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Does the Screw Orientation Effects the Stability of Femoral Neck Fracture?: A Finite Element Analysis

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ABSTRACT

Objectives: The incidence of femoral neck fractures in younger-age people increases due to high-energy trauma. To avoid complications, stable internal fixation is essential. The most commonly used implants for vertically oriented femoral neck fractures are the cannulated and dynamic hip screws. In our study, we compared differently oriented cannulated screw configurations and a standard DHS for fixation of femoral neck fracture.

Materials and Methods: A finite element-based collum femoris fracture was created and was fixed using four differently oriented triangular screw configurations and a dynamic hip screw. The loads were applied using a commercially available software package.

Results: Centrally oriented cannulated screw configuration had the most compression and compression stress on the fracture side, and it had the highest stress values on the implant.

Conclusion: We recommend the use of centrally oriented triangular cannulated screws for femoral neck fracture fixation. With this construct, more compression and compression pressure can be obtained, which can result in the early healing of the fracture. However, it must be kept in mind that this construct exerts more stress on the implant, which could be a reason for implant failure.

Keywords: femoral neck fractures, cannulated screw, dynamic hip screw, screw position, finite element analysis

VİDA KONFİGÜRASYONU FEMUR BOYUN KIRIKLARININ STABİLİZASYONUNA ETKİ EDİYOR MU: ÇOKLU ELEMAN ANALİZİ

ÖZET

Amaç: Yüksek enerjili travma insidansındaki artış ile genç yaşlarda görülen femur boyun kırığı sayısında belirgin bir artma olmuştur. Komplikasyonlardan korunmak için, tedavide stabil internal fiksasyon ön koşuldur. Femur boyun kırıklarının cerrahi tedavisinde en sık kanule vidalar ve dinamik kalça çivileri kullanılmaktadır. Biz çalışmamızda değişik konfigurasyondaki kanule vida uygulamalarının ve dinamik kalça çivisinin stabilizasyonunu karşılaştırdık.

Hastalar ve Yöntemler : Çoklu eleman yazılımı ile femur boyun kırığı modellemesi yaratıldı. Ve kırık dört ayrı kanüle vida konfigirasyonu ya da dinamik kalça çivisi kullanılarak tespit edildi. Aksiyel yükleme yapılarak direnç ve dayanıklılık testleri uygulandı.

Bulgular: Santral oryante kanüle vida konfigirasyonunun kırık hattında en iyi kompresyon sağlayan ve aksiyel yüklenme stresine en dayanıklı model olduğu ortaya kondu.

Sonuç: Femur boyun kırıkları için santral konfigirasyonlu kanüle vida ile tespit yapılmasını önermekteyiz. Bu şekilde kırık hattında maksimum kompresyon sağlanarak, erken iyileşmeye de olanak sağlanmaktadır.

Anahtar sözcükler: Femur boyun kırığı, kanüle vida, dinamik kalça çivisi, vida pozisyonu, çoklu eleman analizi

Although femoral neck fracture is one of the common fractures frequently seen in elderly people, the incidence of femoral neck fracture in younger-age people increases due to high-energy trauma (1). The recommended treatment for young patients with femoral neck fractures is through internal fixation (2). The major pattern of these fractures in this population is the vertical shear fracture type, which corresponds to Pauwels type 3 vertical femoral fracture (3). Due to the vertical orientation of these fractures, strong varus shear moments can lead to displacement, nonunion, and osteonecrosis (4).

To avoid complications, stable internal fixation is essential. The optimal fixation device is controversial. Cannulated screws, dynamic hip screws (DHSs), anatomic locking plates, and proximal femoral nails can be used for the treatment of these fractures. Several biomechanical and finite element (FE) studies have compared these fixation devices, but none of the studies gave a clear recommendation on which of the devices should be used (5-10).

The most commonly used implants for vertically oriented femoral neck fractures are cannulated screws and DHSs. Some studies have evaluated the biomechanical properties of these two fixation devices on synthetic and cadaveric bones, and they found different results (11-13).

In a biomechanical study by Selvan et al., they compared different cannulated screw configurations, and they found that the triangular screw configuration was the stronger construct for femoral neck fracture fixation (14). However, the position of the screws at the femoral head in a triangular fashion was ambiguous.

FE analysis can provide a theoretical basis for the optimal treatment method. Some studies have investigated the femoral neck fractures through FE analysis. They concluded that screw modeling through FE analysis offered a realistic simulation of osteosynthesis with screws (10, 15). In our study we aim to shoe that centrally oriented screw configuration can achieve the strongest compression effect in femoral neck fracture.

