Injury, Int. J. Care Injured 50 (2019) 727–732

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Ideal length of thread forms for screws used in screw fixation of nondisplaced femoral neck fractures

Christina Liu[a,c], Arvind Von Keudell[b,c,1], Michael McTague[c,1], Edward K. Rodriguez[a,d,1], Michael J. Weaver[a,c,*,1]

[a] Harvard Medical School, Boston, MA, USA
[b] Department of Orthopedic Surgery, Massachusetts General Hospital, Boston, MA, USA
[c] Department of Orthopedic Surgery, Brigham and Women's Hospital, Boston, MA, USA
[d] Department of Orthopedic Surgery, Beth Israel Deaconess Medical Center, Boston, MA, USA

ARTICLE INFO

Article history:
Accepted 30 January 2019

Keywords:
Hip fracture
Femoral neck fracture
Lag screw fixation

ABSTRACT

Background: It is common practice when placing cannulated screws within the femoral head when treating femoral neck fractures to avoid the thread-forms from crossing the fracture line. Despite the widespread use of cannulated screws in internal fixation of femoral neck fractures, there is no study to our knowledge that describes the ideal length of thread-forms.
Purpose: The purpose of this study is to determine the thread length that will maximize purchase within the femoral head while minimizing risk of crossing the fracture line. Additional analysis was conducted to identify factors associated with the maximal possible length of treads in minimally and non-displaced femoral neck fractures.
Methods: We performed a retrospective study of all patients treated for a minimally or non-displaced femoral neck fracture from April 1, 2004 through December 31, 2017. Only patients who had received a pre-operative CT or MRI scan were included. Fixation was then templated using radiographs and the distance from the subchondral bone to the fracture line was then measured.
Results: The study included 127 patients. The average estimated length of lag screw threads was 33.2 ± 6.67 mm, with lower quartile of 29.1 mm and higher quartile of 37.2 mm. The median was 32.0 mm and most frequently encountered estimate was 29 mm. Estimated lag screw size did not differ significantly based on age or BMI, but both height ($p < 0.001$) and race (0.04) were positively correlated with estimated lag screw size and males had longer measurements compared to females, 37.2 ± 7.0 mm vs 31.4 ± 5.7 mm ($p < 0.001$), respectively.
Conclusion: In conclusion, we propose an additional lag screw thread form with length 26.0 mm to capture 90% of femoral neck fractures.

Introduction

In 2008 there were almost 341,000 emergency department visits in the United States for hip fractures [1]. That number is projected to surpass 500,000 annually by 2040 [2]. The majority of hip fractures are femoral neck fractures that occur in elderly patients as a result of low-energy trauma [3].

Cannulated screws are the most commonly used implant for internal fixation of femoral neck fractures [4], especially in those under 60 or have good bone health [5], given the quick recovery, short operative time, and low blood loss [6,7]. Most major manufactures offer two standard thread lengths listed in Table 1 below. To optimize purchase within the bone and improve compression across the fracture plane it is important to maximize the amount of screw threads within the femoral head fragment [8,9]. However, to achieve optimal compression between the fracture fragments, it is important for all the tread-forms to be across the fracture site [10]. Though a longer thread form has a higher risk of crossing fracture lines, the greater thread area also offers greater compression across fractures as shown in cadaveric

* Corresponding author at: Harvard Medical School, 25 Shattuck St, Boston, MA 02115, USA.
E-mail addresses: Christina_liu@hms.harvard.edu (C. Liu), avonkeudell@mgh.harvard.edu (A. Von Keudell), mmctague@bwh.harvard.edu (M. McTague), ekrodrig@bidmc.harvard.edu (E.K. Rodriguez), mjweaver@partners.org (M.J. Weaver).
[1] Address: Brigham and Women's Hospital, Department of Orthopaedic Surgery, 60 Fenwood Road, Boston, MA 02115.

https://doi.org/10.1016/j.injury.2019.01.036
0020-1383/

Table 1
Standard thread lengths for large cannulated screws ≥ 6.5 mm.

