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Evaluation of cannulated screw fixation configurations in femoral neck fractures by biomechanical studies: A systematic review

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ABSTRACT

Aim: To investigate the cannulated screw fixation methods used in the treatment of femoral neck fractures with a systematic review.

Methods: PubMed Central, Web of Science, OVID Medline, Embase, and Google Scholar databases were searched to identify relevant studies published until December 2021 with English language restriction. Studies were selected on the basis of the following inclusion criteria: biomechanical study of femoral neck fractures and the use of multiple screw fixation of the fracture.

Results: A total of 10 studies were included in the systematic review. Five studies were conducted using cadavers and five studies using sawbones. Multiple cannulated screw fixation, fully threaded cannulated screw fixation, cannulated screw fixation perpendicular to the calcar, and fixation performed in a wider area have various advantages. During the mechanical tests, axial loading measuring device values, axial failure displacement, load to failure values, and axial loading values were measured for each operation.

Conclusions: There are various surgical techniques and biomedical materials for the detection of femoral neck fractures. In addition, each cannulated screw treatment configuration has advantages and disadvantages. For this reason, the most appropriate treatment configuration should be selected, taking into account the experience of the surgeon and the fracture types.

Keywords: Femoral neck fractures, fully threaded cannulated screws, partially threaded cannulated screws, inverted triangular configuration.

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Introduction

Femoral neck fracture is the most common hip fracture, which usually occurs in elderly patients. It accounts for 3.58% of all fractures and 54% of hip fractures[1]. Its incidence is low in young people and it is mostly caused by high energy injuries [1]. Hip fractures account for approximately 20% of the number of operations in the orthopedic trauma unit [2]. Treatment methods vary according to the fracture type and the age of the patient [3]. Various implants such as cannulated screw fixation, dynamic hip screw, hemiarthroplasty, total hip prosthesis or locking plates are generally used for the treatment of femoral neck fractures. Closed reduction and internal fixation with cannulated screws are the most commonly used treatment modalities for nondisplaced or well-reduced femoral neck fractures[4, 5]. Until now, there has not been a gold standard method of internal fixation [6]. Correct screw placement can increase the stability of internal fixation of the femoral neck fracture and reduce the risk of nonunion [7, 8]. Anatomical reduction and stable internal fixation are the two most important prognostic factors in femoral neck fractures [9]. In the literature, it has been reported that the incidence of Pauwels type III femoral neck fracture is 16-59%, and the incidence of femoral head necrosis is 11-86% [10]. Some studies have reported that 7-22% of patients treated with cannulated screws required revision surgery because of nonunion, avascular necrosis, and fixation failure [11, 12]. However, reduction loss after fixation with a three-partially threaded cannulated screw femoral neck fracture has been reported to be up to 39% in the first three months postoperatively [13]. Recently, fully threaded cannulated screws have come to the fore as alternative means of fixation of femoral neck fractures, with satisfactory radiographic and clinical results [13, 14]. Therefore, achieving satisfactory internal fixation in patients with femoral neck fractures has become a critical problem for orthopedic surgeons.

We conduct this systematic review to investigate and compare the biomechanical results of different cannulated screw options and different fixation configurations of femoral neck fracture.

Material and Methods

A systematic review was performed according to the Preferred Reporting Items for Systematic Reviews guidelines.

Search methods for identification of studies

The following sources of data were searched up to December 2021 by two reviewers (EA, TA): PubMed Central, Web of Science, OVID Medline, Embase, and Google Scholar databases were searched to identify relevant studies published until December 2021 with English language restriction. Each investigator independently evaluated the titles and abstracts of all potentially relevant studies as recommended by the Cochrane Collaboration. The following search terms were used: ‘‘femoral neck fracture’’, ‘‘unstable femoral neck fracture”, ‘‘cannulated screws’’, ‘‘cannulated screws configurations’’. We also scanned other articles that we might not have been able to find by examining the references of the articles.

