Assessing the Use of Tapered Titanium Stems in Treating Periprosthetic Fractures

By:

Kieran Derksen (B.Eng., MPAS-Candidate)

Supervisors:

Dr. Eric Bohm (MD, B.Eng., M.Sc., FRCSC), Mr. Trevor Gascoyne (M.Sc., P.Eng.)

A capstone project submitted to the Faculty of Graduate Studies, Max Rady College of Medicine at the University of Manitoba in partial fulfillment of the requirements for the degree of

MASTER OF PHYSICIAN ASSISTANT STUDIES

ABSTRACT

Background Periprosthetic fractures are a late complication of total hip arthroplasty. There are a variety of surgical techniques and femoral component designs that can be used to treat them depending on surgeon preference and fracture type. Tapered titanium stems have shown promising results in recent studies for the treatment of periprosthetic fractures. *Purpose* The objective of this retrospective study was to investigate the efficacy of using tapered titanium hip stems in a revision arthroplasty procedure for periprosthetic fracture repairs by assessing survivorship, radiographic findings, and self-reported functional outcomes at a post-operative period of at least 2 years. *Methods* A total of 34 patients who received treatment for periprosthetic fractures between May 2008 and January 2016 were assessed for the use of tapered titanium stems. Survivability was determined and radiographs were evaluated for fracture union, stem subsidence, and osseous restoration. The Oxford questionnaire and satisfaction survey were used to determine quality of life, functionality, and pain scores. *Results* Three patients required early revisions after surgery for either trochanteric fracture and dislocation (5 months), infection (10 months), or aseptic loosening (4 months). Complete union was found in 88% of cases and bone stock was unchanged or increased in 91% of cases. Stem subsidence occurred in 44% of cases with a mean migration of 2.6 mm. Although there was a high occurrence of subsidence, the majority of cases measured less than 4 mm, and subsidence did not correlate with survivorship or clinical outcomes. The mean 2 year Oxford score was 37.8 of 48 and on average patients were either satisfied or very satisfied. *Conclusions* This study reports encouraging radiographic and clinical results with minimum 2 year follow-up for the treatment of periprosthetic fractures with tapered titanium femoral stems.

INTRODUCTION

Total hip arthroplasty (THA) is an effective treatment for relieving severe joint pain in a large proportion of the aging population. It is a very successful surgery with a survivorship of up to 95% at 10 years post-operatively (1). There are a variety of surgical approaches and types of implants that exist for hip replacement surgery such as tapering of the stem, use of bone cement, and different types of prosthesis material to make up the hip joint. Yet, with any total hip arthroplasty, serious complications exist that may require additional surgery. The incidence of periprosthetic fractures following THA are approximately 0.4 – 3.5%, but an incidence of 6.6% and as high as 18% have been reported in literature (2–6). An increasing number of indications and functional expectations, as well as an aging population, contribute to the increased prevalence of periprosthetic fractures (7,8). Although these fractures are relatively uncommon compared to other reasons for revision, it is a serious issue which requires an effective method of treatment to promote bone healing and fracture union for improved survivability and quality of life for the patient. Therefore, it is important to research optimal revision techniques and implant types for treating periprosthetic fractures in order to increase stability, promote healing, and improve survivorship of hip replacements.

Periprosthetic fractures are a type of femoral fracture that can occur during procedures, but are more often due to high energy forces or collisions, osteoporosis, osteolysis, or commonly from low energy falls from a standing position (6). These fractures are especially significant in the elderly who have increased fragility, as they are associated with substantial morbidity, disability, and even mortality. Furthermore, biological factors such as altered blood supply to the femur post-operatively, and mechanical issues such as reduced bone volume or misalignment of the prosthesis, contribute to the risk of implant instability (9). Additionally, excess body mass may have an effect on the number of falls, muscle function, and bone health, especially when trauma is not the primary cause of the periprosthetic fracture (10).

Although there are different classification systems, the Vancouver classification model is commonly used to categorize periprosthetic fractures of the femur (11). The efficacy and reliability of this model has been validated and is widely used in literature (12). This model also has practical use as it aids in the surgeon's decision-making process when determining optimal management strategies for periprosthetic fractures. Duncan (11) describes this classification which is divided into the following types: A, B, and C. Type A fractures include trochanteric fractures and are further subclassified as AG for those involving the greater trochanter or AL which involves the lesser trochanter. Type B fractures are subclassified as B1, B2, and B3. These types pertain to fractures along the shaft of the stem or slightly distal of the shaft. Type B1 fractures involve a fixed stem whereas type B2 fractures involve a loose stem. Thirdly, type B3 fractures are similar to B2, but significant bone loss is evident along with poor proximal bone stock and a loose stem. Finally, type C fractures include those distal to the tip of the prothesis.

The consideration of a number of factors is required when determining an approach to surgically managing periprosthetic fractures. These factors include fracture type and location (as mentioned above), implant type, bone stock quality, implant stability, surgeon experience, and anticipated patient's level of functioning or physical activity post-operatively (8,9). With such a variety of factors, it is difficult to study or find agreement on optimal surgical management. Specific surgical considerations are also made prior to operation. Among these are the management and preservation of femoral blood supply and surrounding soft tissue, as well as consideration for the use of trochanteric re-attachment plates. Depending on the fracture pattern, anatomical reduction and internal fixation may be adequate; however, more severe fractures often require revision arthroplasty. Typically, when fractures are minimally displaced and stems have good fixation, stem revision is not necessarily required, and open reduction and fixation with either trochanteric re-attachment plates or cerclage wires may be performed. Yet, for those fractures with increased fracture displacement and stem loosening, long-stem protheses are often the best treatment choice. Furthermore, plates, screws, and cerclage wires are used to provide additional support. Bone allografts may also be used depending on the severity of bone stock loss (9).

