mix	Rasp only, leave cancellous bone	Manual insertion with finger packing	None
SECOND	Hand mix	More aggressive rasp, pulsatile lavage	Cement gun/ Distal canl plug	Early distal centralisers
THIRD	Vacuum mix/ centrifugation	More aggressive rasp, brushing & pulsatile lavage	Cement gun with pressurisation/ Distal canal plug	Proximal & distal centralisers

Table 2: Patient Demographics

	EXETER	**C-STEM**
Total no. of hips	102	153
Total no. of patients	83	117
Bilateral arthroplasties	19 (23%)	36 (31%)
Right [n (%)]	55 (53.9%)	70 (45.8%)
Left [n (%)]	47 (46.1%)	83 (54.2%)
Male [n (%)]	55 (66.3%)	58 (49.6%)
Female [n (%)]	28 (33.7%)	59 (50.4%)
Mean age [y (range)]	42.3 (17-66)	46.3 (18-72)

Table 3: Indications for total hip replacement

	EXETER	C-STEM
Avascular necrosis of femoral head	15	23
Ankylosing spondylitis	11	23
Rheumatoid arthritis	11	16
Seronegative spondyloarthropathy	9	7
Fracture neck of femur – Failed cancellous screw fixation with avascular necrosis	8	10
Revision arthroplasty	10	3
Perthes' disease – OA	3	8
Fracture neck of femur & non-union	1	3
Chronic non-specific arthritis	4	12
Developmental dysplasia of hip	0	3
Tuberculosis hip	1	4
Post-septic sequelae	1	1
Fracture-dislocation hip with secondary OA	1	2
Failed DHS fixation with arthritis hip	4	1
Pathological fracture neck of femur	2	1
Post-encephalitic sequelae with ankylosed hip	1	0
Post-osteotomy/Spline for # neck of femur	1	0

Table 4: Assessment of functional outcome - Age of patients

	EXETER	C-STEM
MEAN AGE (YEARS)	45.40	45.69
RANGE (YEARS)	19-66	19-65

Table 5: Assessment of functional outcome - Follow-up of patients

	EXETER	C-STEM
MEAN FOLLOW-UP(MONTHS)	19.7	20.4
RANGE (MONTHS)	7-49	5-52

Table 6: Complications

	EXETER	C-STEM
Dislocation	3	2
Superficial infection	3	4
Deep infection	2	5
Cortical breach during reaming	2	5
Nerve palsy	3	1
Pulmonary embolism	1	0
Cerebro vascular accident	0	1
Death	0	1
Intra-operative trochanteric fracture	3	6
Periprosthetic fracture	1	3

Table 7: Clinical results – Preoperative and postoperative scores

	EXETER	C-STEM	BOTH
Pre-op pain	14.5	13.5	13.9
Pre-op function	20.5	20	20.2
Pre-op HHS	40.6	38.3	39.1
Post-op pain	41.1	41	41
Post-op function	38.4	36.4	37.1
Post-op HHS	88.2	86.2	86.9

Table 8: Clinical results - Difference in Harris Hip Scores

	EXETER	C-STEM	BOTH
Difference_pain	26.5	27.5	27.2
Difference_functio n	17.9	16.4	16.9
Difference_HHS	47.6	47.9	47.8

Table 9: p value for Harris Hip Score

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DIFF_PN	Equal variances assumed	.867	.359	-.251	29	.804	-.4545	1.81333	-4.16323	3.25414
	Equal variances not assumed			-.236	17.521	.816	-.4545	1.92289	-4.50232	3.59323
DIFF_FN	Equal variances assumed	1.622	.213	-1.638	29	.112	-2.6909	1.64321	-6.05166	.66984
	Equal variances not assumed			-1.733	24.300	.096	-2.6909	1.55284	-5.89373	.51191
DIFF_HHS	Equal variances assumed	1.763	.195	-.591	29	.559	-1.5528	2.62966	-6.93110	3.82542
	Equal variances not assumed			-.543	16.347	.594	-1.5528	2.86001	-7.60534	4.49966

Likelihood Ratio	13.790	3	.003
Linear-by-Linear Association	2.175	1	.140
N of Valid Cases	255		

Table 12: Orientation of femoral stem

			Categorized Orientation			Total
			between -5 and 5	> 5	< -5	
IMPLANT	C stem	Count	145	1	7	153
		% within IMPLANT	94.8%	.7%	4.6%	100.0%
	Exeter	Count	101	1		102
		% within IMPLANT	99.0%	1.0%		100.0%
Total		Count	246	2	7	255
		% within IMPLANT	96.5%	.8%	2.7%	100.0%

Table 13: Chi-square test for femoral stem orientation

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.864[a]	2	.088
Likelihood Ratio	7.347	2	.025
Linear-by-Linear Association	4.174	1	.041
N of Valid Cases	255		

Table 14: Proximal femoral resorption

			PF resorption			Total
			0	1	2	
IMPLANT	C stem	Count	91	5	2	98
		% within IMPLANT	92.9%	5.1%	2.0%	100.0%
	Exeter	Count	46	7	5	58
		% within IMPLANT	79.3%	12.1%	8.6%	100.0%
Total		Count	137	12	7	156
		% within IMPLANT	87.8%	7.7%	4.5%	100.0%