In this FE analysis study, we compared differently oriented cannulated screw configurations and a standard DHS for fixation of femoral neck fracture.

Materials and methods

The FE model, which was created using a FE software (Siemens NX Nastran), had an 80-kg heavy and 170-cm tall male subject as its parameter. Hexahedral elements were assigned for all components in the created model (discretization). In the created finite element model 326876 numerical network element and 574712 nodes were used.

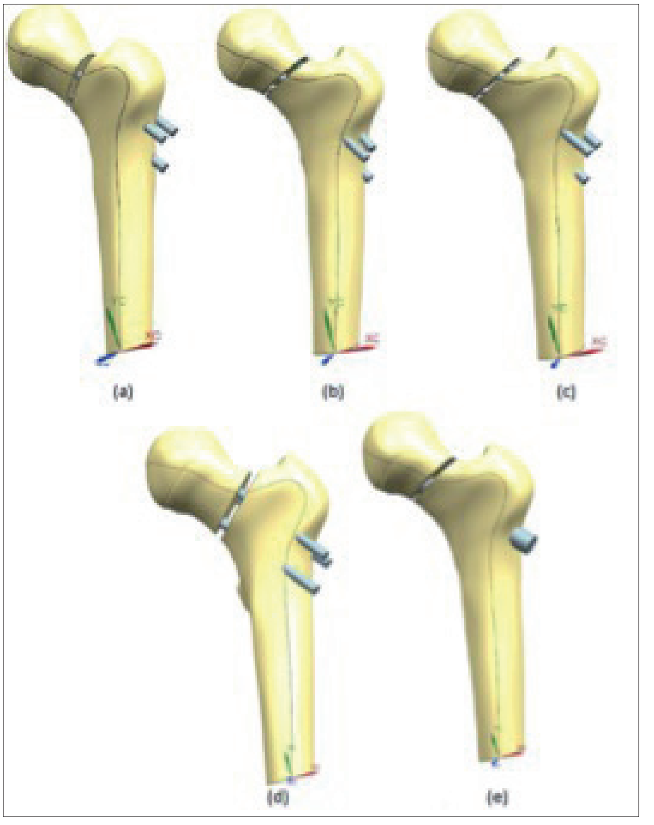

Figure 1. FE Model Geometry **(a)** Anterior screw (AS), **(b)** Divergent screw (DS), **(c)** centrally oriented screws (CS), **(d)** Posterior screw (PS), **(e)** Dynamic hip screw (DHS)

The bone consisted of cortical and cancellous sections and the implants were made of Ti-6Al-4V alloy. All materials were considered as homogeneous, isotropic and elastic.

The femoral neck fracture was performed with a 70-degree vertical orientation to simulate a Pauwels type 3 vertical femoral fracture. To assess the compression on the fracture side, a 0.5-mm gap was created. Compression was calculated as the decreased gap measurement on the fracture side.

Four differently oriented triangular cannulated screw configurations and a dynamic hip screw were applied to the femoral neck fracture model (Figure 1).

One construct [centrally oriented screws (CS)] was created using three 6.5 mm cannulated screw without washers, which were inserted parallel into the femoral neck in a

Table 1. Forces Acting on Femur

Point	*Forces (N)*	*X*	*Y*	*Z*
P0	Joint contact force	-433,8	-263,8	-1841,3
P1	Abductor	465,9	34.5	695
P1	Tensor Fascia lata, proximal part	57,8	93,2	106
P1	Tensor Fascia lata, distal part	-4	-5,6	-152,6
P2	Vastus Lateralis	-7,2	148,6	-746,3

reversed triangle fashion. The triangle was oriented at the center of the femoral head. The inferior screw was positioned 5 mm superior to the inferior margin of the femoral neck, and the two superior screws were inserted 5 mm anterior and posterior cortices of the femoral neck. The screws were 5 mm under the subchondral bone.

Anterior screw (AS) and posterior screw (PS) constructs were created in the same manner mentioned above, but the screws were oriented 15 degrees anterior and 15 degrees posterior to the femoral head, respectively.

Divergent screw (DS) construct was created with a centrally oriented inferior screw and two superior screws, which were oriented 15 degrees anterior and posterior to the femoral head.

Dynamic hip screw (DHS) construct was created with a 135-degree, 12.5-mm lag screw oriented in the center of the femoral head.