Stem design has evolved over the years and various literature addressing short-term outcomes exist. (8,13,14) Uncemented modular tapered stems have previously been used for revision of B2 and B3 periprosthetic fractures as these prostheses provide good axial and rotational stability (14). Axial stability is achieved by having the distal tapered end of the stem driven into the diaphysis of the femur whereas the fluted aspect of the stem provides rotational stability. Additionally, the use of modular femoral stems has been widely accepted and successfully applied for the management of periprosthetic fractures and other surgical revisions for aseptic loosening (8,15). With evidence to support short-term survivability and favorable functional scores in the context of significant bone loss, these modular tapered fluted titanium stems appear to be an appealing solution for periprosthetic fractures requiring stem replacement (8,16). Yet, nonmodular tapered fluted titanium stems have become an attractive option in North America for general revision arthroplasty and have shown comparable results, especially in the short-term follow-up (17). More recently, the tapered titanium stem approach has been considered for revision of periprosthetic fractures as described by Munro et al. (8). Determining stem survivorship as well as radiographic and functional outcomes from the use of tapered titanium hip stems in periprosthetic fractures will provide surgeons with a more informed decision for future prosthesis selection.

Revision hip arthroplasty due to periprosthetic fractures have high rates of complications compared to primary total hip arthroplasty (18,19), so it is important to measure and assess the risk of stem failure. Complications associated with this revision procedure include nonunion and poor osseous restoration, dislocation, implant failure, re-fracture, infection, and aseptic loosening. In a retrospective study that reviewed the outcomes following periprosthetic revision surgery, infection and nonunion were the most commonly reported complications (19). Potential predictors of failure include fracture union rate, bone type, stem fixation, stem migration, distal grip of the stem, prior revision history, and time since implantation. Patient factors including age, body mass, and activity can also contribute to risk of failure. Therefore, it is important to schedule routine follow-up appointments to assess serial radiographs and clinical outcomes in the form of patient surveys for pain perception, joint functionality, satisfaction, and overall quality of life. Although there are many elements used to assess failure risk, specific measures such as patient body mass index (BMI), functional surveys completed by patients, as well as radiographic assessment of subsidence, changes in bone stock, osseous restoration, and fracture union rate have been commonly used (8,13,14,17).

The purpose of this retrospective study was to investigate the efficacy of using tapered titanium hip stems in revision arthroplasty for periprosthetic fracture repairs at 2 year follow-up for survivorship; radiographic outcomes including fracture union, subsidence, and osseous restoration of bone stock; and self-reported functional outcomes. The results of this study can be used to compare the efficacy of other similar and different hip revision systems for periprosthetic fractures.

PATIENTS AND METHODS

Patient Selection and Re-Revisions

All femoral components used in the revision of periprosthetic fracture cases were tapered fluted titanium stems consisting of either the Revitan® Distal Straight stems (Zimmer, Inc) or Wagner SL Revision® hip stems (Zimmer, Inc) (Fig. 1). Between May 2008 and January 2016, Concordia Joint Replacement Group (Winnipeg, Manitoba) recorded 69 femoral revision cases for periprosthetic fractures with these stem models. Of the 69 cases, 32 did not return for a minimum of 2 year follow-up: 15 did not return since their surgery, nine did not return for a minimum of 2 year follow-up for unspecified reasons, and eight patients passed away at an average of 14 months after surgery (0 days to 63 months) without receiving documented follow-up. Of the remaining 37, two did not want to be included in research studies. Therefore, 35 patients with periprosthetic fractures were identified of which four stems were re-revised prior to 2 year follow-up. Of these re-revisions, one was a cup and liner exchange at 3 months post-operatively and was therefore excluded from the study as it was not a revision related femoral failure. Therefore, 34 cases were included in this study. Survivability was then determined by assessing the need for re-revision of a failed femoral component.

Fig. 1 Photograph of a Revitan® Distal Straight stem (left) and a Wagner SL Revision® stem (right).

The majority of patients returned for a minimum of 2 year follow-up; however, not all patients were able to return at exactly 24 months, and some only returned months or years after the minimum 24 month post-operative period. For the purposes of this study, 2 year follow-up included cases within 6 months prior to or after the 24 month mark (23 cases). Patients with longer follow-up times were still included in the analysis of this study. Other than follow-up appointments prior to 1 year and 6 months, the average time for minimum follow-up for this study's objectives was approximately 2 years and 4 months (range of 1 year, 9 months to 5 years, 0 months).

Of all cases, 10 were classified as B1 fractures, 13 were B2 fractures, 8 were B3 fractures, 2 were AL fractures (1 of which involved a fractured stem as well), and 1 was an unstable AG fracture. This study included 11 males and 23 females. The average age at surgery was 75 years (range 47 – 94 years old) and the mean BMI was 28.3 kg/m^2 (range 19.5 – 54.1 kg/m^2).

Operative Approach

Templating occurred prior to surgery in order to estimate stem dimensions. Surgery involved careful approaches to remove the stem and any cement present. In some cases, an osteotomy was performed to better access and remove the failed prosthesis. With each periprosthetic revision, cerclage wires were added circumferentially around the diaphysis of the femur. The femur was prepared by reaming to the predetermined depth. Stability, length, and offset were tested with trial stems. Trochanteric re-attachment plates were used in seven cases. Following discharge, patients were scheduled for frequent follow-up appointments initially, then scheduled to return at intervals of 6 months, 1 year, 2 years, and then various other years beyond that.

