EXPERIMENTAL STUDY

Acta Orthop Traumatol Turc 2016;50(3):373–378
doi: 10.3944/AOTT.2015.15.0298

Comparison of fixation techniques in Vancouver type AG periprosthetic femoral fracture: a biomechanical study

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Objective: The purpose of this study was to biomechanically compare cable, trochanteric grip plate, and locking plate techniques in Vancouver type AG fracture model in an in vitro test environment.

Methods: Fifteen pieces of fourth-generation synthetic femora were separated into 3 groups of 5 models each. A greater trochanteric fracture model was created after femoral stem implantation. Group 1 was fixated with only cable, Group 2 with trochanteric grip plate, and Group 3 with locking plate. Horizontal stiffness, axial stiffness, and failure loads were compared between the groups.

Results: In horizontal compression tests, Group 3 had the highest values, but the only statistically significant difference was between the locking plate group and cable group. Axial distraction test results showed that mean stiffness of Group 1 was 94.6±9.44 N/mm, that of Group 2 was 174.8±28.64 N/mm, and that of Group 3 was 185.6±71.64 N/mm. While locking plate versus cable fixation and grip plate fixation versus cable fixation showed statistically significant differences ($p<0.05$), comparison of locking plate versus grip plate fixation showed no statistically significant difference ($p>0.05$). In axial failure load test, Group 3 had the highest results. The only significant difference was between the locking plate and cable groups ($p<0.05$).

Conclusion: In Vancouver type AG fractures stable fixation may be achieved with grip plate fixation and locking plates, with the former ensuring more stable osteosynthesis.

Keywords: Biomechanical; cable; locking plate; periprosthetic femoral fracture; top Vancouver type AG; trochanteric grip plate.

Fracture of the greater trochanter obtained during or after hip surgery is a pathology that has been increasing in incidence.[1] One reason for this is that hip arthroplasty is being performed more commonly, especially in younger patients who are active and have higher expectancy. Furthermore, weak bone stock due to osteopenia or revision surgery contributes to this growth in incidence. A recent study revealed that around 15,000 hip arthroplasty-related greater trochanter fractures occur annually.[2]

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Submitted: June 19, 2015 **Accepted:** November 17, 2015

Available online at
www.aott.org.tr
doi: 10.3944/AOTT.2015.15.0298
QR (Quick Response) Code

These fractures require good bone contact and stability (sustained for a minimum of a few months) in order to heal and experience union. Lack of stability results in delayed union, nonunion, or malunion of the greater trochanter.[3] The result of trochanteric fracture nonunion may include limping due to abductor strength loss, pain due to trochanteric bursitis, or ultimately failure of the implant due to luxation of the prosthesis.[4]

Obtaining anatomic reduction of fractured greater trochanteric fragments is usually very difficult due to the fact that they are leashed by strong attachments of gluteal muscles. The gluteus medius and minimus muscles apply a great amount of shear forces to the fragment, along with distraction, especially at the time of marked flexion. As a result, obtaining and sustaining reduction and stability of trochanteric fragments is challenging.[5–7]

Cerclage wire fixation was the first approach utilized in greater trochanter repair.[8–10] However, due to frequent wire breakage and nonunion, it was replaced by multifilament steel cables (Dall-Miles cable, Stryker, Kalamazoo, MI, USA) and trochanteric grip plates.[11,12] Evidence shows that cable and grip plate fixation achieve better and more stable fixation,[13] though there is data indicating that fixation failure rates of these methods may be as high as 40%.[14–16]

Advances in locking plate technology in recent years have reduced fracture-related fixation and stability issues. There have been a small number of studies investigating the efficacy of locking plates for the treatment of greater trochanteric fractures, the results of which have predominantly been satisfactory.[17,18]

To date, greater trochanteric fractures have been surgically treated with multifilament cable fixation and grip fixation. With the recent advocation of locking plates, debate has emerged whether one of these 3 constructs is superior. There is a lack of clear information on this topic in the literature. Consequently, we conducted a study to analyze the 3 constructs in terms of stiffness and load to failure in an in vitro environment.