Static analysis was performed on the created finite element model, and the loading types and values are shown in Table 1. The loading data, which was derived from another previous biomechanical study, and the forces acting on the femur during gait were considered (16). The forces acting on the femur through P0, P1 and P2 points and the middle part of the femur were assumed as fixed (Figure 2). The loads were applied using a commercially available software package. The loading data were the walking loading values that were obtained from Anybody kinematics analysis software (AnyBodys; AnyBody Tech, Aalborg, Denmark).

Friction between the surfaces was neglected and the screws were modeled as smooth cylinders. (Threads are not modeled). Connections between the bone and the bone screws were defined with *gluing* link formulation. On the fracture line in formed bone, between two surfaces facing each other *contact* link formulation was used.

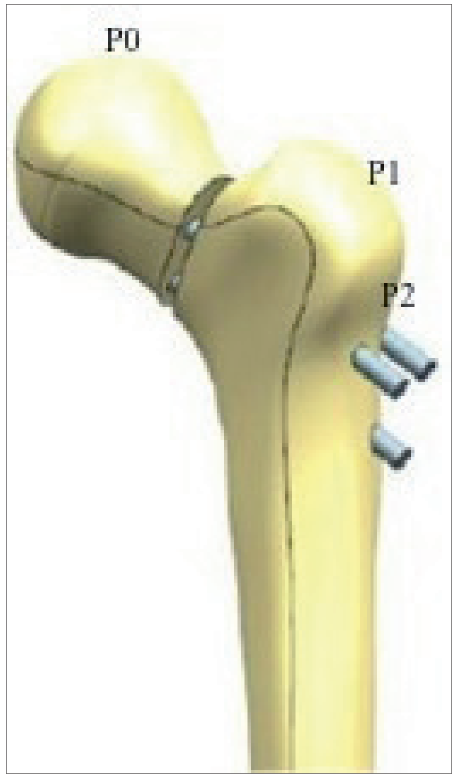

Figure 2. Loading points on femur

Table 2. Compression values at the fracture side and maximum stress values on fracture side and implant

Screw Type	*Compression (mm)*	*Max. Stress on Fracture Side (MPa)*	*Max. Stress on Implant (MPa)*
Centrally oriented	0.446	31.615	303.7
Posteriorly oriented	0.00743	1.71	151.85
DHS	0.238	18.97	162.2
Divergently oriented	0.238	17.2	164.5
Anteriorly oriented	0.223	15.81	16.45

Results

The compression on the fracture side was 0.446 mm in centrally oriented cannulated screw configuration, 0.268 mm in DHS, 0.238 mm in divergently oriented cannulated screw configuration, 0.223 mm in posteriorly oriented cannulated screw configuration, and 0.007 mm in anteriorly oriented cannulated screw configuration. The maximum compression on fracture side is shown in Table 2.

The maximum compression stress on the fracture side was correlated with decreasing gap measurement at the fracture side. Centrally oriented cannulated screw configuration had the most compression stress, which was measured as 31.615 N/mm^2, whereas the posteriorly oriented

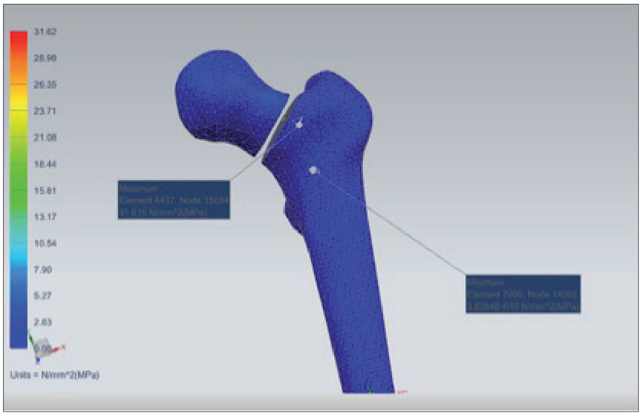

Figure 3. Compression stress on fracture side

cannulated screw configuration had the least compression stress. The maximum compression stress on fracture side for the five models is given in Table 2 (Figure 3A).

The stress on the implant for centrally oriented cannulated screw was 303.7 N/mm^2, 151.85 N/mm^2 for posteriorly oriented cannulated screw, 79.68 N/mm^2 for DHS, 69.8 N/mm^2 for divergently cannulated screw, and 16.45 N/mm^2 for anteriorly oriented cannulated screw. The values of stress on the implant are shown in Table 2.

