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Modular Femoral Neck Fracture After Total Hip Arthroplasty

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1. Introduction

In the middle of the 20th century total hip arthroplasty (THA) became the most popular and the most common reconstructive procedure of the hip. It is important as a last resort in treatment of terrible pain due to progressive hip arthritis of different etiologies. Implanting an artificial hip prosthesis, the surgeon helps the patient by releasing the pain and restoring the range of movement so that the patient can resume his normal activities.

Historically, treatment of progressive osteoarthritis evolved from arthrodesis through different osteotomies, nerve divisions, joint debridements, and interpositions of different organic or inorganic materials between the articular surfaces, towards the final introduction of total hip endoprosthesis. The first endoprostheses were made of glass. Afterwards the quality of the materials progressed from plastic, steel, to cobalt-chromium alloys and finally titanium alloys. Additionally, considerable effort was made to improve the manufacturing techniques, hip biomechanics and the usage of appropriate materials (Harkess & Crockarell, 2007). The studies of materials revealed that orthopaedic implants must be biocompatible; they have to resist all forms of corrosion (Sharan, 1999), resist degradation and withstand all forces that potentially apply. Different designs of total hip endoprostheses follow different philosophies. Two kinds of prosthesis designs are currently used in primary hip arthroplasty. Monoblock is a femoral stem prosthesis made of a single piece, while modular prostheses are made of two modules: the femoral stem and the femoral neck. The stem can be of different sizes, and the neck is of different sizes and different neck angle versions.

According to the American Academy of Orthopaedic Surgeons (AAOS), more than 193,000 total hip replacements are performed yearly in the United States alone. The prediction for the US is that the number of total hip replacements will at least double by the year 2030 (Wilson N., 2008).

2. Modular neck hip prosthesis

Modular neck hip prosthesis has been gaining popularity worldwide for the last thirty years. Modular stems are commonly used in revision hip surgery. The use of this kind of endoprosthesis was first published in 1948 by McBride, then later by Bousquet and Bornard in 1978. Several companies presently offer different versions of modular neck hip endoprostheses for primary total hip arthroplasty (Keppler, 2006). The advantage of this type of endoprosthesis is that the surgeon has an intraoperative choice of neck version and

neck length independently of the stem size. The surgeon can then adjust the femoral offset, correct leg length and achieve hip stability.

Modular hip endoprostheses can be classified as proximal, mid-stem, distal and multi-modular. The proximal ones have modules for sleeve, shoulder and neck, neck, collars and proximal pads (Froehlich, 2006). In this chapter we focus on proximal modular neck endoprostheses.

Important differences exist between the two sexes in femoral neck length, femoral shaft diameter, collum-caput-diaphysis angle (CCD), neck version and offset (Traina, 2009). In order to properly restore the hip biomechanics these parameters must be kept in mind. Appropriate restoration of femoral offset and appropriate soft tissue balancing is necessary. Unsatisfactory restoration of hip biomechanics can and will lead to limping, abductor muscle imbalances, and higher rates of wearing. In order to achieve the best biomechanics of the reconstructed hip, preoperative planning is essential. However, as the femoral version cannot be appropriately and adequately assessed with standard radiographs, modular hip prosthesis offers some advantage during the operation. In addition, some benefits of modular neck hip prosthesis in developmental dysplasia of the hip (DDH) have been reported. One study showed that monoblock stems restore offset in only one out of three patients. Eight different neck shaft angle solutions are necessary to restore the anatomy in 50% of the patients (Massin, 2000).

3. Complications associated with modular neck hip prosthesis

The complications associated with modular neck hip arthroplasty are divided in medical complications and complications associated with surgery and materials. Medical complications, such as cardiovascular, thromboembolic, pulmonary, anaemic and renal complications as well as delirium can be prevented or at least minimized with careful preoperative risk assessment and proper perioperative care (Foerg, 2005). Other complications including joint infection, nerve and blood vessel injury, and bleeding during or after the surgery can be reduced by proper operative techniques. Leg length inequality, prosthesis dislocation, and prosthesis impingement can be prevented with a proper choice of offset and neck version. The highly corrosive environment of the human body demands the use of such biomaterials which will withstand degradation that could lead to another serious complication – failure of the prosthetic material.

Instability is the second most common complication after aseptic loosening (Abraham, 2005). Dislocation rates vary among reports from 0.5% to 11%. The risk of dislocation is associated with time from the operation and with traumatic events, polyethylene wear and pseudocapsule laxity.