Materials and methods

Fifteen pieces of fourth-generation synthetic proximal femora (Sawbones 3406, Sawbones Europe AB, Malmö, Sweden) were separated into 3 groups of 5 models each. All femora received greater trochanteric osteotomies. The trochanteric osteotomies in each group were fixed with different implant systems. In Group 1, osteotomies were fixed with simple multifilament wire fixation. In Group 2, trochanteric grip plate with cables was used for fixation. In Group 3, trochanteric osteotomy sites were fixed by means of locking plate and screws. All groups were tested against mechanical stability. Three dependent variables were tested as the outcome: anteroposterior (AP) stiffness (mimicking shear forces during hip flexion), vertical stiffness against distraction (mimicking hip abduction), and load to failure against distraction.

All models underwent femoral neck osteotomy, which was performed with an oscillating saw, beginning 1.5 cm proximal of the trochanter minor and creating a 45° angle with the femoral shaft. Following osteotomy, all models were prepared with arthroplasty system tools (Synergy, Smith & Nephew, Memphis, TN, USA). The preparation started with a medulla finder, which was followed by incremental reaming of the medullary canals of the models. After incremental rasping, femoral components were applied to the models with the press fit technique. Finally, with the oscillating saw, an osteotomy of the greater trochanter of 30° was created in all models.

In Group 1, fixation was obtained by means of cable alone (Tasarım Medical, Istanbul, Turkey). Holes were created in the greater and lesser trochanter. Cable was passed through these holes, and after manual approximation of the fragments, cable tensioner was applied. Finally, crimps were mounted and applied to the cables, and excess cable was trimmed.

In Group 2, trochanteric grip plate (Sayan, Ortovizyon Medical, Istanbul, Turkey) was used for fixation of the fragments. After adaptation of the grip to the greater trochanter, the first cable was passed just proximal to the lesser trochanter and through the most apical cable hole of the plate. The second cable was passed through a hole made through the lesser trochanter and through the second most proximal plate hole. Two additional cables were applied to the shaft segment of the plate.

Group 3 consisted of constructs fabricated with a hybrid 3.5-mm locking plate (Atılım Medical, Istanbul, Turkey), which incorporated a reconstruction plate design in the proximal region. After bending the proximal region of the plate to adapt to the greater trochanter, six 14-mm locking screws were applied to the trochanteric fragment, and three 14-mm monocortical screws were applied to the shaft region while sustaining anatomical reduction between fragments.

Biomechanical tests were performed on a 10kN Shimadzu Autograph AGS-J model universal testing machine (Shimadzu Corp., Kyoto, Japan). A custom-made metal mount was fabricated to conduct the biomechanical tests. Samples were placed on a specially designed testing jig horizontally to measure stiffness of the construct in the AP plane, simulating the gluteal shear forces on the greater trochanter while standing from a chair. A preload of 5 N was applied, and increasing axial compression to a maximum of 450 N was applied at 5 mm/min displacement speed. Constructs were mounted vertically, and axial distraction with a preload of 5 N was applied, increasing axial distraction until failure of the constructs was performed at 5 mm/min displacement speed (Figure 1). Measurements were recorded by Trapezium 2.0 software (version 2.23, Shimadzu Corp., Kyoto, Japan), and load-displacement curves were plotted. The peak force causing failure of the construct by means of major displacement in fracture line or breakage of hardware or bone model was noted as the failure load value.

Measurement values were analyzed with SPSS software (version 15.0, SPSS Inc., Chicago, IL, USA). Kruskal-Wallis test was utilized with 95% confidence interval, and a p-value of <0.05 was considered statistically significant.

Results

AP compression test was used to calculate stiffness of the construct against AP compressive forces. Mean stiffness values of the constructs according to the AP compression test results were as follows: Group 1: 63.8±7.39 N/mm (range: 54–74 N/mm); Group 2: 122.2±13.14 N/mm (range: 101–133 N/mm); and Group 3: 128.4±19.73 N/mm (range: 95–144 N/mm). These results were statistically significant ($p<0.05$). Intergroup comparisons revealed that locking plate fixation versus grip plate fixation showed no statistically significant difference ($p>0.05$), while the only statistically meaningful difference ($p<0.05$) was between the locking plate fixation group and cable fixation group (Figure 2).