Study eligibility criteria

Studies were selected based on the following inclusion criteria: (1) a biomechanical study of femoral neck fracture and (2) the use of multiple cannulated screws fixation of the fracture. The exclusion criteria were (1) case report, reviews, animal study

Data extraction

The following information is taken from the included articles: authors, date of publication, study design, study subjects, fixation device used, measuring device used, and results of biomechanical tests performed.

Methodological quality assessment

The Newcastle-Ottawa scale was used in this study to evaluate the methodological quality of the nonrandomized studies. It was categorized in three dimensions. Each dimension consists of questions divided into subcategories.

Selection (a maximum of four stars), comparability (a maximum of two stars), and exposure or outcome (a maximum of three stars). A work can be given a maximum of six stars. Two of the authors (EA, TA) independently evaluated the quality of all studies.

Results

Initially, it identified 233 studies from selected databases. After the abstracts and titles of these studies were scanned, 212 were excluded. The remaining 21 studies underwent full-text review and 11 studies were excluded. Details on identifying relevant studies are shown in the flowchart of the study selection process (Fig. 1). The number of subjects included in this study, study design fixation device material, osteotomy and specimen position, and degree of displacement are summarized in Table 1 and Table 2.

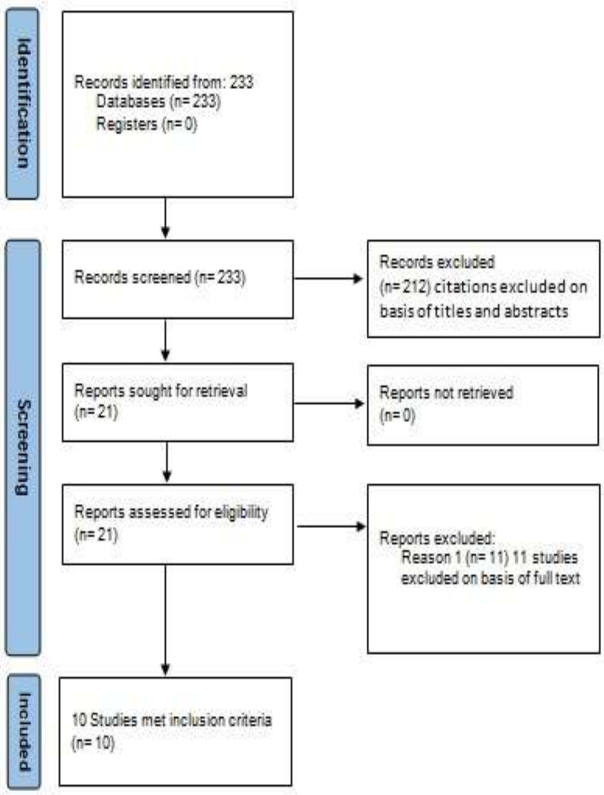

Figure-1. Study flowchart. The 10 studies were included.

In one study by Gumustas et al.[15], the synthetic left femur was randomly divided into 4 equal groups. The mean maximum strength was found to be 36.1±3.2 N/mm2 in Group 1, 27.3±4.1 N/mm2 in Group 2 and 21.9±3.2 N/mm2 in Group 3. The mean displacement at the osteotomy line at the mean moment of maximum strength (21.9±3.2 N/mm2) in Group 3 was 11.5±2.1 mm, while the displacement was 6±1.3 mm in Group 2 and 5.8±1.1 mm in Group 1. ($p<0.05$). In addition, the displacement at the mean maximum strength (27.3±4.1 N/mm2) in Group 2 was 9.1±1.7 mm. Additionally, in this study, the stabilization in the group using 4 screws (Group 1) was higher than the groups using 3 screws (Group 1 and 2). was good ($p<0.05$) [15].