Discussion

The goal of the treatment of collum femoris fracture in younger patients is the obtainment of union without complications. It was reported that after obtaining anatomical reduction, implant choice and positioning of the implant was mandatory for satisfactory results. The authors agreed that the parallel inverted triangle cannulated screw was the best choice for the treatment of collum femoris fractures (17), but there was no report about the position of the inverted triangle cannulated screw in the femoral head on lateral plane.

Our model simulated a Pauwels type 3 collum femoris fracture wherein strong varus shear forces were presented. We found that centrally oriented cannulated screw configuration had more compression effect and more compression pressure on the fracture side. For this reason, screwing must not be parallel to each other. However, this construct had the maximum stress on the screws.

In an FE analysis, Mei et al. investigated the cannulated screw placement and drilling frequency on femoral neck fractures, and they found that the best screw configuration for femoral neck fracture fixation was the inverted isosceles triangle configuration and screw position, Pauwels angle and drilling frequency can affect the mechanical strength of femoral neck fixation (10). In line with this study, our results have shown that implant choice and screw position affect the fixation stability of femoral neck fractures.

A number of studies assessed the fixation of femoral neck fractures (18-21), but the accepted screw configuration for these fractures was the parallel screws in triangular configuration. In a biomechanical study on synthetic bones by Selvan et al., they tested six different screw configurations, and they found that the triangular screw placement had a higher peak load, lesser displacement, and more energy absorption before failure than linear configurations (14)

The compression effect and compression stress on the fracture side were calculated. Centrally oriented triangular screw configuration had the most compression on fracture side, which is almost two times the compression from other screw configurations. DHS construct had the second most compression effect and compression stress on the fracture side. It is thought that this result was due to centrally oriented screw of DHS like the centrally oriented triangular screw configuration. Comparable with our results, Swiontkowski et al. found that the three cannulated screws had superior biomechanical results than DHS (22).

The stress on the implant was calculated. The centrally oriented cannulated screw had the most stress on fracture side. It was associated with the more compression effect and compression pressure of the centrally configured screws. In a biomechanical study by Aminian et al., they analyzed four different types of constructs for collum femoris fracture and reported that cannulated screws failed in lower loads than the other constructs (23). According to our results, this can be explained as centrally oriented cannulated screws had more stress than the other constructs. However, the most important result that should be reached clinically in femoral neck fracture was fracture healing. So, the priority was the best screw configuration that provided highest compression strength.

This study has several limitations. This is an FE analysis study and not an in vivo study. Studies using large cohorts of patients treated with differently oriented cannulated screws and DHS are needed. Also, these results should be validated with other biomechanical studies. We studied the orientation of screws and DHS on femoral neck, but it is often difficult to obtain such orientation in an actual operation. The use of a surgical navigation could be a solution for this orientation problem. In this study the screw threads were not modeled. In clinical practice, the threaded screws are used to achieve maximum compression and this is another limitation.

Conclusion

We recommend the use of centrally oriented triangular cannulated screws for more compression which can result in the early healing of the fracture.

