ABCResearch

Arch Basic Clin Res 2023; 5(2): 256-262 • DOI: 10.5152/ABCR.2023.22085

Original Article

Optimal Level for Subtrochanteric Femoral Shortening Osteotomy in Crowe Type 4 Patients

Yakup Alpay[1], Kutalmış Albayrak[2], Atakan Ezici[1], Muhammed Bilal Kürk[3], Deniz Akbulut[4], Sarper Gürsu[5]

[1]Department of Orthopedics and Traumatology, VM Medical Park Maltepe Hospital, İstanbul, Türkiye
[2]Department of Orthopedics and Traumatology, İstanbul Surgery Hospital, İstanbul, Türkiye
[3]Department of Orthopedics and Traumatology, Arnavutköy State Hospital, İstanbul, Türkiye
[4]Department of Orthopedics and Traumatology, Van Akdamar Hospital, Van, Türkiye
[5]Department of Orthopedics and Traumatology, Health Science University Baltalimanı Bone Diseases Education and Research Hospital, İstanbul, Türkiye

Cite this article as: Alpay Y, Albayrak K, Ezici A, Kürk MB, Akbulut D, Gürsu S. Optimal level for subtrochanteric femoral shortening osteotomy in crowe type 4 patients. *Arch Basic Clin Res.*, 2023;5(2):256-262.

ORCID IDs of the authors: Y.A. 0000-0001-8448-5081, K.A. 0000-0002-8427-8856, A.E. 0000-0003-1398-8575, M.B.K. 0000-0001-8956-3819, D.A. 0000-0001-8216-7610, S.G. 0000-0003-1770-6969.

ABSTRACT

Objective: To investigate the optimal level for femoral shortening osteotomy in patients with dislocated hips undergoing total hip arthroplasty (THA) and make recommendations to avoid union problems.

Methods: We retrospectively reviewed 65 hips of 55 patients who underwent total hip arthroplasty for Crowe type IV developmental dysplasia of the hip. Osteotomy level is defined as the distance between the lesser trochanter and osteotomy line. The role of osteotomy level and osteotomy level-stem end distance on non-union rates, radiological union time, unsupported loading time, and Harris Hip Scores were investigated with Pearson correlation analyses.

Results: The mean follow-up period was 75.9 ± 32.0 months. The mean radiological union time was 6.5 ± 2.9 months. There was a positive and linear correlation between osteotomy level and radiological union time ($r = 0.385$; $P = .003$). Harris Hip Scores were not correlated with osteotomy level ($P = .503$). The osteotomy performed at a distance of more than 30 mm had higher radiological union times ($P = .002$).

Conclusion: According to the results of the current study, the optimal osteotomy level should be within the 20-30 mm range from the lesser trochanter. Early revision should be avoided for patients with union problems. To prevent non-union, the cable should be well controlled so as not to enter into the osteotomy line.

Keywords: Hip arthroplasty, Crowe classification, osteotomy, hip dysplasia

INTRODUCTION

Developmental dysplasia of the hip (DDH) is a common reason for secondary osteoarthritis of the hip in young adults.[1] Currently, total hip arthroplasty with subtrochanteric shortening osteotomy is the standard treatment method for symptomatic end-stage DDH patients with Crowe type IV.[2] In these severely dysplastic patients, relocation of the hip to the normal anatomic position is crucial to ensure good long-term results.[3] However, there are some anatomical differences that could cause difficulties in hip relocation. If this procedure is also performed as a limb-lengthening surgery, the neurovascular status of the patient must be also considered.[4] To decrease periarticular stiffness and the likelihood of traction neuropathy, shortening osteotomy is essential.

The current literature describes many types of the osteotomy (transverse, oblique, double chevron, and step-cut). The transverse-type osteotomy is a simple and effective technique,[5] but patients may be at risk for delayed union or non-union.[6] To the best of our knowledge, there is no consensus on the most suitable level for transverse osteotomy, and surgeons seemed to be selecting the osteotomy level according to their clinical experience.[7]

Corresponding Author: Yakup Alpay, **E-mail:** yakupalpayy@hotmail.com

Content of this journal is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License.

Received: October 2, 2022
Accepted: December 5, 2022
Publication Date: March 25, 2023

The aim of the present study was to investigate the optimal level for transverse subtrochanteric shortening osteotomy in patients with Crowe type IV, to identify union problems, and to provide recommendations for the prevention of these complications.