Axial distraction until failure test results were used to calculate stiffness of the constructs against vertical distraction. Mean stiffness of Group 1 was 94.6±9.44 N/mm (range: 81–104 N/mm), that of Group 2 was 174.8±28.64 N/mm (range: 132–211 N/mm), and that of Group 3 was 185.6±71.64 N/mm (range: 102–276 N/mm). Distraction stiffness test results were statistically significant ($p<0.05$). Intergroup comparisons revealed that locking plate versus cable fixation and grip plate fixation versus cable fixation showed statistically significant differences ($p<0.05$). However, compari-

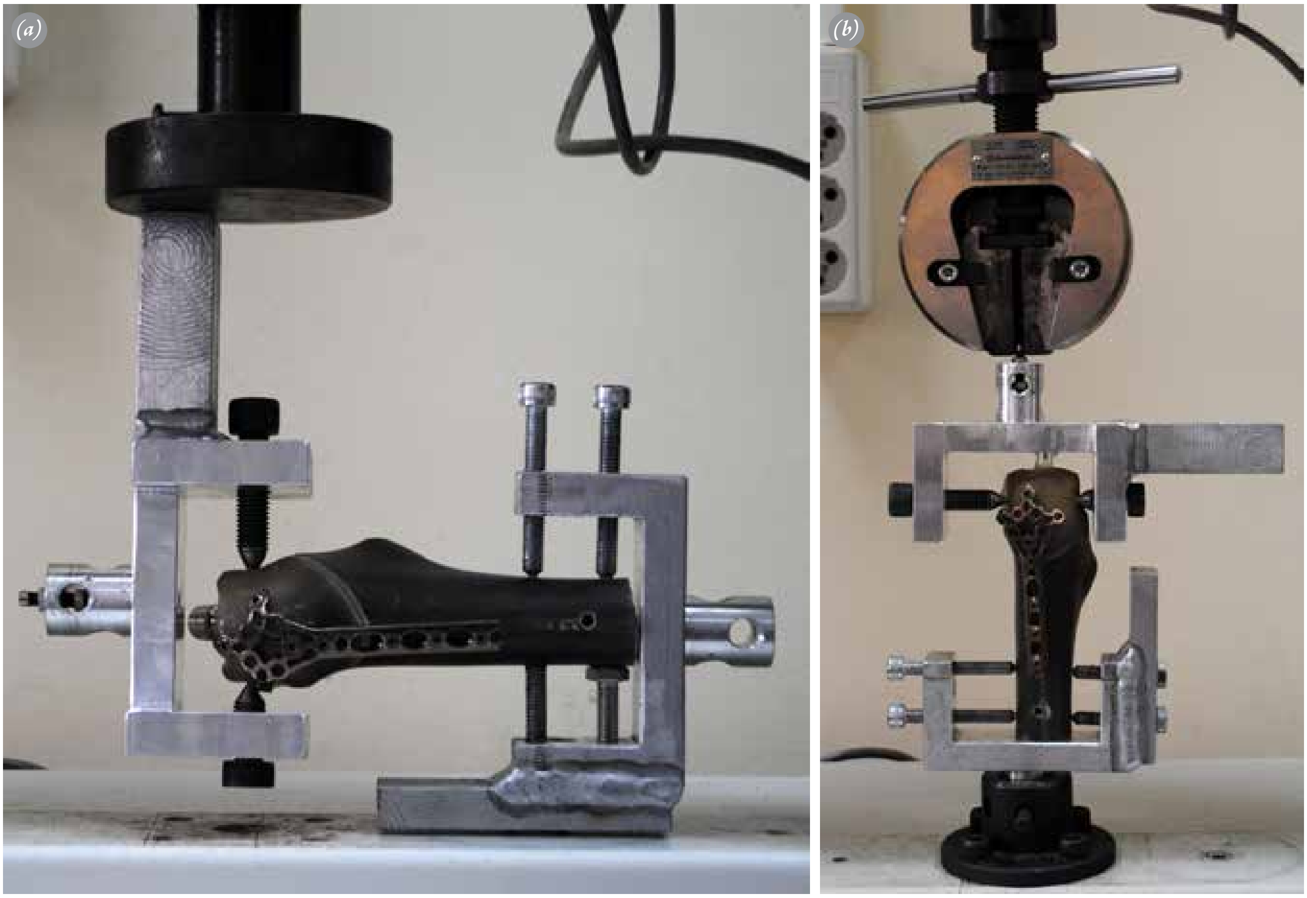

Fig. 1. (a, b) Photos of constructs in the testing machine.