In another study by Liu et al. [16], synthetic femurs were randomly divided into three groups. Posteromedial cortices of the femoral neck were removed in groups B and C. In group A, 8 femurs with intact posteromedial cortex were fixed with three parallel partially threaded screws to form a standard triangle. Higher axial displacement with lower A-P and axial stiffness and load to fracture was found in group B compared to group A ($p\leq 0.001$ for all). Between groups B and C, modified fixation of cannulated screws increased A-P and increased axial stiffness and load to fracture and decreased axial displacement ($p\leq 0.001$ for all) [16].

In a study by Zhou et al.[17], 3D finite element analysis was performed for different placement methods of cannulated tension screws. On the cadaveric femur specimens, one side was treated with the inverted triangle method and the other side was treated with the modified screw fixation method. In 3D finite element analysis, the displacement amount is 3.4966 mm in group A, while it is 3.4227 mm in group D. The amount of displacement in the control group was measured as 3.5747 mm. Considering the shear displacement on the fracture surface of the femoral neck values,

Table 1. Characteristics of included studies.

Study (year)	**Type**	**Number of Materials**	**Screw Configurations**	**Screw Configurations Type**	**Screw Size**	**Osteotomy**	**Specimen Position**
Gumustas (2014)	Third Generation Composite Femurs (Selbones RL.,Turkey)	28(7/7/7/7)	4/3/3/0	3 inverted triangular + 1 calcar transverse screw	6.5 mm cannulated screws	90° osteotomy	25° Adduction
				3 inverted triangular screws	6.5 mm cannulated screws	90° osteotomy	25° Adduction
				1 calcar transverse + 2 parallel screws	6.5 mm cannulated screws	90° osteotomy	16° Adduction
Liu (2019)	Synthetic Femur Models (Sybone, Switzerland)	24(8/8/8)	3/3/3	Partially threaded screws with 3 parallel screws	7.3 mm cannulated screws	70° osteotomy	16° Adduction
				Partially threaded screws with 3 parallel cannulas screws	7.3 mm cannulated screws	70°/30°/15° osteotomy	16° Adduction
				Bottom 2 fully threaded + upper 1 partial threaded screw	6/7mm acutrak and 7.3 mm cannulated screws	70°/30°/15° osteotomy	N/A
Zhou (2020)	Cadaver	N/A	3/3/3/3	2 screws parallel to each other and the head, 1 screw transverse from trochanter major to head	N/A	70° osteotomy	N/A
				1 screw from calcar to head parallel, 2 screws from trochanter major to head transverse	N/A	70° osteotomy	N/A
				1 screw from the midline of the head, 2 screws from the trochanter major transverse to the head	N/A	70° osteotomy	N/A
				2 screws parallel to each other and to the head, 1 screw from the trochanter major to the center of the head	N/A	70° osteotomy	N/A
Zdero (2010)	Third Generation Composite Femurs (Pacific RL., WA)	16(8/8)	3/3	3 inverted triangular screws-large area	6.5 mm cannulated screws	60° osteotomy	0° Adduction
				3 inverted triangular screws	6.5 mm cannulated screws	60° osteotomy	0° Adduction
Tan (2007)	Cadaver	10(5/5)	2/2	2 vertical screw (1 superior , 1 inferior midaxis of the femoral neck)	7.3 mm cannulated screws	70° osteotomy	20° of adduction and 5° to 10° of flexion
				2 horizontal screw (2 superior midaxis of the femoral neck)	7.3 mm cannulated screws	70° osteotomy	20° of adduction and 5° to 10° of flexion
Walker (2007)	Cadaver	14(4/4/6)	2-3/2-3/2-3	2 and 3 screw 135° (1 screw at the medial cortex and 1 at the posterior cortex)	7.3 mm cannulated screws	70° osteotomy	17° Adduction
				2 and 3 screw 145° (1 screw at the medial cortex and 1 at the posterior cortex)	7.3 mm cannulated screws	70° osteotomy	17° Adduction
				2 and 3 screw 150° (1 screw at the medial cortex and 1 at the posterior cortex)	7.3 mm cannulated screws	70° osteotomy	17° Adduction
Wajeesing (2019)	Cadaver	24(8/8/8)	3 /3 /3	Inverted triangle in three different positions A 4.19 cm^2	6.5 mm cannulated screws	60° osteotomy	0° Adduction
				Inverted triangle in three different positions B 2.64 cm^2	6.5 mm cannulated screws	60° osteotomy	0° Adduction
				Inverted triangle in three different positions C 1.35 cm^2	6.5 mm cannulated screws	60° osteotomy	0° Adduction
Lu (2019)	Cadaver	30(5/5/5/5/5/5)	2/2/3/2/2/3	2-DhCCS horizontal fixation	7.3 mm double-head cannulated compression screw (DhCCS)	60° osteotomy	N/A
				2-DhCCS vertical fixation	7.3 mm double-head cannulated compression screw (DhCCS)	60° osteotomy	N/A
				3-DhCCS inverted triangle	7.3 mm double-head cannulated compression screw (DhCCS)	60° osteotomy	N/A
				2-OCCS horizontal fixation	7.3 mm cannulated compression screw (OCCS)	60° osteotomy	N/A
				2-OCCS vertical fixation	7.3 mm cannulated compression screw (OCCS)	6°0 osteotomy	N/A
				3-OCCS inverted triangle fixation	7.3 mm cannulated compression screw (OCCS)	60° osteotomy	N/A
Zhang (2018)	Synthetic Femur Models (ENOVO, China)	20(10/10)	3/3	3 OCCS-triangle fixation	6.5 mm cannulated coMpression screws (OCCS)	70° osteotomy	7° Adduction
				2 HCCS + 1 OCCS-triangle fixation	6.5 mm Headless Cannulated Compression Screws (HCCS) + 6.5 mm cannulated compression screws (OCCS)	70° osteotomy	7° Adduction
Li (2018)	Fourth Generation Composite Femur (Pacific RL.,WA)	N/A	3/3/3/3/3	Triangular configuration 2FTS+ 1 PTS	6.5 mm cannulated screws	70° osteotomy	N/A
				Inverted triangular configuration 2FTS+ 1 PTS	6.5 mm cannulated screws	70° osteotomy	N/A
				Triangle with anterior single screw 2FTS 1+ PTS	6.5 mm cannulated screws	70° osteotomy	N/A
				Triangle with posterior single screw 2FTS+ 1 PTS	6.5 mm cannulated screws	70° osteotomy	N/A
				Vertical configuration 2FTS+ 1 PTS	6.5 mm cannulated screws	70° osteotomy	N/A

Table-2 Mechanical measurement values of included studies.

Study (year)	Axial Loading Measuring Device	Axial Failure Displacement (mm)	Load to Failure	Axial Loading
Gumustas (2014)	Shimadzu autograph AG- X/50Kn (Shimadzu, Kyoto, Japan)	5.8±1.1 mm	36.1 ± 3.2 N/mm2	10-mm compressive deformation by a load of 5 N/mm2 preload in 2 minutes
		11.5±2.1 mm	21.9 ± 3.2 N/mm2	
		6±1.3 mm	27.3 ± 4.1 N/mm2	
Liu (2019)	Instron, (Norwood, MA, ABD)	1.785±0.462 mm	1422.968±110.587 N	400 N load by a load of 10 N/mm2 preload in 2 minutes
		4.857±0.745 mm	1010.918±76.019 N	
		2.859±0.830 mm	1364.580±88.389 N	
Zhou (2020)	Finite element models (MT 180 tension and compression test machine)	3,4966mm	N/A	Up to 600 N at a speed of 100 N/min
		3,7492mm	N/A	
		3.7362mm	N/A	
		3.4227mm	N/A	
Zdero (2010)	Instron 8874, (Norwood, MA, ABD)	10.9± 5.4 mm	3493.5 (164.6) N	Rate, 5 mm/min; maximum displacement, 0.25 mm; preload, 50 N
		16.9± 8.2 mm	2863.5 (207.4) N	
Tan (2007)	Instron Testing Machine 1331 (Instron, Canton, Mass)	3.66±1.92 mm	2.46±1.49 (1.36-5.00) kN	Axial loading of 750 N at 0.5 Hz for 200 cycles
		5.23±1.73 mm	3.75±1.57 (2.33-6.35) Kn	
Walker (2007)	Instron 8874, (Canton, MA, ABD)	N/A	2 screw 414.5 N/mm - 3 screw 502.3 N/mm	Preloaded to 50 N, the crosshead was displaced 2 mm at 1 Hz, and testing was done for 5 cycles
		N/A	2 screw 327.1 N/mm - 3 screw 449.5 N/mm	
		N/A	2 screw 397.3 N/mm - 3 screw 400.7 N/mm	
Wajeesing (2019)	Instron series IX	10.06 (9.99-10.12) mm	862.87 (859.37-866.37) N	N/A
		12.11 (12.00-12.22) mm	622.62 (620.48-624.76) N	
		15.15 (14.95-15.35) mm	324.37 (322.48-326.26) N	
Lu (2019)	Finite element models (SANS testing machine MTS Industry Systems CO.LTD,China)	4.987±0.80 mm	2129 ±150 N	Rate of 1.2 mm/min the linear load of 0-600N
		5.334 ±0.56 mm	1654 ±336 N	
		4.918 ±0.54 mm	2229 ±424 N	
		5.350 ±0.34 mm	1666 ±100 N	
		5.476 ±1.34 mm	1246 ±162 N	
		5.028 ±0.89 mm	2201 ±509 N	
Zhang (2018)	Instron, (Norwood, MA, ABD)	N/A	302.92 ± 80.46 N	N/A
		N/A	446.85 ± 76.25 N	
Li (2018)	Finite element models	0.54 mm	N/A	2100 N
		0.76 mm	N/A	
		1.03 mm	N/A	
		0.72 mm	N/A	
		0.66 mm	N/A	

group A was 0.0113 mm, group B 0.0062 mm, group C 0.1812 mm, group D 0.0889 mm. the control group was measured as 0.0110 mm. Changing the placement of the inverted triangular anterosuperior screw perpendicular to the fracture line has advantages in preventing slippage, preventing rotation, and increasing intercompression. Femoral displacement, equivalent stress of the internal fixation screw, and maximum shear stress of the internal fixation screw were smallest in group D compared with the other groups. This showed that in group D, the femoral equivalent stress was excellent and could provide the most pressure to the fracture surface. The reason for the relatively large sliding displacement of the fracture surface in Group D was the deformation of the femoral neck [17].

In a study by Zdero et al.[18], did a study on 16 synthetic femurs. Fractures were reduced and repaired using group 1 (n= 8) or group 2 (n= 8) cannulated spongy screw methods. Samples were tested for torsional and axial stiffness using subclinical loads followed by axial failure tests. Group 1 was assigned to Group 1 for torsional stiffness (9.9 vs 7.9 Nm/deg, Group 1/Group2 ratio = 1.25, p = 0.018), axial stiffness (1278.1 N/mm versus 1469.0, method 1/method). 2 ratio = 1.15, p = 0.023) and axial fault load (3493.5± (164.6) N vs. 2863.5± (207.4) N, Group 1/ Group 2 ratio = 1.22, p = 0.000). However, statistically significant axial failure displacement (10.9 ± (5.4) mm vs. 16.9 ± (8.2) mm, Group 1/Group 2 ratio = 0.64, p = 0.101) or axial failure energy (29.9 vs. 35.9 J) there were no differences. , Group 1/Group 2 ratio = 0.83, p = 0.453). Group 1 was mechanically more stable than group 2 in femoral neck fracture fixation as determined by three of the five biomechanical measurements and was equivalent to group 2 for two of the five biomechanical measurements [18].

In a study by Tan et al.[19], 10 cadaver femurs were studied. Horizontal and vertical cannulated screw fixation methods were compared in 2 different groups. Overall, mean vertical displacement of the proximal fragment during cyclic loading was 1.1 mm for all 10 constructs. Considering the Maximal Load to failure, it was 3.75±1.57 (2.33-6.35) kN in the horizontal group, while it was 2.46±1.49 (1.36-5.00) kN in the vertical group (p=0.019). But there was no statistical difference in displacement or stiffness at failure. When displacement failure was measured, it was 5.23±1.73 (3.43-7.24) mm in the horizontal group and 3.66±1.92 (2.08-6.86) mm in the vertical group. At the yield point, load, displacement, and stiffness were significantly higher in the horizontal group. Furthermore, there was no side-to-side difference between the left and right hips (p>0.3). Preliminary data suggest that 2 horizontal screws in the superior aspect of the femoral neck provide more secure fixation than 2 vertical screws [19].

In a study by Walker et al.[20], biomechanically evaluated Pauwels type III femoral neck fractures on 14 cadaver femurs. In the study reported here, we compared the relative stiffness of fixation with 2 or 3 cannulated screws in femurs implanted at 135°, 145°, and 150°. Axial Compressive Stiffness (N/mm) value in group 1 (135°) 2 screws 414.5 N/mm - 3 screws 502.3 N/mm, in group 2 (145°) 2 screws 327.1 N/mm - 3 screws 449.5 N/mm , 2 screws 397.3 N/mm - 3 screws 400.7 N/mm in group 3 (150°).These results did not show any statistically significant differences (P = 0.05 at power of 0.93) between the angles of screw placement for axial stiffness and 2 versus 3 screws. AP bending stiffness values at the high angle (150°) was highest among all the angles, showing a significant difference for 2 screws and not 3 screws (P = 0.043 and power of 0.49). There was no significant difference between 2 and 3 screws at each angle. bone mineral density (BMD) values of femurs did not differ significantly among the 3 groups (150°, 145°, 135°) at P = 0.05 and power of 0.05. However, when axial stiffness values for each group (135°, 145°, 150°) were correlated with their respective BMD, the regression coefficient was highest (R2 0 = 0.99 for 2 screws and R2 = 0.77 for 3 screws for 150°). AP bending stiffness did not correlate with BMD (R2 0<0.02).Axial stiffness values were not statistically different at different angles. AP bending stiffness of the high-angle (150°) construct was significantly higher than that of either of the other 2 constructs (for 2 screws only). Two-screw fixation appears to be adequate; adding a third screw may not be necessary [20].

In a study by Wajeesing et al.[21], 24 cadaver femoral bones were studied. An inverted triangle image was obtained in three different positions by dividing it into 3 different areas as A, B and C groups. Femoral neck fracture fixation by using a multiple screw fixation method with cannulated screw, was divided screw area in femoral neck into 3 areas which are area A (4.19 cm^2), area B (2.64 cm^2) and area C (1.35 cm^2). Axial load to failure measurements were made and values of 862.87 (859.37-866.37) N in group A, 622.62 (620.48-624.76) N in group B and 324.37 (322.48-326.26) N in group C were found (p<0.001). Axial failure displacement measurements were made and values of 10.06 (9.99-10.12) mm in group A, 12.11 (12.00-12.22) mm in group B and 15.15 (14.95-15.35) mm in group C were found (p<0.001). It was found that area A with the most area in the femur had better biomechanical effect than other groups[21].

In a study by Lu et al.[22], we evaluated the biomechanical effects of a double-headed cannulated compression screw (DhCCS) and ordinary cannulated compression screw (OCCS) for the treatment of femoral neck fractures on 30 cadaveric bones using computer finite element analysis. Both DhCCS and OCCS 3D models were obtained by using the 3D scan technique. Axial failure yield displacement (mm) values; 2-DhCCS horizontal fixation (A1) 4.987±0.80 mm, 2-DhCCS vertical fixation (B1) 5.334 ±0.56 mm, 3-DhCCS inverted triangle (C1) 4.918 ±0.54 mm, 2-OCCS horizontal fixation (A2) 5.350 ±0.34 mm, 2-OCCS vertical fixation (B2) was measured as 5.476 ±1.34 mm, 3-OCCS inverted triangle fixation (C2) was measured as 5.028 ±0.89 mm (*p*<0.005). Yield load(N) values; A1 group was measured as 2129±150N, B1 group as 1654±336N, C1 group as 2229±424N, A2 group as 1666±100N, B2 as 1246±162N, C2 group as 2201±509N (*p*<0.005). There were no significant differences in yield displacement between the 6 groups (*p*>0.05). The displacement value of the femoral head in the DhCCS group was smaller than in the OCCS group. The displacement value in the two horizontal groups is smaller than in the vertical group. The stress in the horizontal group is more distributed in the screws than in the vertical group. DhCCS has reliable stability for the detection of femoral neck fractures [22].

In a study by Zhang et al.[23], 24 artificial femur bones were analyzed as 3 groups. The posteromedial cortices of femoral neck were removed in groups B and C. In group B and group C, the posteromedial cortex of the femoral neck was removed. Axial load to failure measurements were made and values of 1422.968±110.587 N in group A, 1010.918±76.019 N in group B and 1364.580±88.389 N in group C were found. Axial failure displacement measurements were made and values of 1.785±0.462 mm in group

A, 4.857±0.745 mm in group B and 2.859±0.830 mm in group C were found. The lower A-P and axial stiffness and load to failure along with higher axial displacement were found in group B compared with group A ($p \leq 0.001$). Between groups B and C, the modified fixation of cannulated screws increased A-P and axial stiffness and load to failure and reduced the axial displacement ($p \leq 0.001$). Modified fixation of cannulated screws, characterized by two poor quality fully threaded screws, can improve biomechanical performance and better support the femoral head fragment [23]. In a study by Li et al.[24], they examined unstable femoral neck fractures using 5 different screw configurations on a fourth-generation composite femur. Finite element analysis method was used. Axial failure displacement measurements were 0.54 mm in the triangular configuration group, 0.76 mm in the inverted triangular configuration group, 1.03 mm in the triangle with anterior single screw configuration group, 0.72 mm in the triangle with posterior single screw configuration group, and 0.66 mm in the vertical configuration. It was observed that the peak von Mises stresses of the screws were highest in the middle of the screw close to the fracture line in each group. In each group, the fully threaded screw was subjected to the most stress. The lowest displacement was observed in the triangular model. The volume of bone susceptible to yielding in the femoral neck region was the lowest for triangular configuration. For unstable femoral neck fractures, superior results were obtained by stabilizing the fracture with triangular configuration formed by one superior partially threaded screw and two inferior fully threaded screws [24].

Risk of Bias: The Newcastle-Ottawa scale was used to assess the quality of the 10 studies reviewed. All selected studies were of high quality and scored 6-8.

Discussion

Many treatment methods such as hemiarthroplasty, total hip replacement, DHS, locking plate, proximal femoral nail and multiple screw fixation are applied in the treatment of femoral neck fractures. Many factors depending on the patient and the surgeon change which implant will be applied in which case. In this study, 10 studies in which cannulated screws were applied in femoral neck fractures were evaluated, and which screw selection and which configuration application was evaluated through the articles. After the fixation of femoral neck fractures, the presence of axial shear forces, varus angulation and displacement of the postoperative proximal part are observed. For this reason, the treatment method is very important.

The cadaver and sawbone femur bones used in the included studies were osteotomized between 15° and 90°. In these studies, 0º and 25º adduction positions were most commonly used while standing. The force in the loading test ranged from 50 N to 2100 N. However, one study performed bone wedge removal at the posteroinferior osteotomy site to simulate a bone defect. [16]. Posterior fragmentation of the femoral neck affects postoperative stability [16].

Pauwels Type 3 fractures are dominated by higher shear stress and varus loading (25). A few of the articles included in this study were osteotomized to 70° and simulated pauwels type 3 fractures. [16, 17, 19, 20, 23, 24].

According to the study of Gumustas et al., the group with 4 screws (3 Inverted triangular + 1 calcar transverse screw) has the highest average maximum strength. Among the groups in which three screws were sent, the group with 2 vertically parallel to the neck and the third crossed with the calcar had higher maximum strength [15].

In the study by Liu et al., unstable stabilization was demonstrated when the fragmented posteromedial cortex was disrupted if fixation was performed with partially threaded cannulated screws (PTS) ($p \leq 0.001$ for all). Biomechanical force and amount of displacement decrease if two-bottom screw-in fully threaded cannulated screws (FTS) are used ($p \leq 0.001$ for all) [16].

In the study of Zhou et al., it is more advantageous to change the anterosuperior screw in the inverted triangle structure perpendicular to the fracture line, preventing slipping and rotation, and increasing the compression between the parts. In the biomechanically strongest recommended strongest fixation, the first screw was advanced close to the lower cortex of the femoral neck and through the calcar. The second screw should be placed close to the posterior cortex of the femoral neck and the third screw should be placed along the anterior part of the femoral neck [17].

In the study by Zdero et al., method 1(3 inverted trianguler screws) showed statistically higher torsional stiffness, axial stiffness and axial fracture load. There was no difference for axial failure displacement or axial failure energy [18]. In the study of Tan et al., the most surprising finding was that the maximum displacement at failure was greater in the horizontal group. According to this study, it is recommended to fix with 2 screws more than 3 screws in the fixation of femoral neck fracture. However, in 2-screw fixation, placing parallel screws horizontally on the top of the femoral neck and head provides better fixation [19].

In the study of Walker et al., screw fixation was performed at 3 different angles (135° -145° - 150°). There was no difference in axial stiffness values of screws configured at different angles. Fixation at 150° has the advantage in AP bending values. 2 screws provide sufficient stabilization. The third screw does not have a significant advantage. Screw placement angle does not matter in 3-screw fixation [20]

In the study of Wajeesing et al., it was shown that area A, which is the most closed area, has a better biomechanical effect than areas B and C, which are less closed areas in femoral neck fractures. Biomechanical effect in B area was better than C area in axial stiffness, axial load up to failure, Axial failure displacement and Axial failure energy. The more screws placed in the femoral neck region, the greater the biomechanical effect on stability [21].

In the study of Lu et al., the displacement value of the femoral head in the DhCCS group is less than in the OCCS group. The displacement values in the two horizontal groups are less than in the vertical group. The displacement value in the three-screw group is less than in the two-screw group. DhCCS has better biomechanical stability. DhCCS is recommended to treat femoral neck fractures. If the femoral neck is small, two horizontal fixations may be preferred [22].

In the study by Zhang et al showed that using one OCCS + two HCCS for the treatment of vertical femoral neck fractures outperformed using OCCS alone [23].

In the study of Li et al., the treatment of unstable femoral neck fractures was investigated using the finite element analysis method. The stress value of the triangular configuration formed by 1 upper PTS and 2 lower FTS shows that it is less subject to fracture displacement and yield stresses in the bone [24].

A stable fixation is the main goal in the surgical treatment of femoral neck fractures. For this reason, many biomechanical studies have been carried out. However, there is no ideal fixation method and no gold standard method for screw configuration in cannulated screw fixation..

The limitations of this study are the use of a wide variety of implants in the sawbone bone and cadaver studies included in the study. Mechanical study results of implants cannot be directly compared. Another reason is that the included studies were conducted using sawbone bones and cadavers, although some studies have measured bone density, so it may differ from the results of clinical studies.

Conclusion

There are various surgical techniques and biomedical materials for the detection of femoral neck fractures. In addition, each cannulated screw treatment configuration has advantages and disadvantages. For this reason, the most appropriate treatment configuration should be selected, taking into account the experience of the surgeon and the fracture types.

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