METHODS

We retrospectively analyzed patients with Crowe type IV hips who underwent total hip replacement with subtrochanteric femoral shortening osteotomy from January 2006 to January 2015. After obtaining the approval of the local ethics committee, the clinical information of the patients was collected. In total, 186 patient charts were reviewed. The need for informed consent was obtained for each patient. The study was approved by the Metin Sabancı Baltalimanı Bone Health Science institutional review board (Date: December 10, 2018, approval ID number: 39-274).

The exclusion criteria of this study were patients with infections, those who smoked cigarettes, and those with diabetes mellitus, obesity (body mass index >30), early onset revision due to instability, and previous hip surgery. Patients who required additional fixation material, such as plate fixation for stability, and those who underwent step-cut and oblique-type osteotomies were also excluded. We only focused on the differences among the osteotomy levels to increase reliability. After applying the exclusion criteria, only 65 hips (10 bilateral) of 55 patients who underwent transverse subtrochanteric shortening osteotomy were finally included. The number of hips in each osteotomy group is summarized in Table 1. A total of 11 patients (9 female and 2 male) in group I, 28 patients in group II (27 female and 1 male), and 26 patient in group III (25 female and 1 male) were evaluated.

The mean postoperative follow-up time was 75.9 ± 32.0 months (range 48-156 months). Acetabular and femoral component designs were not identical in all hips. Regarding the femoral design, only standard uncemented diaphyseal and metaphyseal press-fit stems (S-Rom, Depuy Warsaw, Indiana; Echelon, Smith and Nephew, Memphis, USA; or Omnifit, Stryker Howmedica Osteonics Corp., Mahwah, NJ, USA) were included. Zweymüller stem (Smith and Nephew, Memphis, Tenn, USA) stems were also included. However, patients receiving metaphyseal press-fit tapered stems were also excluded due to the standardization of the osteotomy level stability and the absence of osteointegration property of the distal part of the stem.

A detailed physical and radiological examination was performed in the outpatient follow-up period. Union was evaluated radiologically every month. All patients were recommended to perform partial weight-bearing activities in the sixth week, and progressive weight-bearing was allowed according to the patients' clinical and radiological situations. Moreover, the time when the patients discontinued the use of walkers and the time during unsupported walking were also obtained from the charts.

The osteotomy level was measured by evaluating the postoperative first view. First, the lesser trochanter midpoint was located. Osteotomy level is defined as the distance between the lesser trochanter and osteotomy line. The distance between the osteotomy line and the distal tip of the femoral stem was also measured (Figure 1). The distribution of the patients is shown in a scatter plot (Figure 2). Two patients have non-union within the osteotomy level range of 0-20 mm. Five patients have non-union within the osteotomy level of more than 30 mm. None of the patients have non-union within the osteotomy level range of 20-30 mm. The patients with osteotomy levels between 0 and 20 mm were classified as group I, those with osteotomy levels between 20 and 30 mm as group II, and those with osteotomy levels >30 mm as group III. Groups were compared in terms of radiological union time, non-union, clinically unsupported loading time, and Harris Hip Scores.

The United States Food and Drug Administration defines a non-union as a fractured bone that has not completely healed within 9 months of injury and that has not shown progression toward healing over 3 consecutive months on serial radiographs.[8] Moreover, non-union was also defined as the absence of bone trabeculae crossing over the osteotomy line and sclerotic osteotomy line and the lack of progressive changes. In the present study, the union situation of the osteotomy line was evaluated according to the presence of callus at 3 of the 4 cortices (lateral, medial, anterior, and posterior).[9] Callus bridging was evaluated by an orthopedic surgeon with 5 years of experience. The surgeon was blinded to the study design and purposes.

MAIN POINTS

- The most important finding of this study is that the optimal osteotomy level distance should be within the 20–30 mm range from the lesser trochanter to reduce osteotomy site union problems.
- Early revision should be avoided for patients with union problems due to the surface properties of the femoral stem.
- The cable may enter the osteotomy line, which is a potential cause of union problems.