Table 15: Chi-square test for proximal femoral resorption

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	6.576[a]	2	.037
Likelihood Ratio	6.350	2	.042
Linear-by-Linear Association	6.414	1	.011
N of Valid Cases	156		

Table 16: Ectopic bone formation

			ECT_BONE				Total
			0	1	2	3	
IMPLANT	C stem	Count	84	6	6	2	98
		% within IMPLANT	85.7%	6.1%	6.1%	2.0%	100.0%
	Exeter	Count	47	5	4	2	58
		% within IMPLANT	81.0%	8.6%	6.9%	3.4%	100.0%
Total		Count	131	11	10	4	156
		% within IMPLANT	84.0%	7.1%	6.4%	2.6%	100.0%

Table 17: Chi-square test for ectopic bone formation

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	.733[a]	3	.865
Likelihood Ratio	.716	3	.869
Linear-by-Linear Association	.514	1	.473
N of Valid Cases	156		

Table 18: Cement mantle fractures

			CEM_FRAC		Total
			absent	present	
IMPLANT	C stem	Count	96	2	98
		% within IMPLANT	98.0%	2.0%	100.0%
	Exeter	Count	57	1	58
		% within IMPLANT	98.3%	1.7%	100.0%
Total		Count	153	3	156
		% within IMPLANT	98.1%	1.9%	100.0%

Table 19: Chi-square test for cement mantle fractures

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.019[b]	1	.889		
Continuity Correction[a]	.000	1	1.000		
Likelihood Ratio	.020	1	.888		
Fisher's Exact Test				1.000	.689
Linear-by-Linear Association	.019	1	.890		
N of Valid Cases	156				

Table 20: Distal cortical hypertrophy

			DIST_CH		Total
			absent	present	
IMPLANT	C stem	Count	93	5	98
		% within IMPLANT	94.9%	5.1%	100.0%
	Exeter	Count	57	1	58
		% within IMPLANT	98.3%	1.7%	100.0%
Total		Count	150	6	156
		% within IMPLANT	96.2%	3.8%	100.0%

Table 21: Chi-square test for distal cortical hypertrophy

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.124[b]	1	.289		
Continuity Correction[a]	.396	1	.529		
Likelihood Ratio	1.264	1	.261		
Fisher's Exact Test				.413	.275
Linear-by-Linear Association	1.117	1	.291		
N of Valid Cases	156				

Table 22: Radiolucencies

			Radiolucency				
			absent	In zone 1	In zones 1 and 7	In all zones	Total
IMPLANT	C stem	Count	91	4	2	1	98
		% within IMPLANT	92.9%	4.1%	2.0%	1.0%	100.0%
	Exeter	Count	55	1	1	1	58
		% within IMPLANT	94.8%	1.7%	1.7%	1.7%	100.0%
Total		Count	146	5	3	2	156
		% within IMPLANT	93.6%	3.2%	1.9%	1.3%	100.0%

Table 23: Chi-square test for radiolucencies

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	.807[a]	3	.848
Likelihood Ratio	.864	3	.834
Linear-by-Linear Association	.013	1	.909
N of Valid Cases	156		

Table 24: Subsidence of femoral stem – Both groups

	4 months	6 months	9 months	1 year	15 months	2 years
Number of hips	20	29	19	24	11	17
Mean (mm)	0.31	0.53	0.76	1.03	1.06	1.28
Median (mm)	0.31	0.43	0.76	0.92	1.16	1.24
Std. deviation (mm)	0.17	0.28	0.26	0.34	0.31	0.29
Range (mm)	0.76	1.07	1.23	1.35	0.89	1.20
Minimum (mm)	0.04	0.09	0.17	0.38	0.45	0.70
Maximum (mm)	0.8	1.16	1.40	1.73	1.34	1.90

Table 25: Subsidence of femoral stem – Exeter group

	4 months	6 months	9 months	1 year	15 months	2 years
Mean (mm)	0.40	0.57	0.79	1.28	1.33	1.44
Median (mm)	0.42	0.45	0.90	1.32	1.33	1.45
Std. deviation (mm)	0.10	0.30	0.39	0.32	0.01	0.26

Range (mm)	0.27	1.07	1.23	1.10	0.02	0.72
Minimum (mm)	0.23	0.09	0.17	0.63	1.32	1.18
Maximum (mm)	0.50	1.16	1.40	1.73	1.34	1.90

Table 26: Subsidence of femoral stem – C-stem group

	4 months	6 months	9 months	1 year	15 months	2 years
Mean (mm)	0.28	0.48	0.75	0.82	1.00	1.17
Median (mm)	0.29	0.39	0.76	0.88	1.10	1.21
Std. deviation (mm)	0.18	0.25	0.17	0.17	0.32	0.27
Range (mm)	0.76	0.90	0.64	0.61	0.87	0.94
Minimum (mm)	0.04	0.22	0.40	0.38	0.45	0.70
Maximum (mm)	0.80	1.12	1.04	0.99	1.32	1.64