4. Prosthesis size and materials

Modular neck hip endoprostheses are made of different numbers of modules. The prosthesis used for primary THA is made of two modules, the femoral stem and the femoral modular neck. The femoral stem comes in different sizes in order to fit different femoral dimensions. The numbers of stem sizes differ from one manufacturer to the other. The femoral neck comes in different sizes and versions as well, and the number again depends on the manufacturer. The two modules connect at the stem neck junction called the taper. The

modularity gives important advantage for fine adjustments of leg length and femoral anteversion.

The materials used for modular femoral stem and modular neck are made of cobalt alloys (Co-Cr-Mo; cobalt-chromium-molybdenum) and of titanium alloys (Ti-6Al-4V; titanium-aluminium-vanadium). Cobalt alloys are among the strongest materials used for implants and can resist high-loading. The added molybdenum increases the strength even more. Chromium is added for hardness and makes the alloy more resistant to corrosion. The unique property of titanium alloys is their tissue biocompatibility. Corrosion is very limited in titanium alloys and they resist to crevice corrosion because they form a passive layer of oxide films (titanium oxide) on their surface. The biomaterials used have to resist crevice corrosion, fretting corrosion, galvanic corrosion, and pitting corrosion in order to withstand the degradation process. Also, the materials must have proper mechanical and wear properties.

5. Modular neck fracture

An increasing number of recently published case reports and studies describe catastrophic failures of modular femoral neck prostheses resulting from material fracture. The Swedish Hip Arthroplasty Register Annual Report of femoral hip stems noted overall femoral stem implant failure in 493 prostheses out of the 299,368 primary hip arthroplasties performed from 1979 to 2008 (1.4%) (Garellick et al., 2009). A report on the Metha Short Hip Stem Prosthesis (Aesculap AG, Tuttlingen, Germany) also showed a 1.4% failure rate of modular necks (68 neck failures out of 5000 THA) (Grupp, 2010). According to the Wright Company, the Profemur (Profemur Z, Wright Medical Technology, Inc., Arlington, TN, USA) modular neck fracture rate in 198,331 implanted endoprostheses has been calculated to 0.028% (Wright Medical Technology Inc., 2010). The Profemur world wide fracture rate in all necks, including long and short necks is reported to be 0.058% (6 fractures out of every 10,000 THA) (Wright Medical Technology Inc., 2010). Both in Wright and in Aesculap, the necks were made of titanium alloys. This complication is supposed to occur in almost all cases with long necks, heavier patients and male patients. Both studies concluded that titanium long necks should be replaced with cobalt chrome alloy necks because they are safer (Wright Medical Technologies Inc., 2010; Grupp, 2010). The Zimmer Company reviewed over 300,000 primary VerSys prostheses (VerSys Hip System, Zimmer Inc., Warsaw, IN, USA) implanted since the year 2000 and their fracture rate was less than 0.0018% (Hertzler et al., 2009). A center implanting Acumatch M-series cementless hip endoprostheses (Acumatch M-series, Exactech Inc., Gainesville, Florida, USA) reported on fracture rates of 1.6% (8 fractures out of 500 implanted prostheses) (Paliwal, 2010).

There are many reasons for prosthesis fracture. As mentioned in the previous section, orthopaedic implants are subject to crevice corrosion, fretting corrosion, galvanic corrosion and pitting corrosion (Sharan, 1999). The changing demographics of the patients undergoing total hip replacement surgeries could also contribute to the fracture rates. These include increased patient weight, increased physical activities, increased life expectancy, and the timing of the operation (Chrowninshield, 2006).

Fretting is a phenomenon which occurs between two contacting bodies experiencing reciprocating motion. In our case small scale reciprocating movements occur between the femoral stem and the femoral neck at the taper junction. When the main factor causing

fretting is oxidation the process is called fretting corrosion. The more the neck is in varus position and the longer the neck is, the greater is the tendency for fretting because of the increased lever arm. Microscopic cracks develop in the fretting zone that can lead to femoral neck fracture. Studies in vitro show that mechanical loading accelerates the corrosion process (Goldberg and Gilbert, 2002).

Another type of process occurring at the taper connection is crevice corrosion. The crevice between two modules will be a corrosion site if there is enough space to allow the income of an aqueous solution (Colliere et al., 1992). The crevice should be sufficiently narrow to maintain a stagnant zone. As corrosion in this zone progresses, oxygen depletion will lead to an excess of positively charged ions in the surrounding aqueous environment of the crevice. The negatively charged chloride ions will migrate to balance them. As a result, hydrochloric acid will form. Hydrochloric acid can dissolve titanium or cobalt alloys which are otherwise stable. Once the crevice corrosion has begun it continues even in the absence of loading.