Radiographic Outcomes

Radiographs were reviewed to assess fracture type, survivability, and determine fracture healing in regards to several outcome measures, including fracture union and bone bridging, subsidence, and osseous restoration. The radiographic assessment included X-ray images of the fracture prior to surgery as well as post-operative views. These radiographs, and subsequent follow-up imaging, primarily included the femoral component in both AP (anterior-posterior) and lateral views. All measurements were made on digital radiograph images using Impax software.

When assessing femoral union, post-operative and subsequent follow-up images were assessed for callus bridging across the fracture and osteotomy sites in both AP and lateral views

(Fig. 2). Additionally, radiographs were assessed for potential migration of the fracture component (8,13,14). Various methods for measuring femoral component migration have been studied in order to assess accuracy (20).

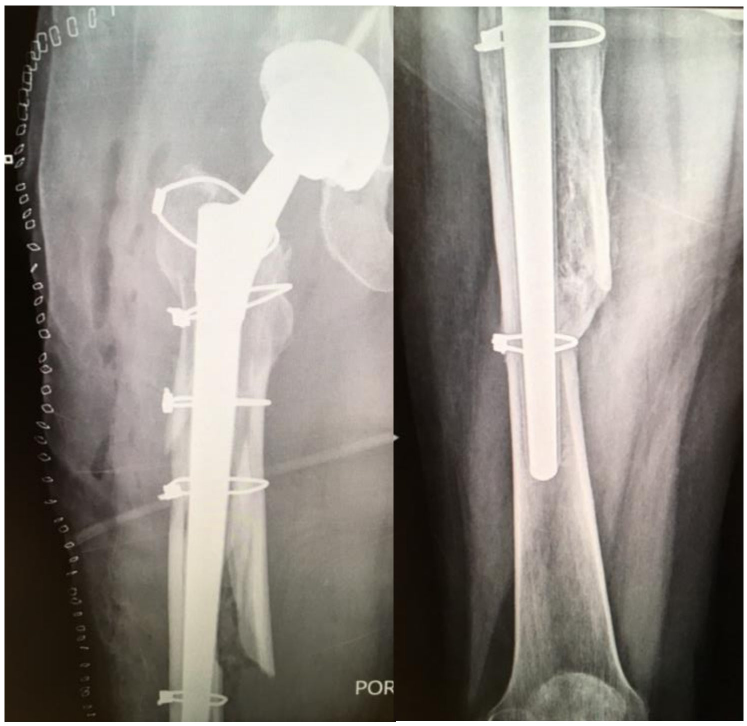

Fig. 2 Left: Immediate post-operative radiograph of a periprosthetic fracture repair. Right: Fracture union and bone bridging at the fracture site at 2 years post-operatively.

Another radiographic finding assessed was subsidence, which occurs when the femoral stem migrates inferiorly following the arthroplasty procedure. Similar to other studies (8,14), subsidence was measured from the shoulder of the femoral stem to the most distal cerclage wire available on sequential radiographs (Fig. 3). Accuracy of the scale was confirmed by using the known femoral head size for each case. As described by Munro et al (8), subsidence was divided into three categories: 0 to 3 mm, 3 to 10 mm inclusive, and greater than 10 mm. Furthermore, if subsidence was present, additional follow-up radiographs were assessed for progression or stability of the subsidence. Subsidence more than 10 mm has been regarded as prosthesis failure (13) and determined to be clinically significant (21).

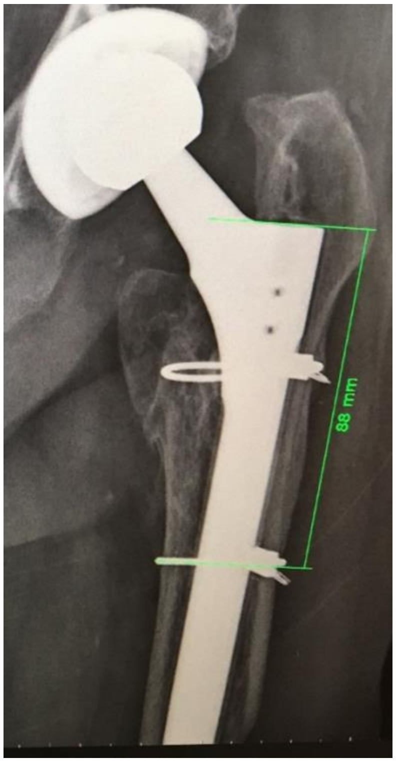

Fig. 3 Impax software used to assess digital radiographs for subsidence by measuring the distance between the center of the most distal cerclage wire and the shoulder of the stem.

Finally, femoral bone stock changes and osseous restoration were assessed on radiographs. Osseous restoration can be qualitatively measured by assessing for bone defect resolution, but was quantitatively determined by measuring cortical and medullary thickness and by calculating cortical index (22,23).

Functional Scores

Clinical outcomes and quality of life were determined from standardized questionnaires including the Oxford Hip Score which includes 12 questions used to assess patient function and pain following hip replacement surgery. Total scores ranged from 0 (worst score) to 48 (best score) (24,25). Mean Oxford scores were determined at 2 years post-operatively. Additionally, a 5-point scale was used to assess patient satisfaction (1 – very satisfied, 2 – satisfied, 3 – neutral, 4 – unsatisfied, 5 – very unsatisfied) at 2 years post-operatively. Only 16 of 31 patients completed post-operative surveys at 2 years as eight patients did not return for adequate follow-up, and seven patients did not complete the survey during their follow-up visit.