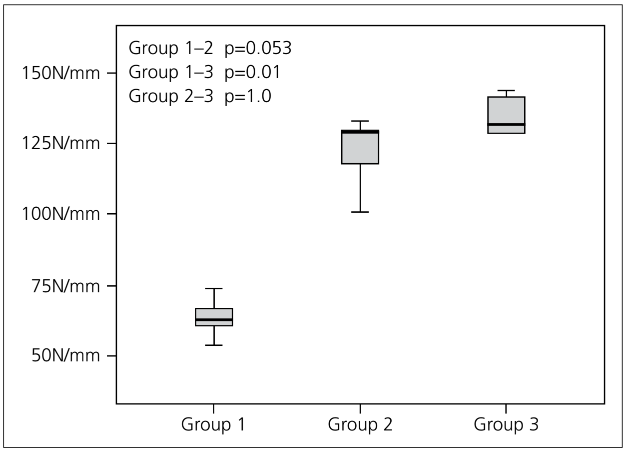

Fig. 2. Compression test results.

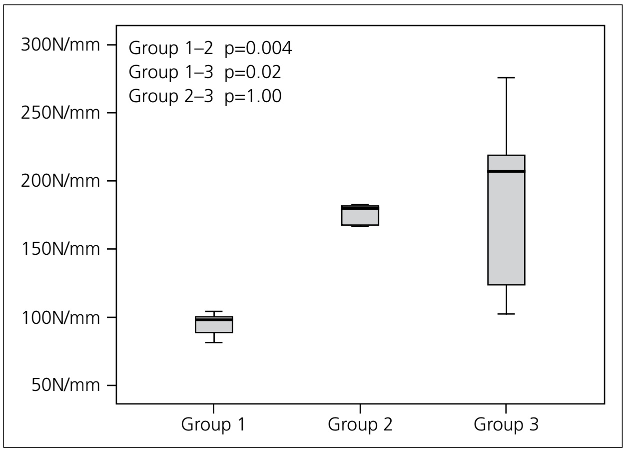

Fig. 3. Distraction test results.

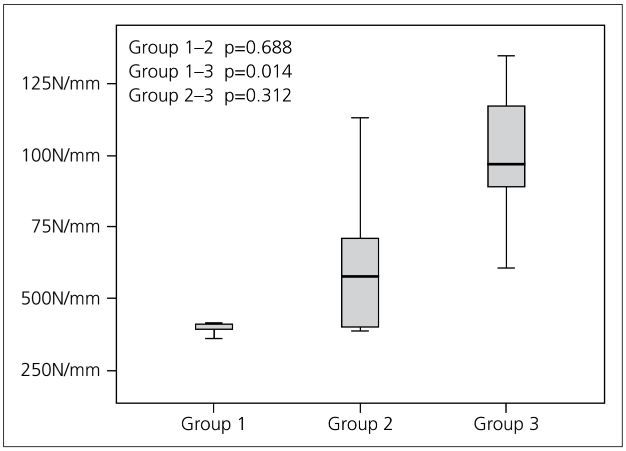

Fig. 4. Failure load test results.

son of locking plate versus grip plate fixation ($p>0.05$) showed no statistically significant difference (Figure 3).

Axial failure load test returned average values for Groups 1, 2, and 3, respectively, as follows: 394±23.13 N (range: 361–419 N), 642±304.98 N (range: 386–1132 N), and 997±281.56 N (range: 608–1346 N). The results of this test were statistically significant ($p<0.05$). Intergroup comparisons showed that the only significant difference was between the locking plate and cable fixation groups ($p<0.05$) (Figure 4).

Discussion

The present study compared the biomechanical properties of the 3 most common methods of greater trochanteric fracture fixation: cable fixation, grip plate, and locking plate. The results of our study revealed that the strongest of the 3 is locking plate fixation; however, results of the trochanteric grip plate group and locking plate group were not statistically significant in terms of compression, distraction loadings, and failure load tests.