Figure 1: Double-tapered Exeter Universal femoral stem

Figure 2: Triple-tapered C-stem femoral stem

Figu **TOGRAPHS**

FLEXION

EXTENSION

ADDUCTION

Figure 4: C-STEM CLINICAL PHOTOGRAPHS

FLEXION

ADD

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Figure 6: C-stem h

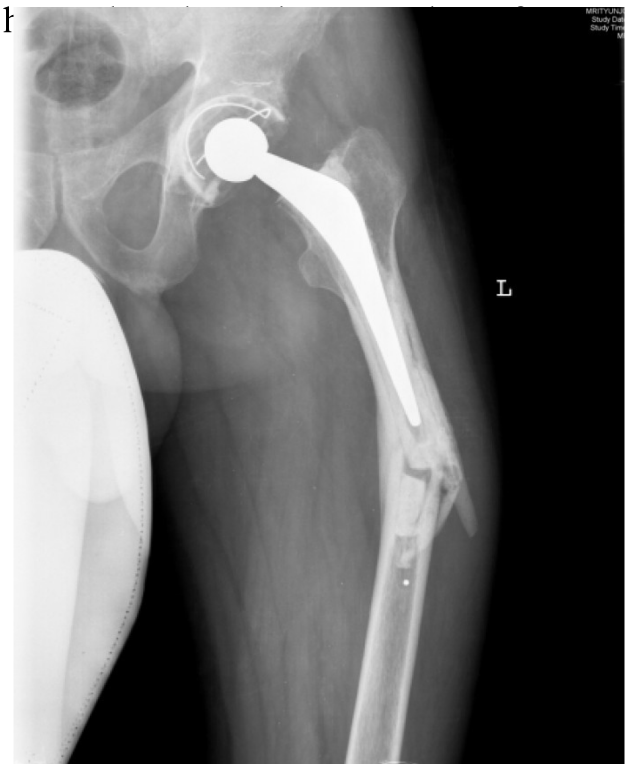


Figure 7: Exeter hip showing Barrack grade A cementing technique

Figure 8: Exeter hip showing Barrack grade B cementing technique

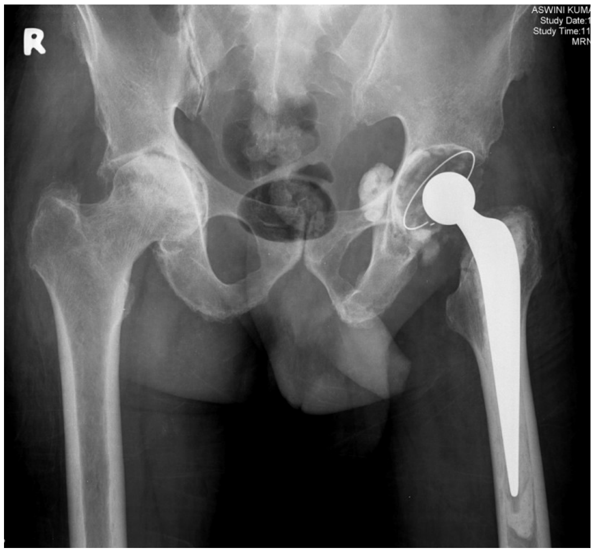


Figure 9: Exeter hips with Barrack grade C cementing technique