Statistical Analysis and Relationships

Pearson linear correlation coefficients (r) were determined using SPSS software to evaluate relationships between radiographic findings, functional scores, and patient demographics. Of particular clinical interest was comparisons between radiographic subsidence with functional outcomes to assess whether radiographic and clinical data were associated with one another in assessing failure risk. Subsidence was also correlated with cortical indices in an attempt to assess stem stability at 2 years post-operatively. Furthermore, subsidence was compared with the use of trochanteric re-attachment plates and stem models to assess whether differences between stem design and surgical management existed. The relationship between subsidence and fracture class was also determined to assess whether higher grade fractures were associated with increased subsidence. BMI was measured against subsidence as well to determine if heavier patients impacted the degree of subsidence. Fracture type was also correlated with functional scores to assess whether more severe fractures resulted in increased subsidence and worsened clinical outcomes. Finally, age and BMI were correlated against functional scores as heavier and older patients may score lower on average.

SPSS software was used to conduct statistical analyses to find intra-rater reliability and correlations between data. Intraclass correlation coefficients (ICC) for subsidence and cortical indices along with the upper and lower bounds for a 95% confidence interval (CI) were calculated to measure intra-rater reliability. Intra-rater reliability was excellent for radiographic measurements of subsidence and cortical indices. Subsidence had an ICC of 1.000 (CI 95%, 1.000 – 1.000). An average ICC of 0.997 (CI 95%, 0.995 – 0.999) was determined for the cortical index.

Ethics Approval

All data was reviewed and collected at Concordia Joint Replacement Group. This retrospective database study was approved by the Bannatyne Research Ethics Board at the University of Manitoba.

RESULTS

Re-Revisions

Three patients required re-revisions. These re-revisions occurred as early as 4 months and as late as 10 months post-operatively. One re-revision occurred due to aseptic loosening at 4 months. Another re-revision was for a trochanteric fracture and joint dislocation at 5 months post-operatively. Finally, one stem was re-revised at 10 months as a result of joint infection. However, no other re-revisions of the femoral stem were required and none occurred beyond 10 months. Subsidence was not accurately determined for two of these cases; however, subsidence (13 mm at 4 months post-operatively) was present on the stem re-revised for aseptic loosening.

Radiographic Outcomes

Bone bridging and fracture union was identified in nearly all cases. Of the 34 patients, 30 patients (88%) had evidence of complete fracture union, three of which were the early re-revision cases. Bone or callus bridging across the fracture site was identified, as well as across the osteotomy for stems with fracture union. One case (B3) had near complete fracture union at 2 years and 8 months with 2 mm of subsidence and evidence of spot welding. Further imaging was unavailable for this case.

Overall, 15 of 34 cases (44%) showed evidence of subsidence. From these cases, subsidence occurred in one type A fracture (7%) which included a fractured stem. Otherwise, five cases of subsidence occurred in B1 fractures (33%), four in B2 fractures (27%), and five in B3 fractures (33%). Five cases (33%) had less than 3 mm of subsidence, seven cases (47%) were between 3 mm and 10 mm inclusive, and three cases (20%) were greater than 10 mm (greatest was 16 mm). Two cases were less than 3 mm. Seven cases required trochanteric re-attachment plates and subsidence (less than 3 mm) occurred in two of these cases. The mean stem migration was 2.6 mm.

Overall, osseous restoration and increased or maintenance of bone stock occurred in 31 of 34 patients (91%). At 2 years, 17 of 23 patients (74%) showed osseous restoration and increased bone stock with a higher cortical index at follow-up measurements. For patients beyond 2 years, seven of eight had an increased cortical index, and one index remained unchanged. Osseous restoration and stabilization was identified in additional follow-up radiographs.

Functional Scores

Self-reported pain and functional outcomes were good among patients who completed the surveys. The mean Oxford scores at 6 months, 1 year, and 2 years were 32.2 (N = 17), 35.1 (N =

20), and 37.8 (N = 16), respectively. At 2 years post-operatively, 44% (N = 7) were very satisfied, 50% (N = 8) were satisfied, and 6% (N = 1) expressed a neutral opinion. In the case of a re-revision for infection, the patient scored 38 on the 1 year Oxford survey. Survey results for the other re-revision cases were not completed.

Statistical Analysis and Relationships

Correlations were determined to be significant at a 95% confidence level (2-tailed test). Particular relationships of interest were those involving subsidence (Table 1). However, subsidence had no significant associations. Furthermore, the use of trochanteric re-attachment plates did not correlate with other outcome measures. No significant differences in 2 year Oxford or satisfaction scores were found when comparing B1, B2, and B3 fracture types together. Fracture types AG and AL were not included as there was limited data. In regards to this study's objectives, no other relevant or significant associations were identified. Although no correlations were found to be significant, the power for this study was unsatisfactory due to sample size.

Table 1. Correlations between subsidence with other outcome measures of interest.

Outcome Measure	Correlation coefficient (r)	p value
2 year Oxford score	-0.152	0.574
2 year satisfaction score	-0.149	0.581
Change in cortical index at 2 years	-0.040	0.839
Stem model	-0.193	0.326
Fracture classification	-0.103	0.603
BMI	0.118	0.676

DISCUSSION

Re-Revisions

Overall, a survivorship of 91% was determined at 2 years post-operatively which was good as comparable to other literature (10,13,15,26). Of the stems in this study, three (9%) were re-revised within 10 months. Yet all remaining stems beyond 10 months showed 100% survivorship at an average minimum of 28 months follow-up and at further follow-up assessments up to 5 years post-operatively. Prosthesis failure or re-revision did not occur beyond 10 months. Two patients passed away after 2 year follow-up without recorded complications of their joints. Short-term follow-up for the two re-revision cases for infection and trochanteric fracture with dislocation was insufficient and subsidence was inaccurate; however, these stems showed incomplete union of the fracture site prior to re-revision. Functional scores were unavailable for these cases.

Radiographic Outcomes

Including stems requiring early re-revision, 88% of the 34 cases showed fracture union. Yet, of the 31 cases with follow-up at or above 2 years, 30 (97%) showed complete fracture union. Therefore, 22 cases meeting 2 year follow-up and eight cases with later follow-up (2 years, 7 months to 5 years, 0 months) showed complete fracture union. The single case at 2 year follow-up showing incomplete union had minimal subsidence (2 mm) as well as evidence of spot welding along the distal shaft of the implant. This fracture was determined to have incomplete union as both the lateral and AP plain views did not accurately show complete osseous formation across the fracture site and osteotomy site. However, there was evidence of bone growth and an increased cortical index. These findings suggest a degree of stem stabilization. Literature also reports high short-term survivorship and low rates of re-revision for subsidence and infection among other reasons for tapered fluted femoral stems (8). Other studies assessed similar tapered fluted stems and found comparable radiographic results to this study, including union rate (Table 2).

Table 2. Radiographic and clinical outcomes reported in literature for periprosthetic fractures treated with tapered fluted titanium stems.

Study	Number of patients	Mean follow-up (months)	Union rate	Maintenance or improvement of bone stock	Total stems re-revised	Cases of infection	Cases of loosening	Subsidence (mm)	Clinical outcomes (normalized mean scores)
Park et al. (2009) (13)	27	56	93% by 12 months	Not reported	0	1	0	>5 in 1 stem >10 in 1 stem	Harris Hip Score: 85
Neumann et al. (2012) (14)	55	67	100% by 6 months	Not reported	2	1	2	>5 in 2 stems	Harris Hip Score: 72
Munro et al. (2013) (8)	55	54	98% by 24 months	89%	2	1	1	<3 in 5 stems 3-10 in 2 stems >10 in 2 stems	Oxford Hip Score: 76
Current study	34	28	88% by 24 months	91% by 24 months	3	1	1	<3 in 5 stems 3-10 in 7 stems >10 in 3 stems	Oxford Hip Score: 73

Subsidence was a common occurrence but also variable, with an average inferior migration of 2.6 mm. In the re-revision case with aseptic loosening, subsidence was 13 mm at 4 months post-operatively. In this case, an early re-revision was required as the fracture increased in size and neither fracture union or spot welding was evident. For cases in which subsidence occurred at 2 year follow-up and further follow-up radiographs were available, only one case showed an increased 3 mm subsidence, three cases had subsidence of 1 mm or 2 mm, and four cases had no additional subsidence on follow-up. The six subsidence cases without further follow-up originally had 5 mm or less of distal movement of the stem. However, for the 44% of cases where subsidence occurred, spot welding and distal fixation of the stem was present in all cases at 2 years and/or in all available follow-up images. Interestingly, 38% of the cases were actually measured to have negative subsidence of -1 mm to -4 mm at a minimum of 2 years. The variability of subsidence measurements and negative subsidence suggests possible error in measurement or inconsistency among radiographs of the same patient. Although measurements were accurately reproducible with an intra-observer ICC of 1.000, inter-observer error was not determined as there was only one rater. Additional observers could potentially add variability to measurements and may make some of the current measurements falsely high or low. It is likely that negative subsidence and minor variation in lengths may be attributed to how the radiographs were taken, because adequate positioning of the patient is necessary to accurately measure the most distal cerclage wire to the shoulder of the femoral component. Although cerclage wires are fairly fixed circumferentially around the femur and have been used in other studies as reference points (8,14), patient rotation can also affect the position of the wires on radiographs and therefore alter the distance between the wires and the shoulder of the stem (Fig. 4). Radiograph inconsistencies, evidence of osseous bridging and fracture union, presence of distal spot welding, and generally small measurements of subsidence support the concept of better implant fixation, and therefore, stabilization of subsidence.

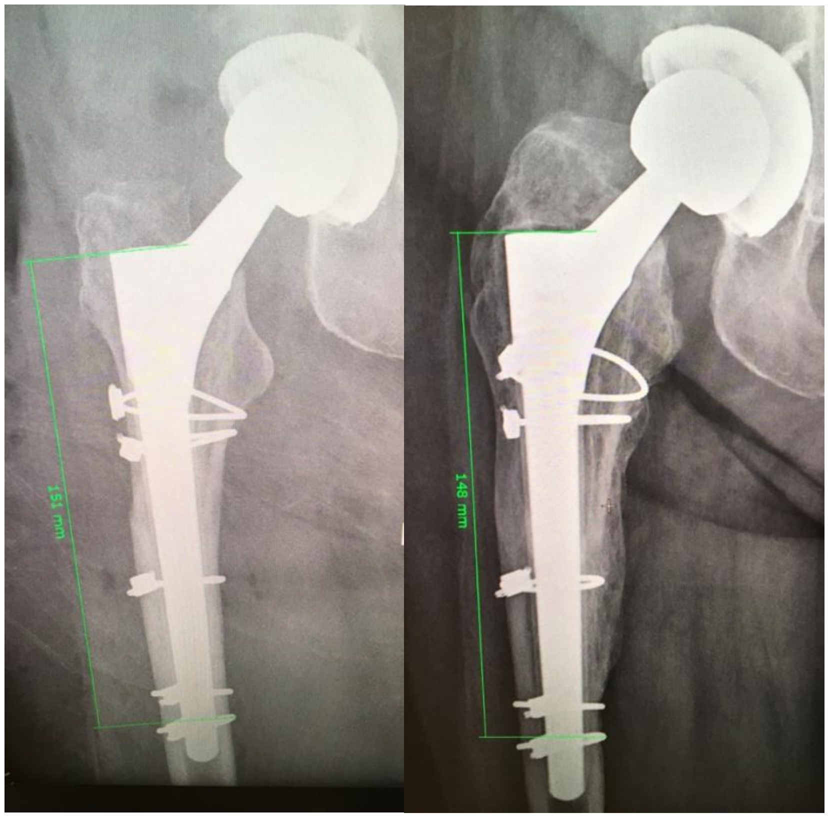

Fig. 4 3 mm of subsidence at 2 years post-operatively. Patient rotation and image quality differs between the immediate post-operative image (left) and the follow-up image (right).

Some studies found that 3 mm or less of subsidence was not considered to be clinically significant (27,28). Furthermore, Park et al (13) and Neumann et al (14) defined definite loosening as subsidence greater than 5 mm or if demarcation was continuous around the stem. Yet, Park et al (13) stated that subsidence above 10 mm has been regarded as prosthesis failure, which Kolstad et al (21) agreed was clinically significant. Subsidence greater than 5 mm only occurred in four cases in the current study, one of which failed at 4 months. This result was comparable to similar studies (Table 2). Two cases that did not require re-revision were above 10 mm. However, both cases showed fracture union, spot welding, improved cortical indices, reduced subsidence on further follow-up, and good Oxford and satisfaction scores. For the surviving cases in this study with subsidence greater than 5 mm at a minimum follow-up of 2 years, the mean Oxford score was 33 and the mean satisfaction score was 1.7. The degree of subsidence is one factor to consider when assessing survivorship of stems. It is also important to recognize subsidence progression and other features of stem fixation such as fracture union, osseous restoration, and spot welding. In the current study, there were no statistical relationships between degree of subsidence with fracture union or clinical outcomes.

Maintenance or improvement of bone stock and cortical indices was observed in 91% of all patients, but in 100% of patients with at least 2 year follow-up. These results were comparable to Munro et al. (8). Although this parameter was more challenging to accurately measure, the intra-rater ICC was still excellent (0.997). For patients where additional follow-up radiographs were available, bone stock changes showed either stabilization or improvement (increased cortical index). It has been suggested that osseous restoration is associated with long-term results, and that the Wagner revision stem has had success with new bone formation (22). However, qualitative radiograph assessments and the cortical index are only two aspects of describing bone remodeling. It is also important to consider initial degree of bone loss, intraoperative technique during the revisions, and mechanical stability.

Functional Scores

For those patients that completed pain and functional surveys, the scores showed improvement and overall good outcomes. Generally, for the Oxford survey, pre-operative scores are essential when determining outcome measures because they provide a baseline number for comparison. However, as mentioned earlier, pre-operative scores were limited due to the nature of these fractures and urgency for revision. Although there is no firm cut off for scores, categories have been suggested such that scores less than 27 are poor, 27 to 33 are fair, 34 to 41 are good, and greater than 41 are excellent (24,29). Using this categorization, the average Oxford scores at 1 year (35.1, N = 20), and at 2 years (37.8, N = 16) were good. In a similar study, Munroe et al (8) reported a mean Oxford score, normalized to a range from 0 to 100, of 76 (N = 28). Normalizing the scores in this study would yield similar results with a mean of 73 (N = 20) at 1 year and 79 (N = 16) at 2 years. Furthermore, in a cross-sectional study, Garbuz et al (15) compared the quality of life for patients with two different femoral stems and reported a mean normalized Oxford score of 79 (N = 31) for the tapered fluted titanium stem. In regards to satisfaction scores, patients averaged between “satisfied” and “very satisfied” at 2 years. No patient was dissatisfied with their revision prosthesis at 2 years post-operatively.

Statistical Analysis and Relationships

Among the relationships described in this study, none were statistically significant (Table 1). However, Oxford scores at 6 months were moderately correlated with age ($r = -0.496$, $p = 0.043$) and Oxford scores at 2 years were moderately correlated with BMI ($r = -0.698$, $p = 0.025$). This suggests that more elderly and larger patients rated lower on pain and functional scores. Murray et al (24) also suspected that elderly patients tend to score lower.

Limitations

There were several limitations in this study. Firstly, there was no control group as this was a retrospective study. Outcome measures are only available if they have been accurately and reliably recorded. As a result, there were missing data points for various patients. In addition to this limitation, scheduled follow-up appointments were not always attended on time. The majority of patients in this study had a minimum 2 year follow-up appointment, but several patients were seen at a later time. This affected the ability to compare radiographic measurements across all patients within a similar time frame. Another limitation was the unspecified reasons for patients to not return for follow-up appointments. Other potential and less likely reasons for poor and unrecorded follow-up may include the patient passing away or requiring a revision elsewhere. Pre-operative pain and functional scores did not exist due to the nature of these fractures and the urgency to surgically correct them. In regards to the radiographic assessment, images were not always consistent within one patient's imaging set or between patients. There were occasional image quality issues such as with rotation, patient positioning, and X-ray exposure. This affected the ability to appropriately scale and compare images over the years. Furthermore, there was user bias, as only one observer assessed radiographic measurements. In terms of fracture classification, Lindahl et al (5) found that a significant number of fractures originally classified as fixed were in fact loose, as it was difficult to make the distinction on radiographs alone. Therefore, this could decrease the number of B1 fractures and increase the number of B2 or B3 fractures in this study, thereby affecting correlational data. Having experienced orthopaedic surgeons assess fracture type and fracture healing may have produced slightly different results as well.

CONCLUSION

This study showed promising 2 year post-operative results to suggesting that tapered fluted titanium stems are a viable option for the repair of periprosthetic fractures. Although three re-revisions were required prior to 1 year follow-up, survivorship beyond that period was excellent with good fracture union and osseous restoration, minimal subsidence and stabilization upon further follow-up, and good clinical outcomes. Of the many implant choices surgeons have for the management of periprosthetic fractures, tapered fluted titanium hip stems appear to be a desirable option especially in the short-term (8,13–15). Although this study addressed a limited number of longer term (up to 5 years) results that showed maintenance of fracture union and stabilization, the majority of cases and primary outcomes were assessed at 2 years post-operatively. The correlations between radiographic findings and clinical outcomes were insignificant, but consideration of both radiographic and clinical outcomes is still important in practice. Subsidence of 3 mm or less appeared to be insignificant, but the clinical significance of subsidence increases as the inferior migration increases (13,14,21). The findings from this study can be used to further justify tapered fluted titanium stems for the use of periprosthetic fracture repair, as there were good 2 year outcomes which were also comparable to recent literature. Further research on the long-term use of these stems may be beneficial; however, with good fixation of the stem, subsidence may be a less likely cause for failure in the long-term.

ACKNOWLEDGEMENTS

The author would like to thank Dr. Eric Bohm (MD, B.Eng., M.Sc., FRCSC) for his mentorship with the project, Trevor Gascoyne for his mentorship and assistance with the statistical analysis, and Sarah Tran for her aid with the database. The author would also like the thank the Orthopaedic Innovation Centre and Concordia Joint Replacement Group for their accommodation with this project.

REFERENCES

1. Haas SB, Sculco TP. Hip and Knee Replacement Surgery FAQs - HSS.edu [Internet]. Hospital for Specialty Surgery. 2016 [cited 2018 Nov 26]. Available from: https://www.hss.edu/conditions_hip-knee-replacement-surgery-faqs.asp

2. Della Rocca GJ, Leung KS, Pape H-C. Periprosthetic Fractures: Epidemiology and Future Projections. J Orthop Trauma [Internet]. 2011 Jun [cited 2019 Jan 23];25:S66–70. Available from: https://insights.ovid.com/crossref?an=00005131-201106002-00009

3. Pivec R, Issa K, Kapadia BH, Cherian JJ, Maheshwari AJ, Bonutti PM, et al. Incidence and Future Projections of Periprosthetic Femoral Fracture Following Primary Total Hip Arthroplasty: An Analysis of International Registry Data. J Long Term Eff Med Implants [Internet]. 2015 [cited 2019 Jan 23];25(4):269–75. Available from: http://www.dl.begellhouse.com/journals/1bef42082d7a0fdf,4bdc1cd97aa810ac,6471eb13341b3876.html

4. Abdel MP, Houdek MT, Watts CD, Lewallen DG, Berry DJ. Epidemiology of periprosthetic femoral fractures in 5417 revision total hip arthroplasties. Bone Joint J [Internet]. 2016 Apr 1 [cited 2019 Jan 23];98–B(4):468–74. Available from: http://online.boneandjoint.org.uk/doi/10.1302/0301-620X.98B4.37203

5. Lindahl H, Malchau H, Herberts P, Ran Garellick G. Periprosthetic Femoral Fractures Classification and Demographics of 1049 Periprosthetic Femoral Fractures from the Swedish National Hip Arthroplasty Register. J Arthroplasty [Internet]. 2005 [cited 2019 Jan 23];20(7):857–65. Available from: https://ac-els-cdn-com.uml.idm.oclc.org/S0883540305001117/1-s2.0-S0883540305001117-main.pdf?_tid=575b4847-4def-4e1d-ad0b-

ee651b974041&acdnat=1548293804_e3707297e4c9c98e5c87f46991f669f0

6. King SW, Lamb JN, Cage ES, Pandit H. Periprosthetic femoral fractures following total hip and total knee arthroplasty. 2018 [cited 2019 Jan 23]; Available from: https://doi.org/10.1016/j.maturitas.2018.08.010

7. Bozic BKJ, Kurtz SM, Lau E, Ong K, Vail TP, Berry DJ. The Epidemiology of Revision Total Hip Arthroplasty in the United States. J Bone Jt Surg. 2009;91:128–33.

8. Munro JT, Garbuz DS, Masri BA, Duncan CP. Tapered Fluted Titanium Stems in the Management of Vancouver B2 and B3 Periprosthetic Femoral Fractures. Clin Orthop Relat Res. 2014;472(2):590–8.

9. Rüedi T, Perka C, Schütz M. Periprosthetic Fracture Management. Stuttgart: Georg Thieme Verlag; 2013.

10. Marks R. Impact of Obesity on Complications following Primary Hip Joint Arthroplasty Surgery for Osteoarthritis. Arthritis [Internet]. 2015 [cited 2019 Feb 26]; Available from: http://dx.doi.org/10.4172/2167-7921.S1-003

11. Duncan CP, Masri BA. Fractures of the femur after hip replacement. Instr Course Lect [Internet]. 1995 [cited 2019 Feb 18];44:293–304. Available from: http://www.ncbi.nlm.nih.gov/pubmed/7797866

12. Brady OH, Orth M(, Garbuz DS, Masri BA, Duncan CE. The Reliability and Validity of the Vancouver Classification of Femoral Fractures After Hip Replacement [Internet]. Vol. 15, The Journal of Arthroplasty. 2000 [cited 2019 Feb 18]. Available from: https://ac-els-cdn-com.uml.idm.oclc.org/S0883540300911811/1-s2.0-S0883540300911811-main.pdf?_tid=b6f321dc-3f4f-48ca-874d-0922613c67d4&acdnat=1550532148_142290bb0bbad44a202f2447e7e6dbae

13. Park MS, Lim YJ, Chung WC, Ham DH, Lee SH. Management of Periprosthetic Femur Fractures Treated With Distal Fixation Using a Modular Femoral Stem Using an Anterolateral Approach. J Arthroplasty [Internet]. 2009;24(8):1270–6. Available from: http://dx.doi.org/10.1016/j.arth.2009.07.013

14. Neumann D, Thaler C, Dorn U. Management of Vancouver B2 and B3 femoral periprosthetic fractures using a modular cementless stem without allografting. Int Orthop. 2012;36(5):1045–50.

15. Garbuz DS, Toms A, Masri BA, Duncan CP. Improved outcome in femoral revision arthroplasty with tapered fluted modular titanium stems. Clin Orthop Relat Res. 2006;(453):199–202.

16. Sporer SM, Paprosky WG. Femoral Fixation in the Face of Considerable Bone Loss. Clin Orthop Relat Res. 2004;429(429):227–31.

17. Sandiford NA, Garbuz DS, Masri BA, Duncan CP. Nonmodular Tapered Fluted Titanium Stems Osseointegrate Reliably at Short Term in Revision THAs. Clin Orthop Relat Res. 2017;475(1):186–92.

18. Zuurmond RG, Van Wijhe W, Van Raay JJAM, Bulstra SK. High incidence of complications and poor clinical outcome in the operative treatment of periprosthetic femoral fractures: An analysis of 71 cases. Injury [Internet]. 2010 [cited 2019 Apr 14];41:629–33. Available from: https://pdf.sciencedirectassets.com

19. Holder N, Papp S, Gofton W, Beaulé PE. Outcomes following surgical treatment of periprosthetic femur fractures: a single centre series. Can J Surg [Internet]. 2014 Jun [cited 2019 Apr 14];57(3):209–13. Available from: http://www.ncbi.nlm.nih.gov/pubmed/24869614

20. Biedermann R, Krismer RM, Professor Stöckl AB, Registrar S, Mayrhofer P, Professor A, et al. THE JOURNAL OF BONE AND JOINT SURGERY Accuracy of EBRA-FCA in the measurement of migration of femoral components of total hip replacement [Internet]. J Bone Joint Surg [Br]. 1999 [cited 2019 Mar 24]. Available from: https://online.boneandjoint.org.uk/doi/pdf/10.1302/0301-620X.81B2.0810266

21. Kolstad K, Adalberth G, Mallmin H, Milbrink J, Sahistedt B. Acta Orthopaedica Scandinavica The Wagner revision stem for severe osteolysis: 31 hips followed for 1.5-5 years. 2009 [cited 2019 Mar 24]; Available from: https://www.tandfonline.com/action/journalInformation?journalCode=iort20

22. Böhm P, Bischel O. Femoral revision with the Wagner SL revision stem: Evaluation of one hundred and twenty-nine revisions followed for a mean of 4.8 years. J Bone Jt Surg - Ser A. 2001;83(7):1023–31.

23. Callaghan JJ, Salvati EA, Pellicci PM, Wilson PD, Ranawat CS. Results of revision for mechanical failure after cemented total hip replacement, 1979 to 1982. A two to five-year follow-up. J Bone Jt Surg - Ser A. 1985;67(7):1074–85.

24. Murray DW, Fitzpatrick R, Rogers K, Pandit H, Beard DJ, Carr AJ, et al. The use of the Oxford hip and knee scores. J BONE Jt Surg Annot [Internet]. 2007 [cited 2019 Mar 31]; Available from: https://online-boneandjoint-org-uk.uml.idm.oclc.org/doi/pdf/10.1302/0301-620X.89B8.19424

25. Fitzpatrick R, Dawson J, Fitzpatrick R, Carr A, Murray D. QUESTIONNAIRE ON THE PERCEPTIONS OF PATIENTS ABOUT TOTAL HIP REPLACEMENT [Internet]. Vol. 78. 1996 [cited 2019 Mar 30]. Available from: https://online-boneandjoint-org-uk.uml.idm.oclc.org/doi/pdf/10.1302/0301-620X.78B2.0780185

26. Philippe H, Nicolas D, Jerome D, Isaac G, Alexandre P, Jerome A, et al. Long, titanium, cemented stems decreased late periprosthetic fractures and revisions in patients with severe bone loss and previous revision. Int Orthop. 2015;39(4):639–44.

27. Al-Najjim M, Khattak U, Sim J, Chambers I. Differences in subsidence rate between alternative designs of a commonly used uncemented femoral stem. J Orthop [Internet]. 2016 Dec [cited 2019 Apr 20];13(4):322–6. Available from: http://www.ncbi.nlm.nih.gov/pubmed/27436922

28. Liska WD, Doyle ND. Use of an Electron Beam Melting Manufactured Titanium Collared Cementless Femoral Stem to Resist Subsidence After Canine Total Hip Replacement. Vet Surg [Internet]. 2015 Oct 1 [cited 2019 Apr 20];44(7):883–94. Available from: http://doi.wiley.com/10.1111/vsu.12353

29. Kalairajah Y, Azurza K, Hulme C, Molloy S, Drabu KJ. Health Outcome Measures in the Evaluation of Total Hip Arthroplasties-A Comparison Between the Harris Hip Score and the Oxford Hip Score. J Arthroplasty [Internet]. 2005 [cited 2019 Mar 31];20(8). Available from: https://pdf.sciencedirectassets.com