Historically high failure rates of cerclage and cable fixation techniques necessitate new methods for fixation of greater trochanter fractures. The trochanteric grip plate was designed as an alternative method and has been relatively successful. A retrospective study by Zarin et al. investigated union rates of claw plate fixation after hip arthroplasty-related trochanteric fixations and reported 28 unions in 31 patients.[19] Another study comparing grip plates to older methods examining differences in functional outcomes, union rates, dislocation rates, limping, and need for walking aid also proved that grip plates significantly improved results.[4] In our study, cable fixation was found to be the weakest among the 3 groups. Thus, the results of the present study support those in the existing literature, as we found grip plates superior to the cable system.

While grip plates have improved outcomes, controversy remains surrounding their efficacy. Some studies have found it to be effective only against vertical distraction forces and claimed that it offered poor stability against anterior shear forces seen during flexion.[17] It is known that the abductor muscles apply a distractive force on the greater trochanter while walking but cause an anterior shear moment while standing from a chair.[17] Additional conflicting data on grip plate fixation of trochanteric fracture in the literature show high failure rates (19%) and incomplete reduction ratios as high as 15%.[20] For resolution of such complicated cases of failure and nonunion, dual locking plates (anterior and lateral) have been advocated, and successful unions and good functional outcomes have been reported.[18] A study by Baril et al. compared trochanteric grip plate versus Y-shaped plate fixation, which provides lateral and anterior fixation of the trochanteric fragment. They reported that Y-shaped plate fixation provided better results under specific conditions.[21] Our study produced parallel results comparing locking plate versus grip plate fixation. While locking plates showed better results, they were not statistically significant.

Following their recent development, locking plates have been widely used for orthopedic trauma and are increasingly being used for periprosthetic fracture management. Periprosthetic fractures are difficult to repair because the medullary cavity is often filled with the prosthetic stem, which limits the use of standard bicortical screws. In such cases, locking-angle stable plates have proven effective, as they permit stable constructs with only monocortical screw insertion. Other studies demonstrated good results with the use of locking plates for reconstruction of Vancouver type B1 and C periprosthetic fractures.[22–24]

The present study is not without limitations. Firstly, it was conducted in vitro. The models did not include soft tissue, so the fixation methods were easier to compare than in an in vivo environment. Secondly, the study could not simulate the peripheral muscle and ligament structures, which may change the mechanical characteristics. Though their mechanical properties are similar to human bones, the bones used in the study were not real bones and thus did not have the properties of osteoporotic bones in which periprosthetic fractures are common. Lastly, because of technical issues, our study lacks stability tests for true rotational forces, which are valid and strong forces in the hip joint in vivo. Conversely, we attempted to compensate for this limitation by testing constructs for AP stiffness by applying AP shear forces. While this test does not truly reflect the rotational forces around the hip joint, we believe that it is a good method to mimic these forces in an in vitro environment.

In conclusion, stable fixation of Vancouver type AG fractures is critical to avoid related complications and obtain better functional results. It has been well established that cable-only fixation methods are inadequate. For such cases, grip plate fixation and locking plates provide better and safer fixation, with the former ensuring more stable osteosynthesis. Further biomechanical and controlled patient group studies are required to provide conclusive data regarding the fixation of greater trochanter fractures.

Acknowledgments

We thank Meric Mericliler, MD, for assistance with statistical analysis. Implants for this work were donated by TasarimMed Turkey, Ortovizyon Medical Turkey and Atilim Medical Turkey.

Conflics of Interest: No conflicts declared.