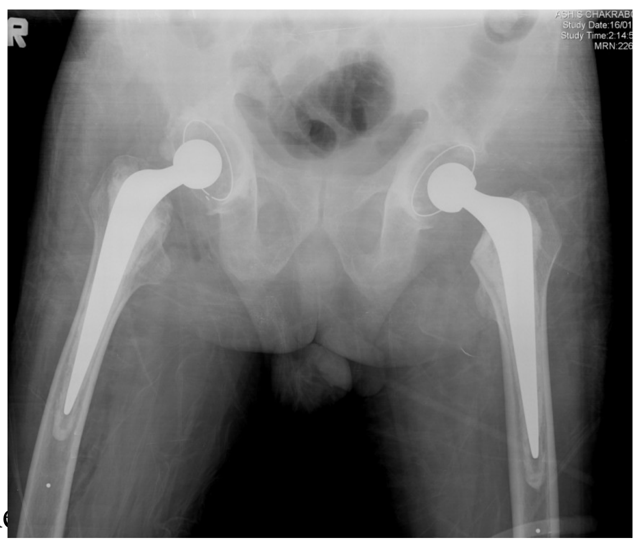
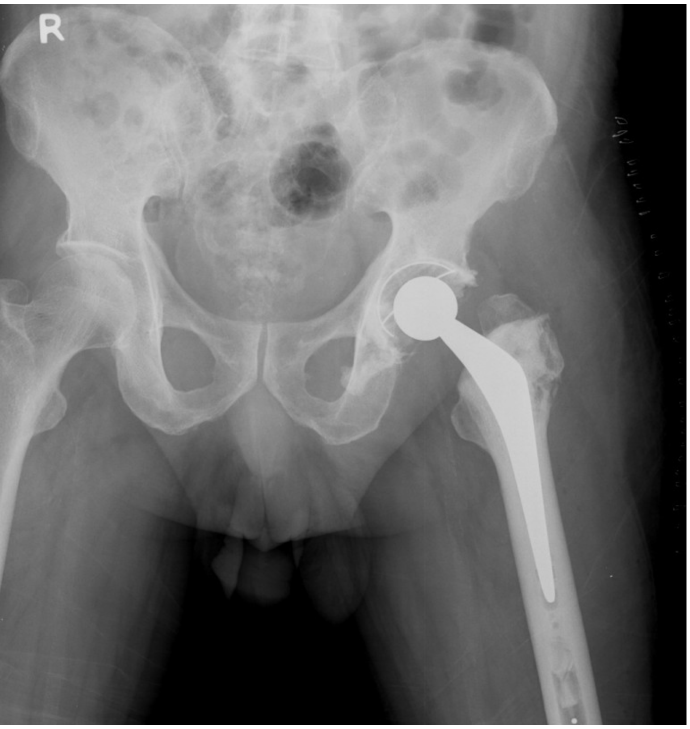
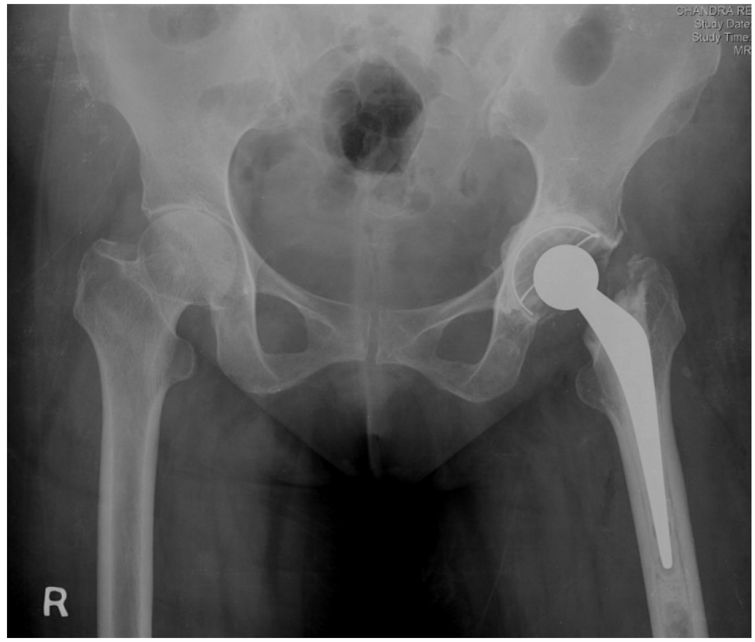


Figure 10: Ceme





Barrack grade A

Barrack grade B

Barrack grade C

Barrack grade D

Figure 11: C stem hip oriented in varus of more than 5 degrees

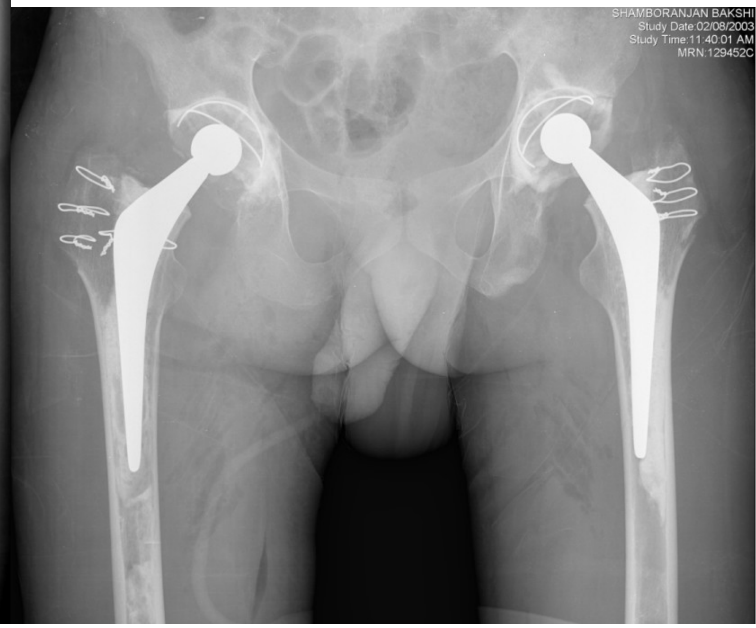


Figure 12: Immediate post-op and follow-up radiographs of Exeter hips with Engh second degree proximal femoral resorption

Figure 13: Immediate post-op and follow-up radiograph of C-stem hip with Engh second degree proximal femoral resorption

