ACTA
ORTHOPAEDICA
et
TRAUMATOLOGICA
TURCICA

EXPERIMENTAL STUDY

Acta Orthop Traumatol Turc 2011;45(4):266-269
doi:10.3944/AOTT.2011.2338

The biomechanical assessment of fixation methods in periprosthetic femur fractures

Mehmet GÜLŞEN,[1] Vasfi KARATOSUN[1], Bahadır UYULGAN[2]

[1]Department of Orthopaedics and Traumatology, Medical Faculty, Dokuz Eylül University, İzmir, Turkey;
[2]Department of Metallurgical and Materials Engineering, Engineering Faculty, Dokuz Eylül University, İzmir, Turkey

Objective: The aim of our study was to compare the biomechanical properties of different fixation methods used in periprosthetic femur fractures.

Methods: We created sawbone models with Mallory Type 2 periprosthetic femur fractures. The periprosthetic fractures were fixed with cables, cables and strut graft, or cables and plates. The biomechanical properties of these three different fixation methods were compared with the intact femur, the intact femur with prosthesis and the femur with periprosthetic fracture without fixation.

Results: The periprosthetic fracture without fixation had a significantly lower yield point value than the periprosthetic fractures with fixation ($p<0.05$). There was no significant difference between the three different fixation methods of the periprosthetic fractures. The intact femur with a prosthesis showed statistically higher values than all three fixation methods of perioprosthetic fractures.

Conclusion: Mallory Type 2 periprosthetic fractures should be fixed. There is no difference among the fixation methods used in the study and none of them provide a stability equivalent to that of an intact femur with prosthesis.

Key words: Arthroplasty; biomechanics; composite; femur; fracture; hip; periprosthetic.

In line with the increase in the mean age of the population, the number of primary and revision arthroplasties performed are steadily increasing. Thus, it can be expected that the number of periprosthetic fractures will also rise.[1]

Although a variety of treatment modalities for periprosthetic fractures have been recommended in the literature, no consensus exists on the most appropriate type of fixation.[2,3] Options include many cable and plate systems used alone or in combination.[4,5] Unfortunately, a review of the literature revealed no biomechanical studies comparing fixation modalities in the treatment of Mallory Type 2 periprosthetic fractures (linear or spiral fractures, extending 4 cm distal to trochanter minor).[6] The present study was conducted to evaluate the commonly used fixation techniques for this type of fracture.

Materials and methods

Eight synthetic composite femurs (no: 3303, Sawbones®, Malmö, Sweden) were biomechanically tested to detect the yield point and rigidity values of

Correspondence: Vasfi Karatosun, MD. Erzene Mah. 166/16 Sok. No: 8/12, Bornova 35050, İzmir, Turkey.
Tel: +90 232 - 412 33 60 e-mail: vasfi.karatosun@deu.edu.tr

Submitted: September 2, 2009 **Accepted:** December 21, 2010

the proximal femur under axial loading. Initially, these 8 intact femurs were directly tested (Group 1). Next, the head and neck portions of the femurs were resected and implanted with a 1/3 hydroxyapatite-coated Versys prosthesis (Zimmer®, Warsaw, IN, USA) and tested (Group 2). After the completion of the Group 2 testing, a Mallory Type 2 periprosthetic fracture was created with an oscillating saw 4 cm distal to the lesser trochanter in the 8 femurs and tested (Group 3). Then, the models were fixed with 2 Cable-Ready® cables (Zimmer®, Warsaw, IN, USA) with a 35 mm distance between the cables (Fig. 1) and tested (Group 4). Next, fixation with 2 Cable-Ready® cables was strengthened with a cortical strut graft, 20x85 mm in dimensions, harvested from composite bone (Fig. 1) and tested (Group 5). Lastly, the test was repeated after fixation with a Cable-Ready® Cable Grip System (Zimmer®, Warsaw, IN, USA) which included a titanium plate, 23x121 mm in dimensions, and 4 cables (Fig. 2) (Group 6). In the last 3 groups, the cables were tigthened to 400 N by a tensioning device (Zimmer®, Warsaw, IN, USA).