Concern was raised in the past that galvanic corrosion can arise from inappropriate combinations of dissimilar metal components. Galvanic corrosion is an electrochemical process in which two physically connected dissimilar metals experience metallic deterioration while being exposed to electrically conductive fluids. Different metals have different electrochemical characteristics. When two dissimilar metals are placed together, electrons will start to flow spontaneously from one metal to the other. The loss of electrons from the active metal is called oxidation and oxidation will lead to the process of corrosion (Shetty, 1989). Corrosion will start the release of metal ions and will cause among other complications damage to the prosthesis surface. This can lead to the loss of material strength and eventually to failure.

There is also a form of extremely localized, symmetric corrosion called pitting corrosion. It leads to the creation of small holes in the metal. The mechanism of pitting corrosion is probably the same as crevice corrosion.

The studies of modular neck adapters and stems showed that fretting leads to microcracks on the surface (Grupp, 2010; Wright Medical Technologies Inc., 2010). Fretting is accompanied with crevice corrosion and pitting corrosion. As mentioned above, the passive oxide film formed in titanium alloys is permanently destroyed by fretting corrosion and crevice corrosion. Fretting reduces the fatigue strength of titanium alloys. Fretting at the connection can be increased by the intraoperative contamination of taper with small particles of bone or tissue. Contamination should always be prevented by assembling the device carefully and drying the components before the assembly (Grupp, 2010). Both studies concluded that the change of femoral neck material from titanium alloys to cobalt alloys increases the safety of the connection (Grupp, 2010; Wright Medical Technologies Inc., 2010). Cobalt alloys have the same fatigue strength, they form the passive oxide layer and have excellent fretting corrosion characteristics in comparison to titanium alloys. Cobalt alloys are superior in stiffness and modules of elasticity, notch sensitivity, crack propagation, and abrasion compared to titanium alloys. However, cobalt alloys are inferior to titanium alloys in characteristics of crevice corrosion and are more allergenic. The authors recommended that heavier patients, especially those weighing more than 100 kg, and more physically active male patients require long necks made of cobalt alloys.

Froehlich et al. did a follow up of their experience with seven different modular stems implanted since 1984 (Froehlich, 2006). They implanted 2,248 stems for primary THA in

cemented and uncemented way. They used S-Rom (S-Rom Modular Hip System, JMPC/DePuy, Warsaw, IN, USA), Apex Modular (Apex Modular Hip System, Global Orthopaedic Technology, Unanderra, NSW, Australia), K2 Apex (Apex K2 Modular Hip System, Omni Life Science, Inc., East Taunton, MA, USA), OTI/Encore R-120 cemented stem, OTI/Encore R-120 porous c.c. cementless stem (R-120 Modular Stem, DJO Surgical, Austin, TX, USA), UniSyn (UniSyn Total Hip System, Hayes Medical, Inc., El Dorado Hills, CA, USA) and Cremascoli Modular Neck (Wright Medical Technologies, Inc., Arlington, TN, USA). They experienced 12 femoral component failures, 2 in a c.c. proximal modular neck and 10 in proximal modular titanium shoulder neck. The authors remain enthusiastic about modularity and continue to use modular stems in their practice. The reason for failure in their cases was a single high load event and suggested quasi-static shear failure of the pin alignment. The OTI/Encore modular neck failure occurred in the distal neck engagement taper (Froehlich, 2006). The company increased the upper taper diameter, the lower taper diameter, the surface area, and the distal taper length so that the fatigue testing results improved.

Several recent case reports exist describing the failure of modular necks of the Profemur prostheses (Profemur Z, Wright Medical Technologies Inc., Arlington, TN, USA) (Atwood, 2010; Wright G., 2010; Wilson D. J., 2010). They describe a well integrated implant that could only be removed with trochanteric osteotomy. Usually the initiation site for failure was the anterior and superior part of the neck. Degradation of the polished surface was noted at the insertion point of the taper. Also, evidence of abrasion and corrosion was seen (Dangles, 2010). The Federal Drug Administration Manufacturer and User Facility Device Experience (FDA MAUDE) database describes 98 adverse effects for the Profemur modular neck prosthesis for the years 2000-2009. 37 of those include breakage of the femoral neck (FDA MAUDE, as cited in Skendzel et al., 2011). Skendzel et al. reported on two cases of fractured Profemur modular neck and concluded that the long varus necks used increased the bending moment by 32.7% when compared to short varus necks (Skendzel et al., 2011). The stress was concentrated at the modular junction. Removal of the complete femoral component was required during revision surgery because the Morse taper could not be removed. Both patients experienced a traumatic event before the failure. Atwood et al. described the fracture of a Profemur long straight neck in a man of 2 m height and 109.8 kg weight who fell on his hip (Atwood, 2010). The surgery revealed a crack of 2 mm below the stem edge. They found the initiation site near the lateral-anterior corner of the neck. They also found signs of crevice corrosion and fretting wear.

Grupp et al. studied the Metha Short Hip Stem Prosthesis (Metha Short Hip Stem Prosthesis, Aesculap AG, Tuttlingen, Germany) as a consequence of several reports of failed titanium alloy femoral necks (Grupp, 2010). Out of 5,000 THA they found 68 neck adapter failures. They found neither processing or material deviation nor incorrect dimensioning. The retrieved prostheses showed a similar fracture pattern with the fracture starting in the anterolateral area at the upper part of the cone where there is maximum biomechanical stress. The reason for failure was attributed to fretting, fretting corrosion, and crevice corrosion which lead to the loss of fatigue strength of titanium alloy. The combination of factors listed above, as well as contamination of the cone adapter with fluids or particles, increased patient weight, high activity level, male gender, and CCD angle of 135 and smaller increased the rate of failure. They concluded that the change to cobalt-based alloy modular necks increases the safety of cone connection.

However, some studies did not show any problems regarding modular femoral components. The study by Toni et al. showed no clinical complications related to modular necks (Toni et al., 2001). They studied 216 hip prostheses of AnCA Fit type (AnCA Fit, Cremascoli Ortho, Milan, Italy) which were implanted from June 1995 to December 1997. Another study by Duwelius et al. using the Zimmer M/L Taper Hip Prosthesis with Kinectiv Technology (Zimmer M/L Taper Hip Prosthesis with Kinectiv Technology, Zimmer, Warsaw, IN, USA) on 634 patients from April 2007 to November 2008 showed no complications related to modular neck failure (Duwelius et al., 2010). The stem and neck were manufactured from titanium alloy (Ti6Al4V).

6. Case report

At the Depatment of Orthopaedic Surgery and Sports Trauma, Celje General and Teaching Hospital, Celje, Slovenia, modular hip prostheses have been used since the year 1992 in selected patients. The first prosthesis used was GSP (Cremascoli Ortho, Sorem Ortho, Toulon, France) and at the time of writing the prosthesis in use is the Profemur Z (Wright Medical Technology, Inc., Arlington, TN, USA). From 1992 to 2008, 306 modular neck hip prostheses of three different types were implanted at our department. From 1992 to 2004, 88 GSP modular neck hip prostheses (Cremascoli Orthopaedics, Sorem Ortho, Toulon, France) were implanted. From 2002 to 2006 we implanted 58 Anca Dual Fit hip stems (Cremascoli Ortho, Milan, Italy). In 2006 we started implanting Profemur Z modular neck hip prostheses (Wright Medical Technology, Inc., Arlington, TN, USA) and 160 of these were implanted by the end of 2008.

In December 2010, a 69-year old male was admitted to our hospital's emergency department with acute pain in his right hip. The pain appeared after a fall on his right side from standing height. The examination revealed right inguinal tenderness and shortening of his right lower extremity with external rotation. The review of standard radiographic exams showed modular prosthesis neck fracture. This was the first such complication seen at our department (Fig. 1). The patient's height was 178 cm and he weighed 110 kg (BMI 34.7). He was treated at our institution in 1998 when he was 56 years old. At that time his BMI was 31.6 (weight 100 kg). The operation was performed because the patient suffered from rheumatoid arthritis with the involvement of his right hip. A fully modular cementless total hip endoprosthesis was implanted (fully hidroxy-apatite coated femoral stem (GSP) with modular cobalt-chromium long straight neck, 28 mm diameter ceramic head, and acetabulum of the press-fit type (ANCA-Fit) with ceramic acetabular insert, (Cremascoli Orthopaedics, Sorem Ortho, Toulon, France). None of the postoperative visits or radiographic exams showed any signs of wear or other complications. The patient was pain free before the event.