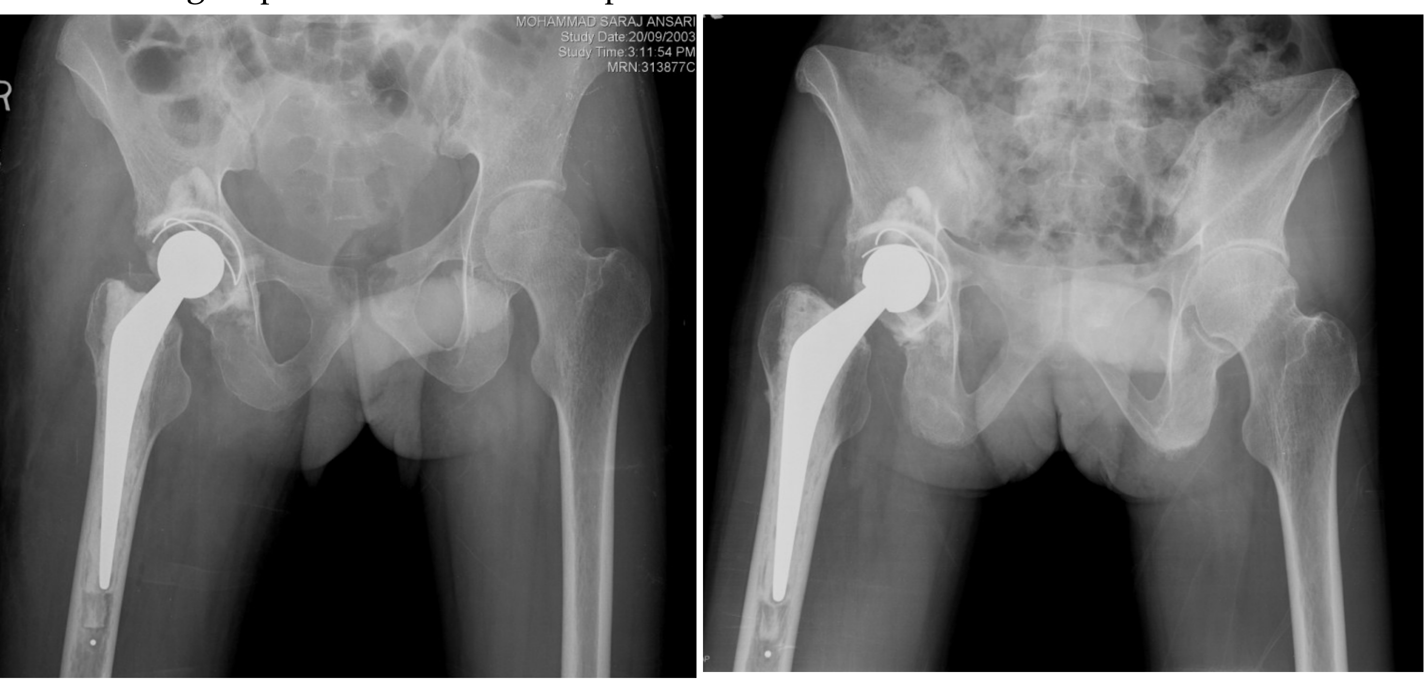


Figure 14: Exeter hip with Brooker grade 1 ectopic ossification – both hips

Figure 15: Exeter hip with Brooker grade 2 ectopic ossification

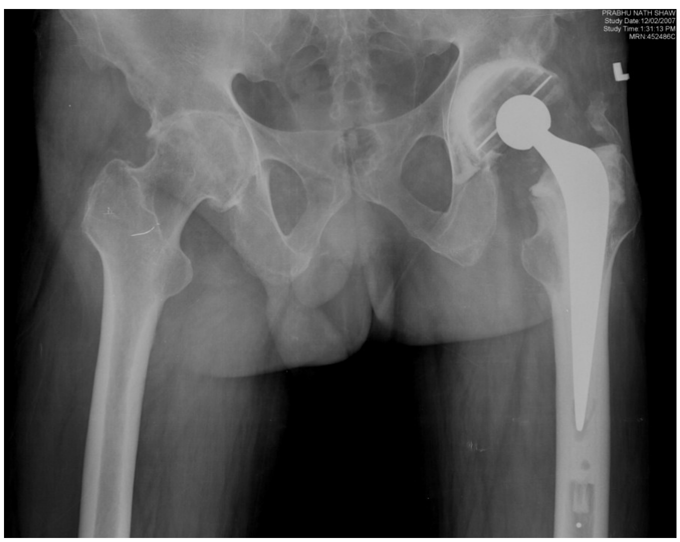


Figure 16: Exeter hip with Brooker grade 3 ectopic ossification

Figure 17: C-stem with Brooker grade 1 ectopic ossification – left hip

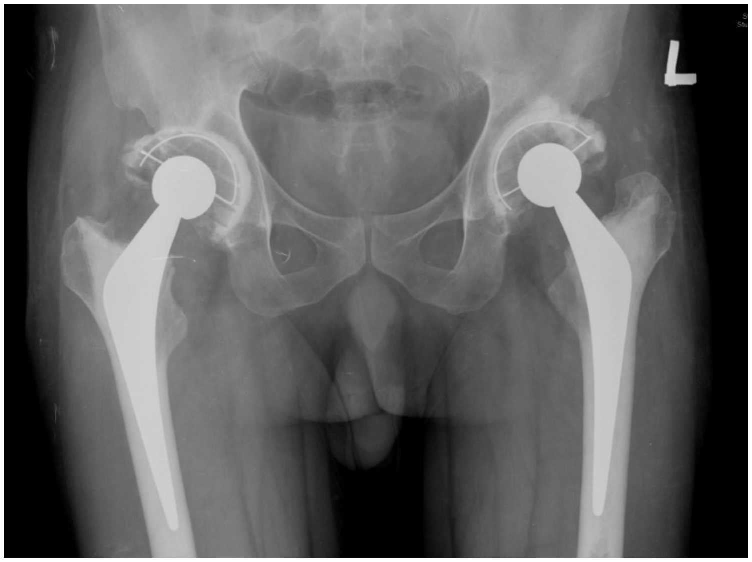


Figure 18: C-stem with Brooker grade 2 ectopic ossification – right hip