References

1. Pauyo T, Drager J, Albers A, Harvey EJ. Management of femoral neck fractures in the young patient: A critical analysis review. World journal of orthopedics. 2014;5:204-17. [CrossRef]
2. Johansson T, Jacobsson SA, Ivarsson I, Knutsson A, Wahlstrom O. Internal fixation versus total hip arthroplasty in the treatment of displaced femoral neck fractures: a prospective randomized study of 100 hips. Acta orthopaedica Scandinavica. 2000;71:597-602. [CrossRef]
3. Luttrell K, Beltran M, Collinge CA. Preoperative decision making in the treatment of high-angle "vertical" femoral neck fractures in young adult patients. An expert opinion survey of the Orthopaedic Trauma Association's (OTA) membership. Journal of orthopaedic trauma. 2014;28:e221-5. [CrossRef]
4. Dedrick DK, Mackenzie JR, Burney RE. Complications of femoral neck fracture in young adults. The Journal of trauma. 1986;26:932-7.
5. Zhang Y, Tian L, Yan Y, Sang H, Ma Z, Jie Q, et al. Biomechanical evaluation of the expansive cannulated screw for fixation of femoral neck fractures. Injury. 2011;42:1372-6. [CrossRef]
6. Kunapuli SC, Schramski MJ, Lee AS, Popovich JM, Jr., Cholewicki J, Reeves NP, et al. Biomechanical Analysis of Augmented Plate Fixation for the treatment of Vertical Shear Femoral Neck Fractures. Journal of orthopaedic trauma. 2015;29:144-50. [CrossRef]
7. Rupprecht M, Grossterlinden L, Sellenschloh K, Hoffmann M, Puschel K, Morlock M, et al. Internal fixation of femoral neck fractures with posterior comminution: a biomechanical comparison of DHS(R) and Intertan nail(R). International orthopaedics. 2011;35:1695-701. [CrossRef]
8. Rupprecht M, Grossterlinden L, Ruecker AH, de Oliveira AN, Sellenschloh K, Nuchtern J, et al. A comparative biomechanical analysis of fixation devices for unstable femoral neck fractures: the Intertan versus cannulated screws or a dynamic hip screw. The Journal of trauma. 2011;71:625-34. [CrossRef]
9. Tsouknidas A, Anagnostidis K, Maliaris G, Michailidis N. Fracture risk in the femoral hip region: A finite element analysis supported experimental approach. Journal of biomechanics. 2012;45:1959-64. [CrossRef]
10. Mei J, Liu S, Jia G, Cui X, Jiang C, Ou Y. Finite element analysis of the effect of cannulated screw placement and drilling frequency on femoral neck fracture fixation. Injury. 2014;45:2045-50. [CrossRef]
11. Clark DI, Crofts CE, Saleh M. Femoral neck fracture fixation. Comparison of a sliding screw with lag screws. The Journal of bone and joint surgery British volume. 1990;72:797-800.
12. Blair B, Koval KJ, Kummer F, Zuckerman JD. Basicervical fractures of the proximal femur. A biomechanical study of 3 internal fixation techniques. Clinical orthopaedics and related research. 1994:256-63.
13. Husby T, Alho A, Ronningen H. Stability of femoral neck osteosynthesis. Comparison of fixation methods in cadavers. Acta orthopaedica Scandinavica. 1989;60:299-302.
14. Selvan VT, Oakley MJ, Rangan A, Al-Lami MK. Optimum configuration of cannulated hip screws for the fixation of intracapsular hip fractures: a biomechanical study. Injury. 2004;35:136-41.
15. Wieding J, Souffrant R, Fritsche A, Mittelmeier W, Bader R. Finite element analysis of osteosynthesis screw fixation in the bone stock: an appropriate method for automatic screw modelling. PloS one. 2012;7:e33776. [CrossRef]
16. Abdullah A AM, Alias M, Tarhan G., editor. Finite element analysis of cemented hip arthroplasty: Influence of stem tapers. International Multiconference of Engineers and Computer Scientists; 2010; Hong Kong. https://www.researchgate.net/publication/44260959
17. Yang JJ, Lin LC, Chao KH, Chuang SY, Wu CC, Yeh TT, et al. Risk factors for nonunion in patients with intracapsular femoral neck fractures treated with three cannulated screws placed in either a triangle or an inverted triangle configuration. The Journal of bone and joint surgery American volume. 2013;95:61-9. [CrossRef]
18. Luttrell K, Beltran M, Collinge C. Pre-operative Decision-Making in the Treatment of High-Angle "Vertical" Femoral Neck Fractures in Young Adult Patients. An Expert Opinion Survey of the Orthopaedic Trauma Association's (OTA) Membership Journal of orthopaedic trauma. 2014;28:221-5. [CrossRef]
19. Lapidus LJ, Charalampidis A, Rundgren J, Enocson A. Internal fixation of garden I and II femoral neck fractures: posterior tilt did not influence the reoperation rate in 382 consecutive hips followed for a minimum of 5 years. Journal of orthopaedic trauma. 2013;27:386-90; discussion 90-1. [CrossRef]
20. Kakar S, Little D, Einhorn TA. Can we improve fixation and outcomes in the treatment of femoral neck fractures? The use of pharmaceuticals. Journal of orthopaedic trauma. 2009;23:413-21. [CrossRef]
21. Bhandari M, Tornetta P 3rd, Hanson B, Swiontkowski MF. Optimal internal fixation for femoral neck fractures: multiple screws or sliding hip screws? Journal of orthopaedic trauma. 2009;23:403-7. [CrossRef]
22. Swiontkowski MF, Harrington RM, Keller TS, Van Patten PK. Torsion and bending analysis of internal fixation techniques for femoral neck fractures: the role of implant design and bone density. Journal of orthopaedic research: official publication of the Orthopaedic Research Society. 1987;5:433-44. [CrossRef]
23. Aminian A, Gao F, Fedoriw WW, Zhang LQ, Kalainov DM, Merk BR. Vertically oriented femoral neck fractures: mechanical analysis of four fixation techniques. Journal of orthopaedic trauma. 2007;21:544-8. [CrossRef] .