Major Manufacturer	Standard thread lengths (mm)
DePuy Synthes® Cannulated Screw System	16 mm
	32 mm
Smith & Nephew® Large Cannulated Screw System**	16 mm
	22 mm
	32 mm
	46 mm
Stryker® Asnis III Cannulated Screw System	20 mm
	40 mm
Zimmer Biomet® 6.5/8.0 mm Cannulated Screw System	16 mm
	40 mm
Zimmer® Magna-FX Cannulated Screw Fixation System	16 mm
	32 mm

** 16 and 32 mm part of 7.0 mm Cannulated Screw Set, 22 and 46 mm part of 6.5 mm and 8.0 mm Cannulated Screw Sets.

femoral heads [11]. While a recent RCT showed no significant difference in outcomes between the 16 mm and the 32 mm screw in terms of nonunion, AVN, or re-operation it was underpowered to detect a subtle difference between implants [12]. There is no study to our knowledge that describes the ideal length of thread-forms for cannulated screws in the fixation of femoral neck fractures.

The primary aim of this study is to identify the thread length that will maximize purchase within the bone while minimizing risk of the tread-forms from crossing the fracture line in minimally and non-displaced femoral neck fractures. The secondary goal of this study was to identify factors associated with the maximal possible length of treads in minimally and non-displaced femoral neck fractures.

The study was approved by the Brigham and Women's Hospital Institutional Review Board (Protocol 2018P000705).

Patients and methods

Study design

We performed a retrospective study of all patients treated at two ACS level 1 trauma centers between April 1, 2004 and December 31, 2017.

Study participants

Cases were identified retrospectively by querying the hospital database for patients with femoral neck fracture who received pre-operative computerized tomography (CT) or magnetic resonance imaging (MRI). Inclusion criteria for the study were as follows: (1) Pre-operative CT or MRI imaging and (2) femoral neck fractures. Exclusion criteria were: (1) severely displaced or angulated fracture; (2) pathologic fracture secondary to malignancy or infection; (3) peri-prosthetic fractures; (4) poor imaging documented on final radiology report; and (5) no coronal reformatted images. Baseline characteristics for patient (age, gender, race, height, body mass index (BMI), and mechanism of injury) were recorded. A total of 127 patients met the inclusion criteria and were included in the study (Fig. 1).

Imaging and measurements

The pre-operative CT and MRI images were reviewed in a standard fashion. Mid-coronal slices of reformatted coronal CT and MRI sequences were used. Fracture lines were identified in the region of the femoral neck and possible trajectories for cannulated lag screws were templated. These trajectories were made to mimic screw paths of an inverted triangle configuration, with screws perpendicular to fracture plane and parallel to femoral neck axis. Care was taken to identify the lesser trochanter to ensure an appropriate simulated start-point for the planned screw trajectory. The distance between the subchondral bone and the fracture line was then measured along both the superior and inferior screw trajectory so that each patient had two screw measurements as seen in Fig. 2. This distance from proximal femoral head to fracture line reflected the maximum possible thread-form length on the lag