Figure 19: C-stem with Brooker grade 3 ectopic ossification – both hips

Figure 20: Exeter hip showing distal cortical hypertrophy

Figure 21: C-stem showing distal cortical hypertrophy – left hip

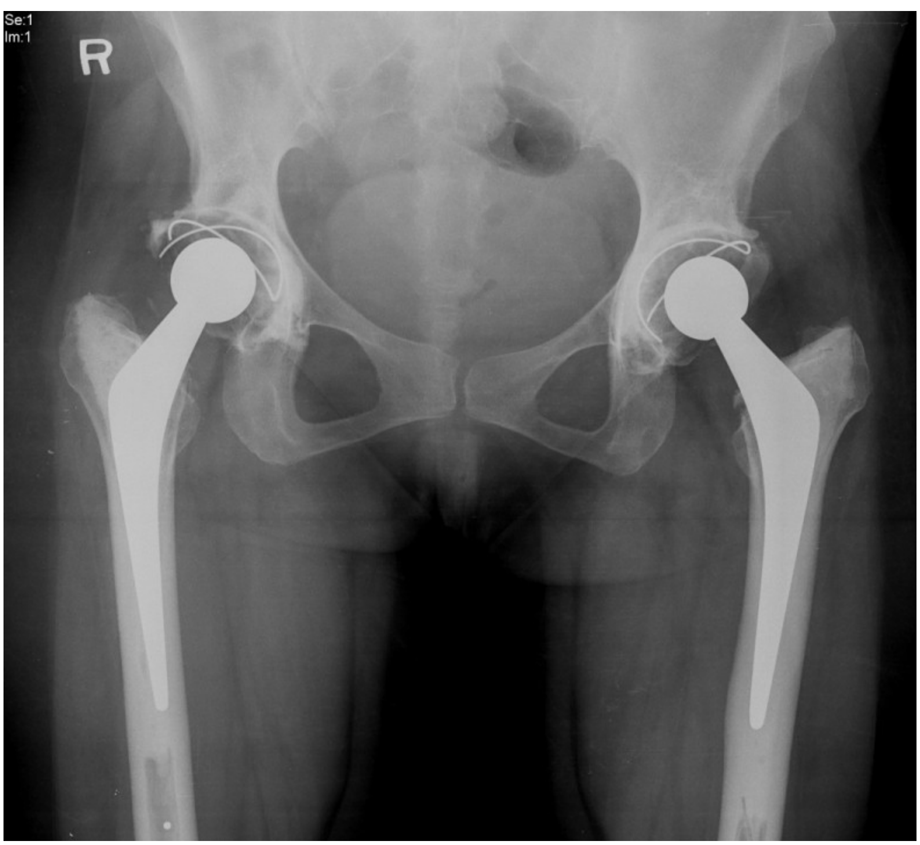


Figure 22: Exeter hip showing radiolucency in Gruen zones 1 and 7

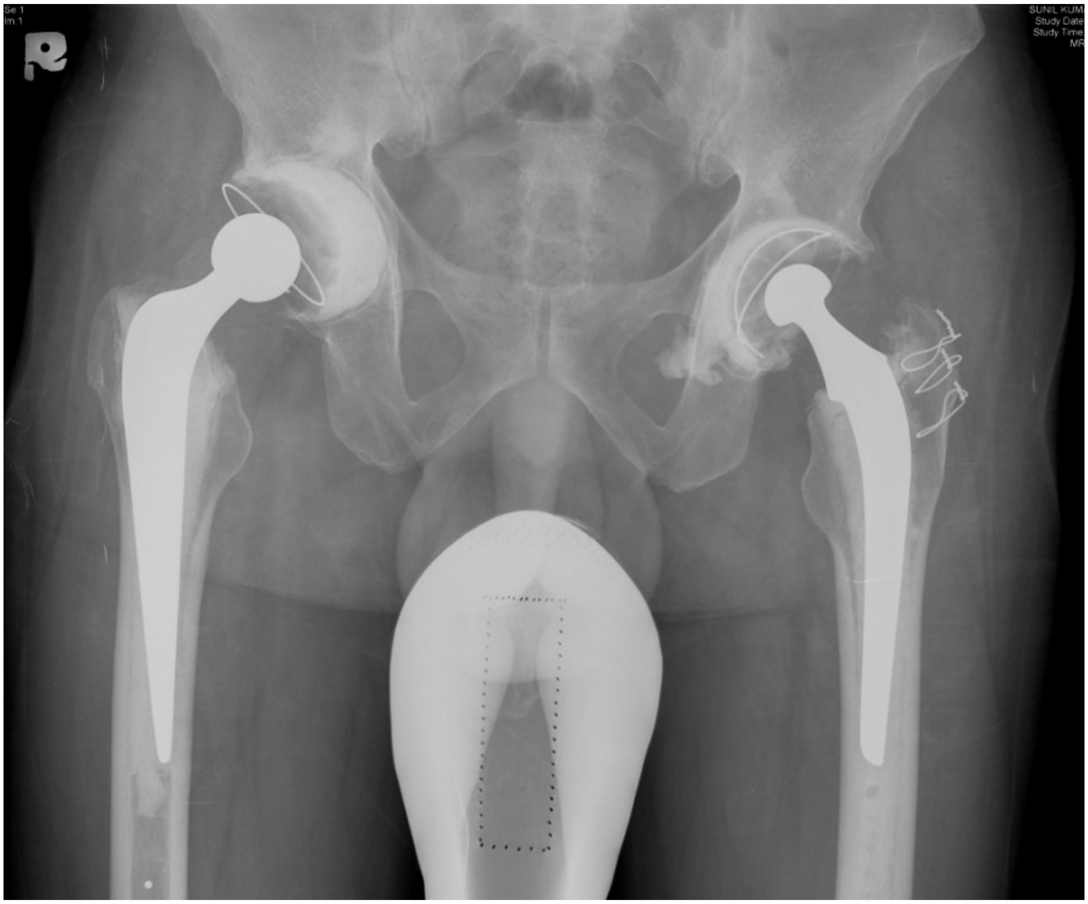


Figure 23: Exeter hip showing radiolucency in Gruen zones 1-7 – case of septic loosening (Immediate post-op & follow-up at 5 years)