References

1. Hendel D, Yasin M, Garti A, Weisbort M, Beloosesky Y. Fracture of the greater trochanter during hip replacement: a retrospective analysis of 21/372 cases. Acta Orthop Scand 2002;73:295–7.
2. Pritchett JW. Fracture of the greater trochanter after hip replacement. Clin Orthop Relat Res 2001;390:221–6.
3. Koyama K, Higuchi F, Kubo M, Okawa T, Inoue A. Reattachment of the greater trochanter using the Dall-Miles cable grip system in revision hip arthroplasty. J Orthop Sci 2001;6:22–7.
4. Barrack RL, Butler RA. Current status of trochanteric reattachment in complex total hip arthroplasty. Clin Orthop Relat Res 2005;441:237–42.
5. Bergmann G, Graichen F, Rohlmann A. Is staircase walking a risk for the fixation of hip implants? J Biomech 1995;28:535–53.
6. Dall DM, Miles AW. Re-attachment of the greater trochanter. The use of the trochanter cable-grip system. J Bone Joint Surg Br 1983;65:55–9.
7. Bergmann G, Deuretzbacher G, Heller M, Graichen F, Rohlmann A, Strauss J, et al. Hip contact forces and gait patterns from routine activities. J Biomech 2001;34:859–71.
8. Harris WH, Crothers OD. Reattachment of the greater trochanter in total hip-replacement arthroplasty. A new technique. J Bone Joint Surg Am 1978;60:211–3.
9. Jensen NF, Harris WH. A system for trochanteric osteotomy and reattachment for total hip arthroplasty with a ninety-nine percent union rate. Clin Orthop Relat Res 1986;208:174–81.
10. Nercessian OA, Newton PM, Joshi RP, Sheikh B, Eftekhar NS. Trochanteric osteotomy and wire fixation: a comparison of 2 techniques. Clin Orthop Relat Res 1996;333:208–16.
11. Hamadouche M, Zniber B, Dumaine V, Kerboull M, Courpied JP. Reattachment of the ununited greater trochanter following total hip arthroplasty. The use of a trochanteric claw plate. J Bone Joint Surg Am 2003;85-A:1330–7.
12. Hodgkinson JP, Shelley P, Wroblewski BM. Re-attachment of the un-united trochanter in Charnley low friction arthroplasty. J Bone Joint Surg Br 1989;71:523–5.
13. Hersh CK, Williams RP, Trick LW, Lanctot D, Athanasiou K. Comparison of the mechanical performance of trochanteric fixation devices. Clin Orthop Relat Res 1996;329:317–25.
14. Ritter MA, Eizember LE, Keating EM, Faris PM. Trochanteric fixation by cable grip in hip replacement. J Bone Joint Surg Br 1991;73:580–1.
15. Silverton CD, Jacobs JJ, Rosenberg AG, Kull L, Conley A, Galante JO. Complications of a cable grip system. J Arthroplasty 1996;11:400–4.

16. McCarthy JC, Bono JV, Turner RH, Kremchek T, Lee J. The outcome of trochanteric reattachment in revision total hip arthroplasty with a Cable Grip System: mean 6-year follow-up. J Arthroplasty 1999;14:810–4.
17. Cloutier LP, Laflamme GY, Petit Y. Biomechanical analysis of trochanteric fracture fixations using a Y-shaped locking plate. J Orthop Trauma 2013;27:702–7.
18. Laflamme GY, Leduc S, Petit Y. Reattachment of complex femoral greater trochanteric nonunions with dual locking plates. J Arthroplasty 2012;27:638–42.
19. Zarin JS, Zurakowski D, Burke DW. Claw plate fixation of the greater trochanter in revision total hip arthroplasty. J Arthroplasty 2009;24:272–80.
20. Jarit GJ, Sathappan SS, Panchal A, Strauss E, Di Cesare PE. Fixation systems of greater trochanteric osteotomies: biomechanical and clinical outcomes. J Am Acad Orthop Surg 2007;15:614–24.
21. Baril Y, Bourgeois Y, Brailovski V, Duke K, Laflamme GY, Petit Y. Improving greater trochanteric reattachment with a novel cable plate system. Med Eng Phys 2013;35:383–91.
22. Fulkerson E, Koval K, Preston CF, Iesaka K, Kummer FJ, Egol KA. Fixation of periprosthetic femoral shaft fractures associated with cemented femoral stems: a biomechanical comparison of locked plating and conventional cable plates. J Orthop Trauma 2006;20:89–93.
23. Kampshoff J, Stoffel KK, Yates PJ, Erhardt JB, Kuster MS. The treatment of periprosthetic fractures with locking plates: effect of drill and screw type on cement mantles: a biomechanical analysis. Arch Orthop Trauma Surg 2010;130:627–32.
24. Sariyilmaz K, Dikici F, Dikmen G, Bozdag E, Sunbuloglu E, Bekler B, et al. The effect of strut allograft and its position on Vancouver type B1 periprosthetic femoral fractures: a biomechanical study. J Arthroplasty 2014;29:1485–90.