The specimens were 3rd generation cortical analogues similar to the human bone in terms of ultimate tensile strength, ultimate compressive strength and fracture toughness. Each femur was used in all 6 groups, so six loading tests were applied to each femur. The femur was mounted on a metal base with a locking intramedullary nail of 14 centimeters, which was driven into and filled the femoral canal, and fixed with a cortical screw. Femoral condyles were positioned parallel to the compressing plate of the testing machine and to the ground, with both condyles sitting on the base simulating a standing position.

Loading tests were performed in the Mechanical Experiments Laboratory at the Department of Metallurgy and Materials Engineering at Dokuz Eylül University Faculty of Engineering. An Autograph AG-50kNG universal testing machine (Shimadzu Corp., Kyoto, Japan) was used for the tests. Samples were loaded axially towards the head of the prosthesis at a speed of 1 mm/min. Data was collected and recorded at intervals of 50 milliseconds. Failures or downfall loads that could occur on the samples were monitored on real time graphs. With the help of load (N) - displacement (mm) curves resulting from the measurements, yield points and rigidity values of the samples were identified. A sample of the load (N) - displacement (mm) curve is shown in Figure 2. The intersection point of the curve with a second line passing parallel at a distance of 0.2% of the sample length from the linear part of the curve is the yield point. The entire testing setup is displayed in Figure 3. As the samples were used for different configurations, to prevent the destruction or plastic deformation of the samples used in our study, the ratio of 0.2% was reduced to 0.02% and the yield point was taken as the intersection of the curve with the line parallel to the linear part of the curve. The x-axis distance between the linear part of the curve and the line parallel to the linear part of the curve was 0.1 mm. During the loading tests, the point identified by the testing device was exceeded; however, the intersection point of the parallel line of 0.2% was not reached. Therefore, model destruction or plastic deformation did not occur during the tests, since the testing machine automatically stopped loading before the real yielding point (0.2% length deformation).

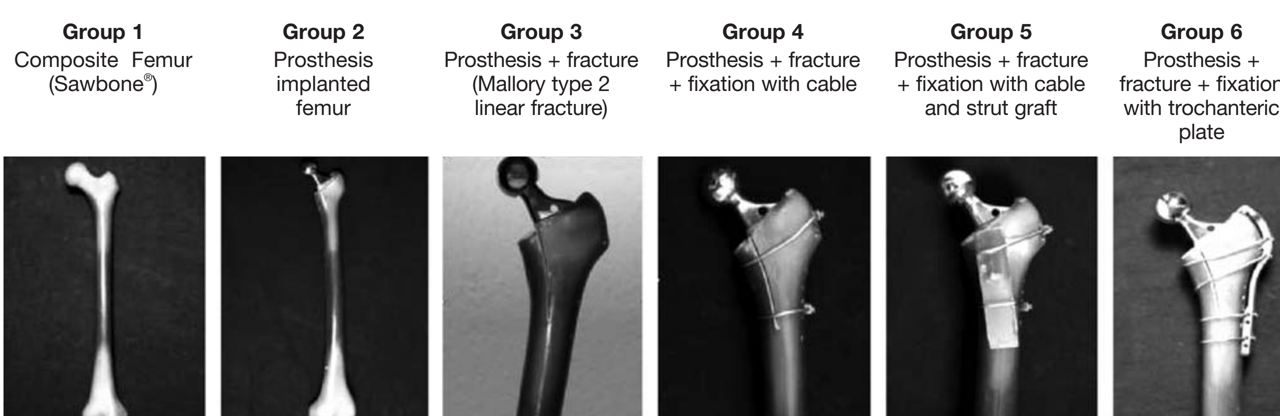

Fig. 1. Details of the groups. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

Table 1. Mean yield point and rigidity values.