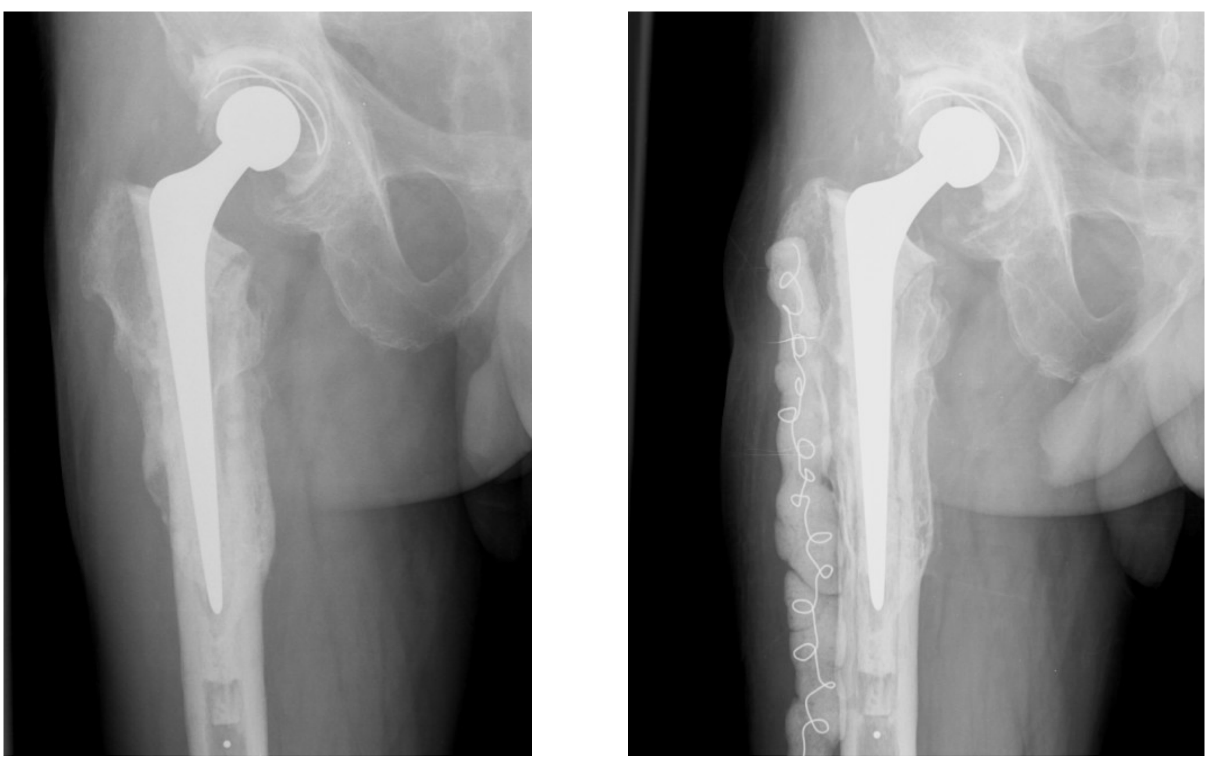


Figure 24: C-stem hip showing radiolucency at Gruen zone 1

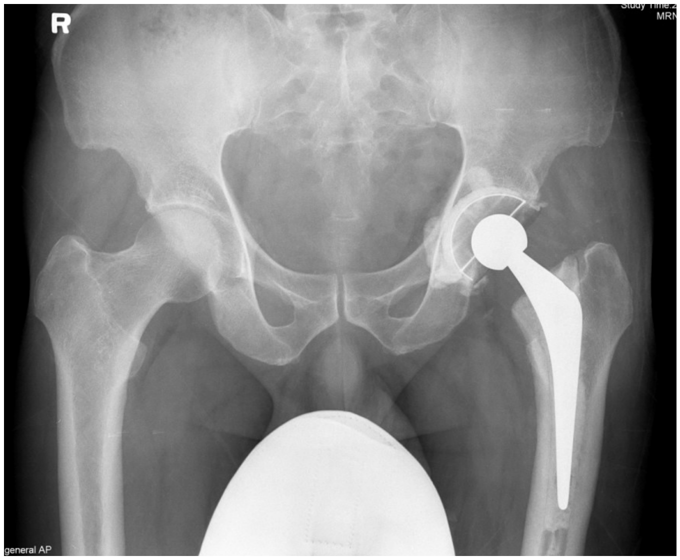


Figure 25: C-stem hips showing radiolucencies in zones 1 and 7 with gross distal migration of both stems indicative of loosening

Figure 26: C-stem hip with radiolucencies in Gruen zones 1-7 – case of septic loosening

PROFORMA

NAME:

AGE:

SEX:

HOSPITAL NO:

UNIT:

ADDRESS:

PHONE: E-MAIL ID:

HISTORY:

DIAGNOSIS:

SIDE:

SURGICAL PROCEDURE:

DATE OF SURGERY:

SURGEON:

POSITION/APPROACH:

IMPLANT USED:

ADDITIONAL PROCEDURES, IF ANY:

POSTOP:

COMPLICATIONS:

FUNCTIONAL OUTCOME ASSESSMENT–HARRIS HIP SCORE

I. Pain (44 possible)

A. None or ignores it 44

B. Slight, occasional, no compromise in activities 40

C. Mild pains, no effect on average activities, rarely moderate pain with unusual activity, may take aspirin 30

D**.** Moderate pains, tolerable but makes concessions to pains. Some limitation of ordinary activity or work. May require occasional pain medicine stronger than aspirin 20

E. Marked pains, serious limitations of activities 10

F. Totally disabled, crippled, pain in bed, bedridden 0

II. Function (47 possible)

A. Gait (33 possible)

1. Limp

a. None 11

b. Slight 8

c. Moderate 5

d. Severe 0

2. Support

a. None 11

b. Cane for long walks 7

c. Cane most of the time 5

d. One crutch 3

e. Two canes 2

f. Two crutches 0

g. Not able to walk (specify reason) 0

3. Distance walked

a. Unlimited 11

b. Six blocks 8

c. Two or three blocks 5

d. Indoors only 2

e. Bed and chair 0

B. Activities (14 possible)

1. Stairs

a. Normally without using a railing. 4

b. Normally using a railing. 2