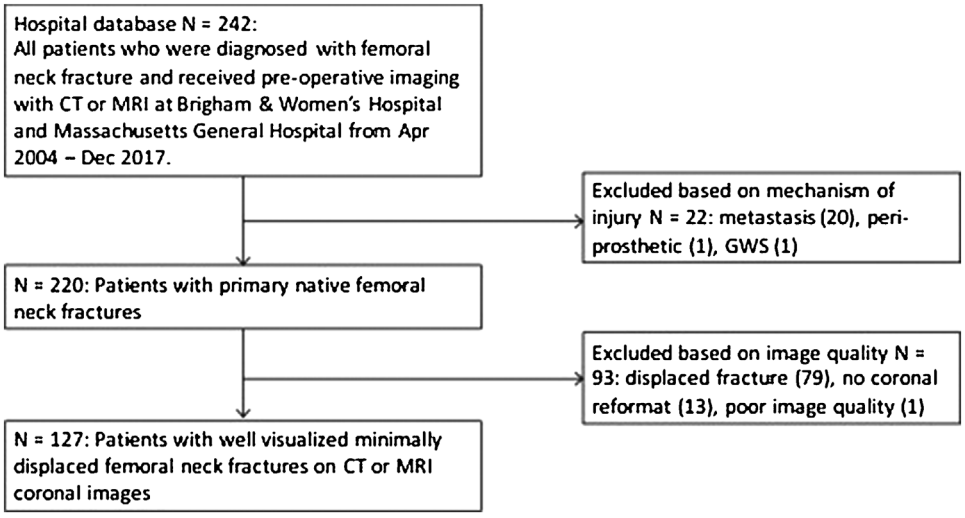

Fig. 1. Derivation of patients include and excluded in the study.

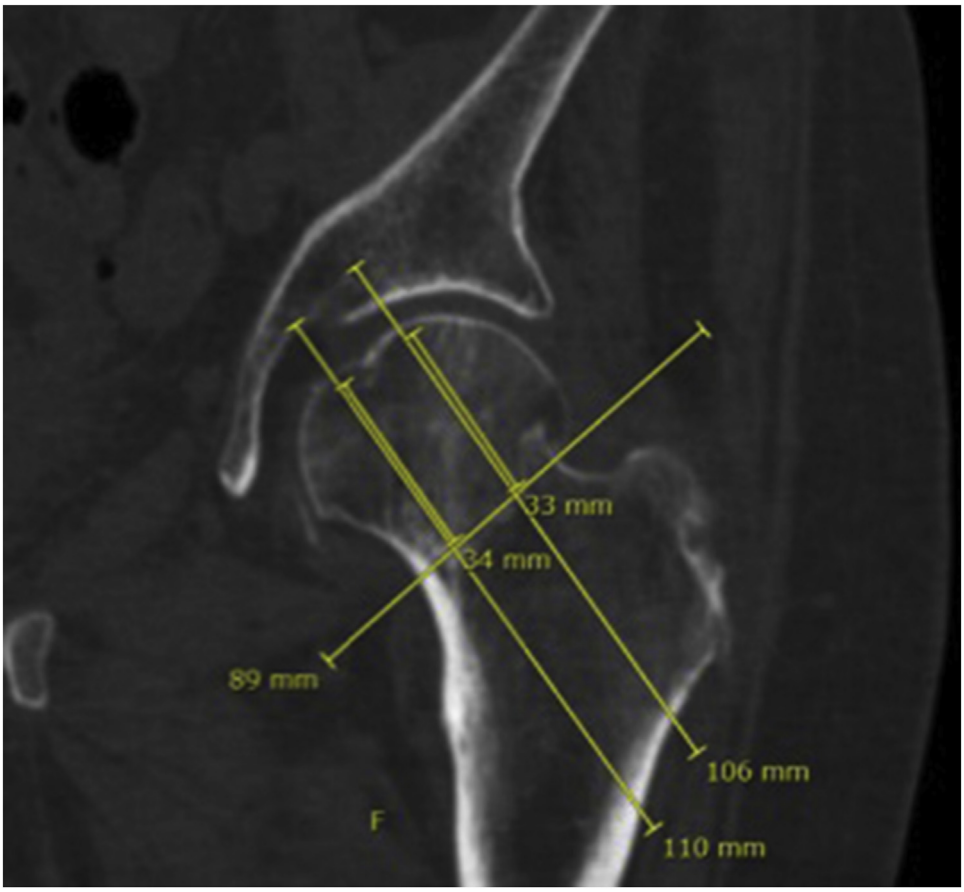

Fig. 2. Modeling lag screw placement and thread form measurements on CT or MRI imaging of femoral neck fracture.

screw without penetrating into the joint or crossing the fracture line. One person performed all radiographic measurements for this study to minimize inter-reader variability. However, inter-reader reliability was performed with 10 randomly selected patients, demonstrating similar estimates.

Variables

Patient demographics, medical histories, and imaging were abstracted from the electronic medical record. Femoral head and neck fragment lengths were defined in millimeters.

Statistical analysis

Categorical variables were compared using a chi square test or Fisher's exact test. Continuous variables, including predicted thread-form length, were analyzed using a Student's *t*-test (ANOVA). Mann Whitney U test was performed for comparing medians of simulated superior and inferior screw estimates. For all tests, an alpha level less than 0.05 was considered statistically significant. Linear regression analysis was performed using SAS/STAT® Software. Cases with missing data point(s) were excluded from the analysis for that variable and noted in the data table.

Results

Of the 242 patients identified from a review of the hospital databases during the study period, 127 patients met the study inclusion criteria (Fig. 1). Of these, 56 patients received preoperative CT imaging while the remaining 71 patients received MRI. Demographic and injury data is presented in Table 2.

Table 2
Characteristics of patients with femoral neck fractures.

	Overall N = 127
Median age, years (range)	71.9 (76.79)
Gender, %	
Female	68.5%
Male	31.5%
Mean height, cm (SD)*	164.9 ± 11.02
Mean BMI, kg/m [2] (SD)**	24.5 ± 5.82
Mechanism of Injury, %	
Fall	79.5%
Trauma	5.5%
Atraumatic	15.0%
Lag screw thread form length, mm (SD)	33.2 ± 6.67

BMI, body mass index; SD, standard deviation.
* 16 cases with no height listed in chart near time of injury.
** 19 cases with no BMI listed in chart near time of injury.

The average length of the maximal possible screw thread forms, as measured by distance from sub-chondral bone to fracture along the superior and inferior simulated screw trajectories, was 33.2 ± 6.67 mm. Based on our measurements, 90% of cases had estimated thread lengths greater than 26.0 mm while 95% of cases had estimates greater than 24.0 mm. Fig. 3 shows the distribution of estimated thread lengths with the lower quartile at 29.1 mm and upper quartile at 37.2 mm. The interquartile range was 8.1 mm with a median of 32.0 mm. Comparison of the simulated superior versus inferior screw trajectories showed a statistically significant difference with relative medians of 31.6 mm and 33.0 mm respectively (p = 0.02).

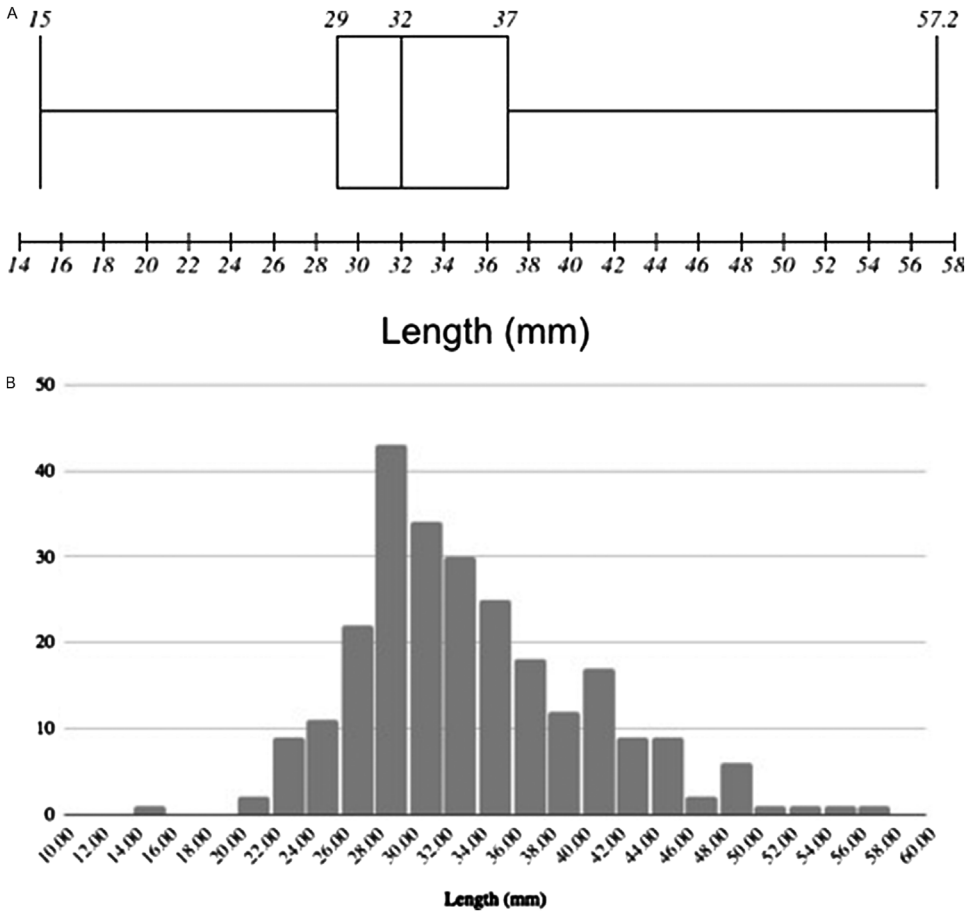

Fig. 3. Depicting length distributions of thread forms (mm) via (A) box-and-whisker plot and (B) histogram.

Concerning secondary outcomes, Table 3 presents the distribution of lag screw thread form lengths based on various factors such as age, gender, race, height, and BMI. The estimated lengths of thread forms were significantly longer in males (mean 37.2 ± 7.0) compared to females (mean 31.4 ± 5.7, $p < 0.001$) and in patients identifying as Hispanic (39.1 ± 9.8, $p = 0.04$) compared to other races. Height was also positively correlated with longer estimated thread form lengths ($p < 0.001$). The estimated lengths of lag screw thread forms was not associated with age ($p = 0.65$) or BMI ($p = 0.32$). Linear regression analysis showed that only height was significantly correlated with thread form length ($p = 0.002$).

Discussion

Presently, most lag screws are manufactured with two standard thread form lengths, 16 mm and 32 mm [12] (Table 1). Based on our data, the commonly available tread-form lengths do not appear to optimally treat non-displaced and minimally-displaced femoral neck fractures. While the 32 mm length may be used safely in approximately 50% of cases, the 16 mm tread is likely too conservative. A tread form length of 26 mm would improve screw purchase considerably and would still not cross the fracture line in over 90% of patients. In addition to analyzing the distribution of possible thread form lengths, our study also showed that increased height is associated with longer possible tread lengths. This is most likely due to the correlation between height and bone size [13,14].

Based on previous biomechanical studies, stability of fracture fixation is determined largely by compression across fracture surface to transfer load sharing [9]. A larger thread area offers greater purchase, and thus increases compression across facture plane [8]. As such, for lag screws to offer the maximum purchase within the bone and compression across the fracture line, the thread form lengths should be equal to the distance from the subchondral bone of the femoral head to fracture line.

A recent study showed a failure rate of fixation of minimally displaced and non-displaced fractures to be 19%, of which over 40% were due to loss of fixation [15]. Our results suggest that a longer thread length of 26 mm may offer better purchase within bone and thus lower this complication rate. Although a RCT from 2009 showed no significant difference in failure rates between patients treated with 16 mm versus 32 mm [12], sample size calculations suggested over 3000 subjects were needed in each arm to detect subtle differences between groups. Further, patients in this RCT were randomized without consideration of femoral head to fracture line distances. It is unclear how many patients randomized to the longer lag screw had thread forms straddling fracture lines, which may also explain the lack of difference between the two groups. Our study suggests that half of patients with minimally and non-displaced femoral neck fractures have estimated femoral head to fracture line distances of less than 32 mm and thus poor candidates for the 32 mm lag screw. Depending on which manufacturer and cannulated screw set used, it may be that only the 16 mm tread lengths are available for this patient population. Either adding tread length options or increasing the minimum tread length would increase the screw purchase possible within the femoral head without compromising lag screw technique by crossing the fracture line.

Our study has a number of limitations. First, the optimal screw type and fixation strategy during the treatment of femoral neck

Table 3
Lag screw thread form length.

	Overall (n = 127)	Lag screw thread form length (mm ± SD)	P value
Age, years:			0.65
<55	15.0%	33.6 ± 6.9	
55-64	15.0%	34.1 ± 6.5	
65-74	23.6%	33.8 ± 7.4	
75-84	22.8%	32.6 ± 7.0	
>85	23.6%	32.5 ± 5.3	
Gender:			< 0.0001
Female	68.5%	31.4 ± 5.7	
Male	31.5%	37.2 ± 7.0	
Race/ethnicity:			0.04
White	85.0%	33.0 ± 6.6	
Black	4.7%	31.6 ± 5.0	
Hispanic	3.1%	39.1 ± 9.8	
Asian	0.8%	28.4 ± 0.7	
N/A	6.3%	35.3 ± 5.0	
Height, cm:			< 0.0001
<150	7.1%	30.5 ± 4.9	
150-159	21.3%	30.6 ± 6.0	
160-169	26.8%	32.0 ± 4.7	
170-179	22.8%	35.2 ± 6.7	
>180	9.4%	39.4 ± 5.8	
N/A	12.6%	33.7 ± 8.4	
BMI, kg/m [2]:			0.32
<18.5	12.6%	33.0 ± 5.4	
18.5-24.9	32.3%	32.4 ± 6.4	
25.0-29.9	32.3%	33.8 ± 6.4	
>30.0	7.9%	32.0 ± 3.8	
N/A	15.0%	34.8 ± 9.1	
Mechanism of Injury:			0.002
Fall*	79.5%	32.9 ± 6.6	
Trauma	5.5%	39.3 ± 7.9	
Other**	15.0%	32.6 ± 5.1	

BMI, body mass index; SD, standard deviation.
* Fall: low impact injury, fall from standing.
** Other: atraumatic, history of primary metabolic bone disorder, chronic steroid use.

fractures with cannulated screws is unknown. There is some data to suggest that using 16 mm threads is adequate and longer areas of thread-forms is not required [12]. Another recent study has shown that using fully threaded screws and crossing the fracture site to prevent collapse is also a viable strategy [16]. The data presented in this study is useful for surgeons who prefer to avoid crossing the fracture site, but wish to maximize the purchase within the femoral head. It is unknown whether differences in screw design of length of thread-forms would lead to a clinically detectible difference in the rate of loss of reduction or failure of fixation. Further, this study was based only on patients with CT or MRI scans available, regardless of method used in clinical care. CT and MRI were chosen as the imaging modality of choice for their high resolution, which allowed accurate determination of fracture angulation and displacement, as well as accurate radiographic measurements of theoretical thread length. Based on radiology reports, patients received CT or MRI either due to inadequate visualization of femoral neck fracture on initial hip XR or for concomitant abdominal or pelvic pathology. Only patients with minimally angulated and displaced fractures were included to ensure accurate simulated screw paths on radiographic imaging, and to reflect clinical practice as most patients who receive screw fixation have minimally displaced femoral neck fractures. It is possible that this population of patients is in some way different from the typical hip fracture patient. Additionally, our measurements were based on simulated screw trajectories, and there could be some difference between the measurements made and the clinical practice of placing screws. The results of this study demonstrate the need for additional prospective clinical studies measuring maximum thread form length in real time of patients presenting with minimally displaced femoral neck fractures.

Conclusion

In conclusion, it appears that the current thread-length options available are not ideal for the fixation of minimally displaced and minimally angulated femoral neck fractures. Given the common occurrence of these injuries, fracture implants should be designed to optimize purchase within the bone while maintaining the lag screw function of the implants. The addition of a 26 mm thread length screw would substantially increase the surface area of the treads making contact within the cancellous bone of the femoral head without crossing the fracture line in the vast majority of patients.

Acknowledgments

This work was conducted with support from Harvard Catalyst | The Harvard Clinical and Translational Science Center (National Center for Advancing Translational Sciences, National Institutes of Health Award UL 1TR002541) and financial contributions from Harvard University and its affiliated academic healthcare centers. The content is solely the responsibility of the authors and does not necessarily represent the official views of Harvard Catalyst, Harvard University and its affiliated academic healthcare centers, or the National Institutes of Health.

References

[1] Kim S, Meehan J, Blumenfeld TSR. Hip fractures in the United States: 2008 nationwide emergency department sample. Arthritis Care Res (Hoboken) 2012;64(5):751–7.
[2] Cummings SR, Rubin SMB. The future of hip fractures in the United States. Numbers, costs, and potential effects of postmenopausal estrogen. Clin Orthop Relat Res 1990;252:163–6.

[3] Antapur P, Mahomed NGR. Fractures in the elderly: when is hip replacement a necessity? Clin Interv Aging 2011;6:1–7.
[4] Ye Y, Hao J, Mauffrey C, Hammerberg M, Stahel PHD. Optimizing stability in femoral neck fracture fixation. Ortho 2015;38(10):625–30.
[5] Rogmark C, Carlsson A, Johnell OSI. A prospective randomised trial of internal fixation versus arthroplasty for displaced fractures of the neck of the femur. Functional outcome for 450 patients at two years. J Bone Jt Surg Br. 2002;84 (2):183–8.
[6] Ravikumar KJMG. Internal fixation versus hemiarthroplasty versus total hip arthroplasty for displaced subcaptial fractures of the femur - 13 year results of a prospective randomized study. Injury 2000;31:793–7.
[7] Bhandari M, Devereaux PJ, Swiontkowski MF, 3rd Tornetta P, Obremskey W, Koval KJ, et al. Internal Fixation compared with arthroplasty for displaced fractures of the femoral neck. A meta-analysis. J Bone Jt Surg Am 2003;85-A(9):1673–81.
[8] Swiontkowski MF, Harrington RM, Keller TSVP. Torsion and bending analysis of internal fixation techniques for femoral neck fractures: the role of implant design and bone density. J Orthop Res 1987;5:433–44.
[9] Stankewich CJ, Chapman J, Muthusamy R, Quaid G, Schemitsch E, Tencer AF, et al. Relationship of mechanical factors to the strength of proximal femur fractures fixed with cancellous screws. J Ortho Trauma 1996;10(4):248–57.
[10] Uhl R. The biomechanics of screws. Orthop Rev 1989;18(2):1302–7.
[11] Frandsen PA, Christoffersen HMT. Holding power of different screws in the femoral head: a study in human cadaver hips. Acta Orthop Scand 1984;55:249–351.
[12] Parker MAS. Short versus long thread cannulated cancellous screws for intracapsular hip fractures: a randomised trial of 432 patients. Injury 2010;41:382–4.
[13] Ruff CB, Trinkaus E, Walker A, Larsen CS. Postcranial robusticity in Homo. I: temporal trends and mechanical interpretation. Am J Phys Anthropol 1993;91 (1):21–53.
[14] Pan N. Length of long bones and their proportion to body height in hindus. J Anat 1924;(58):374–8.
[15] Fixation using Alternative Implants for the Treatment of Hip fractures (FAITH) Investigators. Fracture fixation in the operative management of hip fractures (FAITH): an international, multicentre, randomised controlled trial. Lancet 2017;389(10078):1519–27.
[16] Weil Yoram A, Qawasmi Feras, Liebergall Meir, Rami Mosheiff AK. Use of fully threaded cannulated screws decreases femoral neck shortening after fixation of femoral neck fractures. Arch Orthop Trauma Surg 2018;138 (5):661–7.