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Yield point (N)	1,436.4	1,941.4	936.7	1,302.8	1,281.7	1,401.3
SD	186.1	465.9	152.5	177.7	230.3	248.1
Rigidity (N/mm)	630.1	846.9	753.0	820.1	825.9	780.1
SD	123.9	117.9	70.1	85.6	59.3	79.1

The linearity of load (N) - displacement (mm) curves was observed between 300-600 N in all resulting graphs. The extent of deformation (mm) between these values was identified for each sample. The rigidity values (N/mm) were determined by finding the tangents of the angles between the linear parts of the curves and the extent of deformation on the x-axis.

Statistical analyses were performed using SPSS software (Release 11 for Windows, SPSS Inc., IL, USA). Kruskal-Wallis and Mann-Whitney U tests were used where appropriate. P values less than 0.05 were considered statistically significant.

Results

Results are displayed in Table 1. The lowest yield points were obtained for Group 3, indicating that a fracture without fixation is more prone to deformation. Although all types of fixation improved rigidity, the results were all lower than those of Group 2 (femur with prosthesis without fracture). None of the fixation methods were better than another. The difference in the yield point in Group 3 was significantly different ($p<0.05$) from all other groups. In addition, Group 2 showed statistically higher values than those of Group 3, 4, 5, and 6 (Table 1).

There was also a significant difference between the rigidity of Group 1 and those of the others ($p<0.05$) (Table 1). When the prosthesis was implanted, rigidity increased significantly. There was no significant difference, however, between the different fixation methods using cables, strut grafting or plates.

Discussion

Periprosthetic fractures are still an important complication in hip arthroplasty. According to Berry, the rate of periprosthetic fracture was 0.03% in cemented and 5.4% in uncemented primary total hip arthroplasties. This rate increased to 3.6% and 20.9% in revisions.[6] It is still unclear which fixation method is approppriate for periprosthetic fractures. The present study was aimed to determine the optimal fixation method.

We acknowledge that there are some limitations of our study. For example, composite bones are unsuitable for destructive tests, so limited loads were

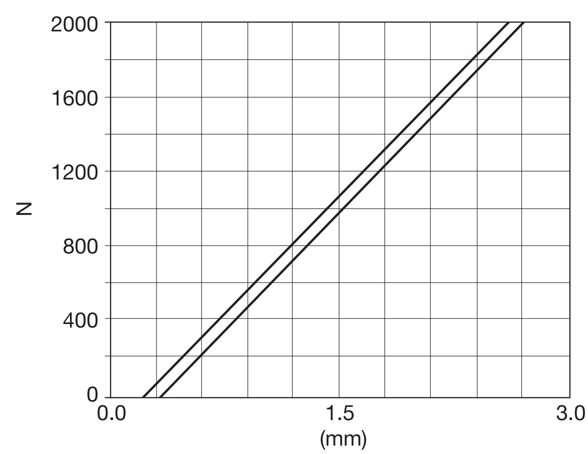

Fig. 2. An example of the load (N) - displacement (mm) curve (Group 5). [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

Fig. 3. Entire testing setup for Group 6. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

applied. In addition, such studies can only simulate immediate postoperative conditions, so the effect of bone healing is obscure. Lastly, in this model we only simulated axial loading.

Although experimental studies cannot always be applied directly to clinical practice, composite femurs seem to be an exception. In the study of Cristofolini et al., the composite femurs were shown to be similar to cadaveric specimens for biomechanical experiments. Moreover, the inter-femur variability of the composite femurs was 20-200 times lower than that of the cadaveric specimens, thus allowing smaller differences to be characterized as significant using the same simple size, if composite femurs were used.[7] However, the use of laboratory spercimens carries some limitations, as Dennis at al. have stated. They have no soft tissue, the smooth cut osteotomies do not always simulate fracture pattern and synthetic femora might have a better screw purchase.[8] Therefore, we believe that our experimental results need to be proven by additional experimental studies.

In the clinical study by Schwartz et al., it was emphasized that the goal of the treatment of intraoperative femoral fractures was to ensure the stabilization of the implant. The stability of the implant was tested during the procedure in all patients, especially when a fracture was noticed intraoperatively, by applying stress to the bone-implant interface either through a rotational load on the femoral head or by further impaction of the implant.[9] The authors considered the component to be stable if no movement was detected at the bone-implant interface. Our results contradict this clinical impression, as the yield point of Group 3 (fracture with prosthesis but without fixation) showed statistically significant difference from all other groups (Table 1). This means that if the periprosthetic fracture is not fixed, axial loading impairs the stability of the system.

There is limited information regarding the biomechanical performance of extramedullary techniques for periprosthetic fracture fixation.[8] Maozen et al. advised the use of computarized analysis models for the assesment of the optimal fixation method.[10] According to Mallory et al., the fixation of periprosthetic fractures with cerclage wires is sufficient for a satisfactory clinical result; however, Greidanus et al. state that most intraoperative periprosthetic fractures of the proximal femur are stable in nature and conservative treatment is adequate for healing.[11] In our opinion, the fixation of Mallory Type 2 periprosthetic fractures is mandatory, as the results of the present study revealed that Group 3 had significantly lower values as compared to the fixation groups (Groups 4 to 6) (Table 1). One can expect an increase in stability by addition of strut graft or plate. However, the method of fixation did not improve the results in our study and there were no difference among the Groups 4, 5, and 6 in terms of axial stability.

Although the results of our study revealed the necessity for the fixation of Mallory Type 2 periprosthetic fractures, none of the tested fixation method seem to be superior.

Conflicts of Interest: No conflicts declared.

References

1. Campbell P, McWilliams TG. Periprosthetic femoral fractures. Current Orthopaedics; 2002;16:126-32.
2. Fink B, Fuerst M, Singer J. Periprosthetic fractures of the femur associated with hip arthroplasty. Arch Orthop Trauma Surg 2005;125:433-42.
3. de Ridder VA, de Lange S, Koomen AR, Heatley FW. Partridge osteosynthesis: a prospective clinical study on the use of nylon cerclage bands and plates in the treatment of periprosthetic femoral shaft fractures. J Orthop Trauma 2001;15:61-5.
4. Zenni EJ Jr, Pomeroy DL, Claude JR. Ogden plate and other fixations for fractures complicating femoral endoprostheses. Clin Orthop Relat Res 1988;(231):83-90.
5. Mallory TH, Kraus TJ, Vaughn BK. Intraoperative femoral fractures associated with cementless total hip arthroplasty. Orthopedics 1989;12:231-9.
6. Berry DJ. Epidemiology: hip and knee. Orthop Clin North Am 1999;30:183-90.
7. Cristofolini L, Viceconti M, Capello A, Toni A. Mechanical validation of whole bone composite femur models. J Biomech 1996;29:525-35.
8. Schwartz JT, Mayer JG, Engh CA. Femoral fracture during non-cemented total hip arthroplasty. J Bone Joint Surg Am 1989;71:1135-42.
9. Dennis MG, Simon JA, Kummer FJ, Koval KJ, Di Cesare PE. Fixation of periprosthetic femoral shaft fractures occurring at the tip of the stem: a biomechanical study of 5 techniques. J Arthroplasty 2000;15:523-8.
10. Maozen M, Jones AC, Jin Z, Wilcox RK, Tsiridis E. Periprosthetic fracture fixation of femur following total hip arthroplasty: A review of biomechanical testing. Clin Biomech (Bristol, Avon) 2010:30.
11. Greidanus NV, Mitchell PA, Masri BA, Garbuz DS, Duncan CP. Principles of management and results of treating the fractured femur during and after total hip arthroplasty. Instr Course Lect 2003;52:309-22.