c. In any manner. 1

d. Unable to do stairs. 0

2. Shoes and Socks

a. With ease 4

b. With difficulty 2

c. Unable 0

3. Sitting

a. Comfortably in ordinary chair one hour 5

b. On a high chair for one-half hour 3

c. Unable to sit comfortably in any chair 0

4. Enter public trannsportation 1

III. Absence of deformity points (4) are given if the patient demonstrates:

A. Less than 30 degrees fixed flexion contracture

B. Less than 10 degrees fixed adduction

C. Less than 10 degrees fixed internal rotation in extension

D**.** Limb-length discrepancy less than 3.2 centimeters

IV. Range of motion (index values are determined by multiplying the degrees of motion possible in each arc by the appropriate index)

A. ***Flexion***

0-45 degrees x 1.0

45-90 degrees x 0.6

90-110 degrees x 0.3

B. ***Abduction***

0-15 degrees x 0.8

15-20 degrees x 0.3

Over 20 degrees x 0

C. ***External rotation in extension***

0-15 degrees x 0.4

Over 15 degrees x 0

D. ***Internal rotation in extension***

Any x 0

E. ***Adduction***

Any x 0

To determine the over-all rating for range of motion, multiply the sum of the index values **X** 0.05.

RADIOLOGICAL ASSESSMENT

Maximum follow-up duration:

INITIAL POSTOP				
CEMENTING TECHNIQUE – BARRACK				
FEMORAL STEM ORIENTATION				
FOLLOW-UP	1st visit	2nd visit	3rd visit	4th visit
PROXIMAL FEMORAL RESORPTION				
ECTOPIC BONE FORMATION				
CEMENT MANTLE FRACTURE				
DISTAL CORTICAL HYPERTROPHY				
ENDOSTEAL CAVITATION				
RADIOLUCENCIES				

SUBSIDENCE OF FEMORAL STEM

	4	6	9	1	15	2

	months	months	months	year	months	years
Subsidence (mm)						

Subsidence at last follow-up:

Last follow-up duration: