Journal of Clinical Case Reports

McSorley et al. J Clin Case Rep 2015, 5:2
DOI: 10.4172/2165-7920.1000497

Case Report Open Access

Do Modern Femoral Stems Break?

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Abstract

In the 1960s and 70s hip arthroplasty was in its infancy. During that time the occurrence of post-operative prosthetic femoral stem fracture was much greater than it is today. However as stem design and materials evolved along with superior cement and cementing techniques, rates of femoral stem fracture radically decreased, at present it is considered a rarity. We present two cases of fractured prosthetic femoral stems, detail the method of failure and the risk factors all surgeons should be aware of to minimize the risk femoral stem fracture.

Keywords: Primary hip arthroplasty; Prosthesis fracture; Femoral prosthesis; Femoral stem

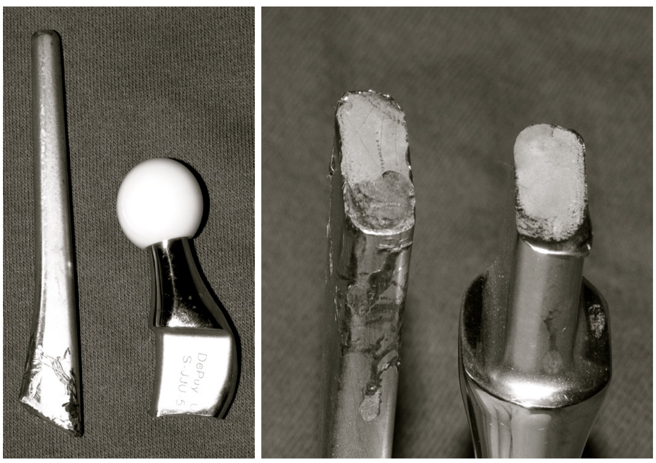
Case Reports

Case 1

We present the case of a 43-year-old female with a background history of left Total Hip Replacement who presented to the clinic with progressively worsening left hip and groin pain over the previous 2 years with sudden deterioration in her mobility over one week. On examination she had a significant pain in the left hip and groin on all hip movements associated with tenderness over the left greater trochanter. An Anterior-Posterior (AP) pelvic radiograph identified an oblique fracture through the proximal third of her Charnley Modular femoral stem.

Her primary Total Hip Replacement had been carried out 15 years prior to this presentation for avascular necrosis of the femoral head secondary to Slipped Capital Femoral Epiphysis. A Size 1 Charnley Modular stem was cemented in with a 22.225 mm 9/10+0 Ceramax Head. Her post-op course was uneventful and she was discharged home in a timely manor. She had been pain free in the left hip at all follow-up appointments up to 2 years prior to this presentation. All previous radiographs demonstrated a well positioned prosthesis with no evidence of fracture or loosening. No specific remarks were made about the cement mantle (Figures 1a and 1b).

On diagnosis of the broken stem, she was scheduled for a single stage revision. This was carried out through an anterolateral approach with removal of the proximal fragment of the femoral stem. The distal fragment of the femoral stem was well fixed in cement and was removed using a burr. The remaining bone stock was poor and a new Exeter V40 femoral stem with a 44 mm offset was cemented in place with a 28 mm standard Alumina ceramic femoral head. Eccentric wear was noted in the original polyethylene liner, so this was replaced 52 mm Duraloc Enduron Liner. Post-operatively she was mobilised with full weightbearing as tolerated and discharged for rehabilitation.



Figue 1A-1B: Views of the fractured Charnley Stem after removal.

Case 2

The second case involves a 40-year-old female with a background history of left Total Hip Replacement and increased BMI who presented with sudden onset of severe pain in her left hip. On examination she had tenderness over the left hip and significant decrease in range of motion, both active and passive. An AP pelvic radiograph identified a transverse fracture through the proximal third of her Exeter femoral stem as the source of her symptoms.

Her primary Total Hip Replacement had been carried out 5.5 years prior to this presentation following a subcapital neck of femur fracture. This was carried out through a posterior approach with the insertion of a size zero Exeter V40 femoral stem with a 37.5 mm offset and 28 mm+4 mm alumina femoral head along with a 50 mm Duraloc acetabular cup and Duraloc Enduron Liner. Her post-op course had been uneventful and at her last follow-up, 3 years previously, she had not reported any pain and had excellent function. Stem position at this review was satisfactory with no evidence of loosening (Figure 2).