Revision surgery was scheduled as soon as we received the custom made acetabular cup inlay (ANCA-Fit, Wright Medical Technology Inc., Arlington, TN, USA). The operation was performed by the same surgeon and the previous lateral approach was used. Revision surgery confirmed the fracture of the modular prosthesis neck. It was impossible to remove only the remaining neck from the taper, so that the entire femoral stem had to be removed. The femoral stem was well integrated in the femur and femoral osteotomy was necessary in order to remove the implant. Macroscopically, the tissue showed no metal debris or granuloma. The remaining part of the fractured neck module was approximately 2 mm below the top of the taper (Fig. 2-4).

Fig. 1. Standard antero-posterior radiograph of the patient's right hip at admission. (Courtesy M. Kotnik, M. D.)

In order to properly reconstruct the biomechanics of the hip, cementless revision modular stem with ceramic head (Waldemar Link GmbH & Co, Hamburg, Germany) was used. The acetabular lining was exchanged as well and a custom made ANCA-Fit (Wright Medical Technology, Inc., Arlington, TN, USA) component implanted (Fig. 5). Standard tissue specimens were collected during the revision procedure for microbiologic cultures which showed no bacterial growth.

Fig. 2. Photograph of the retrieved fully-modular prosthesis showing the modular neck fracture.

Fig. 3. A close-up photograph showing the fractured modular femoral neck.

Fig. 4. Photograph showing the removed prosthesis with fractured neck and the remaining of the modular neck in the femoral stem taper.

Fig. 5. Radiograph of the revised right hip with the cementless revision modular prosthesis in place. (Courtesy M. Kotnik, M. D.)

7. Conclusion

Modular neck hip prostheses are nowadays wildly used around the globe. The Profemur stem (Wright Medical Technology Inc., Arlington, TN, USA) only was sold in more than 200,000 units by the end of 2010 (Wright Medical Technologies Inc., 2010). There are many benefits in proximal modularity. The theoretical benefits of modular neck include bone and tissue conservation, restoration of joint biomechanics, reduced blood loss, easier rehabilitation, ease of revision, simple surgical technique, and different modular options (McTighe, 2008). In addition, the possibility of implanting a stem with a retroverted modular neck can prevent cup impingement and dislocation of the prosthesis. Moreover, if revision operation is necessary for the dislocated THA, only exchange of the modular neck might be required. The surgeon has an intraoperative option of choosing the appropriate neck length, neck version and CCD angle independently of the femoral stem size, taking into account the considerable differences in stem sizes between the two sexes (Traina, 2009). The proximal modular neck type of the prosthesis is useful in primary hip arthroplasty due

to the significant differences among the individuals requiring hip reconstruction. Some types of modular neck prostheses offer as much as 60 different variations with modularity compared to only about 10 options offered by monoblock stems (Duwelius, 2010).

However, added modularity brings another possibility for complication. Recent reports emphasize the need for changing the neck material from titanium alloys to the safer cobalt-chromium alloys. Constant evaluation of laboratory material should be continued, even though it does not always guarantee proper information regarding in vivo parameters. Careful preoperative planning should be performed in spite of modular neck THA allowing anatomic reconstruction of the hip. The increased variety of intraoperative surgical options with the fully-modular stems should not be an excuse for bad surgical technique and improper cup position.

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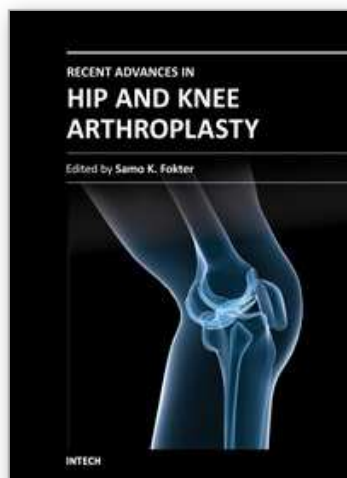
Recent Advances in Hip and Knee Arthroplasty

Edited by Dr. Samo Fokter

The purpose of this book is to offer an exhaustive overview of the recent insights into the state-of-the-art in most performed arthroplasties of large joints of lower extremities. The treatment options in degenerative joint disease have evolved very quickly. Many surgical procedures are quite different today than they were only five years ago. In an effort to be comprehensive, this book addresses hip arthroplasty with special emphasis on evolving minimally invasive surgical techniques. Some challenging topics in hip arthroplasty are covered in an additional section. Particular attention is given to different designs of knee endoprostheses and soft tissue balance. Special situations in knee arthroplasty are covered in a special section. Recent advances in computer technology created the possibility for the routine use of navigation in knee arthroplasty and this remarkable success is covered in depth as well. Each chapter includes current philosophies, techniques, and an extensive review of the literature.

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