A single stage revision was carried out through an anterolateral approach with an uncomplicated removal of the proximal fragment of the femoral stem. The proximal cement mantle was loose and easily removed with a burr. A lateral cortical window allowed the distal femoral stem fragment to be pushed proximally and removed. A new size zero Exeter V40 femoral stem with a 37.5 mm offset was cemented in place with a 28 mm+4 mm femoral head. Post-operatively she was mobilised with full weight-bearing and discharged for rehabilitation on the third day.

Routine outpatient follow up was carried out at six weeks and six

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Received January 14, 2014; **Accepted** February 26, 2015; **Published** February 28, 2015

Citation: McSorley K, Galbraith J, Bennett D, Gul R (2015) Do Modern Femoral Stems Break? J Clin Case Rep 5: 497. doi:10.4172/2165-7920.1000497

Figure 2: Anterior-posterior radiograph showing the broken Exeter femoral stem.

months. On both occasions she reported no pain and had returned to independent mobilising and carrying out her activities of daily living independently. X-rays performed on both occasions show satisfactory prosthesis positioning and no evidence of loosening.

Discussion

These 2 cases represent femoral stem fracture in the modern era of prosthesis, constructed of the stronger compounds and using up-to-date cementing techniques. Early hip prosthesis had high rates of stem fracture, which drove the evolution of the stems to the ones in use today. The Charnley total hip replacement system was not the first total hip prosthesis, it was however the first widespread successful one. Introduced in November 1962 it featured a monoblock flat-backed, stem made from EN58J stainless steal and had a polished surface as demanded by British Standard for use of this material in surgical implants [1]. Rates of stem fractures [2] lead to change in stem surface in 1969 to a matt-finish using the vaquasheen process which deliberately surface-hardened the metal to resist fracture. This was followed in 1974 by the introduction of the round-backed stem which significantly increased the cross-sectional area of the stem over the flat-backed stem to increase stem rigidity and further resist fracturing [3,4]. John Charnley was satisfied he had increased the strength of the implant itself however he was still concerned that cementing technique was the leading cause of fractured prosthesis. This is explained by Wroblewski [5]. "Fracture of the stem is but a dramatic presentation of the end result of loosening of the proximal part of the stem in the presence of distal fixation" So, in 1975, anteroposterior flanges were added to the stem to prevent the escape of cement at the level of the neck resection and also pressurise the cement in the femoral canal. This was designed to prevent subsidence of the stems in the femoral canal as this was reported to be a significant problem related to stem failure [6]. These changes resulted in a shift in the behaviour of the stem to a composite-beam where its predecessor had obeyed the taper-slip principle.

Taper-slip stems are allowed to minimally subside into cement over time to a stable position. While a composite beam forms an immediately stable construct made up of the prosthesis, the cement and the surrounding bone [7]. The composite beam does not tolerate subsidence as well as the taper slip and excellent bonding between the prosthesis and the cement mantle is required to prevent loosening and failure [8].

The flanged, composite-beam Charnley was superseded in 1984 by the Evolution which was made of stronger Ortron 90 designed to reduce stem fracture rates even further. This was followed by the addition of a modular system, the Elite, in 1986. Since then there has been little change in the design of the prosthesis. Comparative follow-up has shown significant decreases in rates of fractured stems using 2nd generation-onwards Charnley prosthesis however these are associated with increased rates of aseptic loosening [9]. Suggesting that advances in stem stiffness and fracture-resistance have simply altered the method in which the stems fail, decreasing the incidence of stem fracture significantly.

The Exeter Hip was designed between 1969 and 1970 in a collaboration between the Princess Elizabeth Orthopaedic Hospital and the Department of Engineering Science of the University of Exeter. It was a double-tapered, collarless stem made from EN58J stainless steal and had a polished surface similar to the Charnley stem from the same era. Initial follow-up [10,11] data revealed satisfactory pain relief and function but there had been 3 stem fractures and 14 neck fractures. Subsidance was also noted radiologically

In 1976 heavier, stronger femoral stems were introduced in a range of sizes. These were manufactured from 316L stainless steal which had no requirement to have a polished surface, these were switched to a matt-finish as it was more cost effective and in theory would not experience the same subsidence of the polished stem. The matt-finished prosthesis however experienced significant increased incidence of focal femoral lysis and aseptic loosening compared with original polished stems [12]. The matt surfaced stems also suffered a high rate of fracture with one centre reporting of 3 out of 27 hips [13]. Thus in 1986 the polished surface was re-introduced with prosthesis manufactured from Orthinox, a stainless steal low-carbon alloy.

Since this re-introduction of polished stems made of the Orthinox there have been very few reports of stem fracture. van Doorn et al. [14] reported one of the first fractured new Exeter stems in a patient who underwent revision surgery with impaction allografting of the femur. In that case, the combination of the fatigue striations and the absence of any defects of the stem indicated that the fracture may have been due simply to overloading of the stem from cantilever bending forces. In our cases cantilever bending was the mechanism of failure. In both cases the stem fractured in a similar location at the proximal end suggesting that stems had poor cement support proximally.

Cantilever bending occurs when a member is fixed at only one end [15], in this case the hip prosthesis fixed in cement. Cantilevers are subjected to moment (M) which can be represented as;

$$M=Fd$$

where F=Force and d=Distance. With femoral stems distance refers to the length of the stem exposed proximally, not adequately encased in cement. Force refers to the cycle of forces exerted by a patient moving their hip in flexion, extension, abduction, adduction, internal and external rotation along with weight-bearing. This moment will affect the Stress (σ) on the cantilever which can be represented as;

$$\sigma=M/Z$$

where Z=section modulus which is a fixed function of the stem determined by several factors including material composition and also its cross-sectional area. Cross-sectional area on the Charnley was increased in 1974 to strengthen the prosthesis by affecting the modulus. Stress can also be represented as;

$\sigma = Fd/Z$

Therefore the magnitude of the stress induced in a cantilever increases linearly with the length of the cantilever. So when proper containment in the proximal femur cannot be achieved, the stem will have little proximal support, which in combination with good distal fixation, results in a longer cantilever that exerts its moment leading to increased stress on the slender distal part of the prosthesis. Rokkum et al. [13] first described this failure mechanism for the matt surface Exeter stem however it has not yet been described in a primary total hip replacement with the new Orthinox Exeter stem nor has it been reported in any detail in the round-backed Ortron 90 Charnley stems. Joint registries and strict follow-up may have led to earlier detection of aseptic loosening and prosthesis at risk of fracture meaning prosthesis never reach the point of failure and fracture as they did in the past. Another explanation is the possibility of under-reporting of femoral prosthesis fracture.

An extensive review of the literature demonstrated several reports of fractured femoral components. However, these cases refer to older prosthesis, alternative prosthesis [16-18] or fractures through the neck of the prosthesis [19-20]. There were none featuring either of these 2 modern prosthesis when used for primary total hip replacement, despite their widespread use worldwide.

Over the decades many studies [2,5,17,21,22] have identified multiple risk factors for prosthetic stem fracture including;

1) Increasing patient weight
2) Higher levels of activity
3) Relatively younger age
4) Male
5) Valgus stem positioning
6) Relatively undersized stem relative to patient's anatomy

Both of the cases described here were relatively young (40 and 43 years of age) and therefore had higher levels of activity. Implying their femoral stems were subjected to a higher number of cycles of cantilever bending as described earlier and increasing the risk of prosthesis fracture. The second case featuring the fractured Exeter stem had an increased BMI, which would increase the Force involved in each cycle, further increasing the risk of prosthesis fracture. Both cases also featured relatively undersized femoral stems given the 2 patients' ages, activity levels and weights.

Learning Points

Risk factors for prosthetic stem fracture must be considered when inserting any femoral stem to avoid inserting undersized prosthesis especially in younger patients or those with predicted high levels of activity. Good cementing technique remains crucial despite advances in prosthesis manufacture and materials as detailed earlier. Sufficient proximal femoral stem fixation is essential in all patients but is especially important in patients with other risk factors for prosthesis fracture.

Conclusion

Primary total hip arthroplasty femoral stems have evolved to resist fracture and reports of fractured stems have significantly decreased with these two established stems. Neither have reported a failure as a result of femoral stem prosthesis fracture in recent times when used in primary total hip arthroplasty. This may be a reflection of earlier detection of loosening and timely intervention. Alternatively it may represent underreporting of femoral stem prosthesis fracture. This article serves to highlight the importance of good cementing technique to ensure good proximal support, especially when inserting smaller stems in young, active patients.

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