Table 1. Comparison of the Results Between Three Groups

		Group I		Group II		Group III		
		Mean ± SD, n (%)	Median	Mean ± SD or n (%)	Median	Mean ± SD or n (%)	Median	*P*
Age (years)		49.7 ± 9.2	50.0	49.0 ± 9.8	50.5	45.0 ± 11.3	42.0	.110[a]
Sex	Female	9 (81.8%)		27 (96.4%)		25 (96.2%)		>.05[b]
	Male	2 (18.2%)		1 (3.6%)		1 (3.8%)		
Follow-up period (months)		69.5 ± 30.9	58.0	68.3 ± 30.8*	57.5	86.8 ± 31.8	83.0	***.019***[a]
Non-union	(–)	9 (81.8%)		28 (100%)		23 (88.5%)		>.05[b]
	(+)	2 (18.2%)		0 (0.0%)		3 (11.5%)		
Incision	Lateral	6 (54.5%)		9 (32.1%)		9 (34.6%)		.406[b]
	Posterior	5 (45.5%)		19 (67.9%)		17 (65.4%)		
Radiological union time (months)		6.2 ± 1.9	6.0	5.5 ± 1.4*	5.0	7.9± 3.9	7.0	***.002***[a]
Unsupported loading time (weeks)		11.6 ± 6.8	8.0	10.7 ± 4.6	9.5	13.9 ± 5.9	12.0	.115[a]
Osteotomy level (mm)		13.5 ± 3.2*,†	14.0	25.2 ± 3.1*	25.0	38.5 ± 6.9	36.5	***.000***[a]
Osteotomy level-stem end distance (mm)		111.8 ± 13.5*	110.0	111.5 ± 18.3*	107.5	85.3 ± 13.8	84.5	***.000***[a]
Harris hip score		79.7 ± 13.2	82.0	81.9 ± 10.7	83.0	78.4 ± 12.4	78.5	.503[a]

[a]Mann–Whitney *U*-test.
[b]Kruskal–Wallis.
[X2]Chi-squared test (Fischer's exact test).
*Difference with group III (*P* < .05).
†Difference with group II (*P* < .05).

Statistical Analyses

In the descriptive statistics of the data, mean, SD, median, lowest, highest, frequency, and ratio values were used. The distribution of the variables was measured with the Kolmogorov–Smirnov test. In the analysis of quantitative independent data, Kruskal–Wallis and Mann–Whitney *U*-tests were used. The chi-squared test was used for the analysis of qualitative independent data, and the Fisher's exact test was used when the chi-squared test conditions were not provided. Pearson correlation analysis was used for the correlation analysis. Using the R^2 value, statistical significance was set at $P < .05$. All statistical analyses were performed using Statistical Package for the Social Sciences version 22 (IBM SPSS Corp., Armonk, NY, USA).

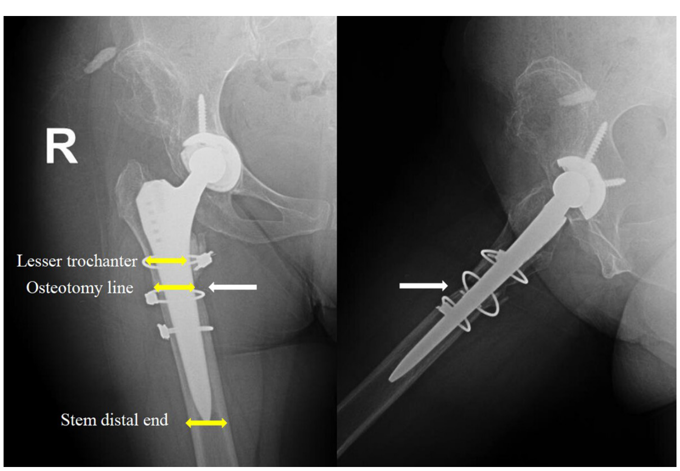

Figure 1. The figure shows the lesser trochanter line, osteotomy line, and stem distal end. Arrows show medial and anterior cortex non-union due to cable entering into the osteotomy line.

Ethical Committee

The ethical approval for the study was obtained from the Health Science University Baltalimanı Metin Sabancı Bone Diseases Education and Research Hospital, the study protocol (approval date: December 10, 2018, number: 39-274).

RESULTS

The mean radiological union time was 6.5 ± 2.9 months (Table 2). The mean osteotomy level was 28.5 ± 10.4. A significant positive and linear correlation was observed between osteotomy level and radiological union time (r=0.385, P=.003) (Figure 2). Radiological union time was calculated as 4.3 + 0.067 × osteotomy level (mm). This model had an R^2 value of 0.148. There was no significant correlation between osteotomy level and Harris hip score (r=–0.150, P=.262) (Figure 3). Unsupported loading time also was not correlated with osteotomy level (r=0.161,

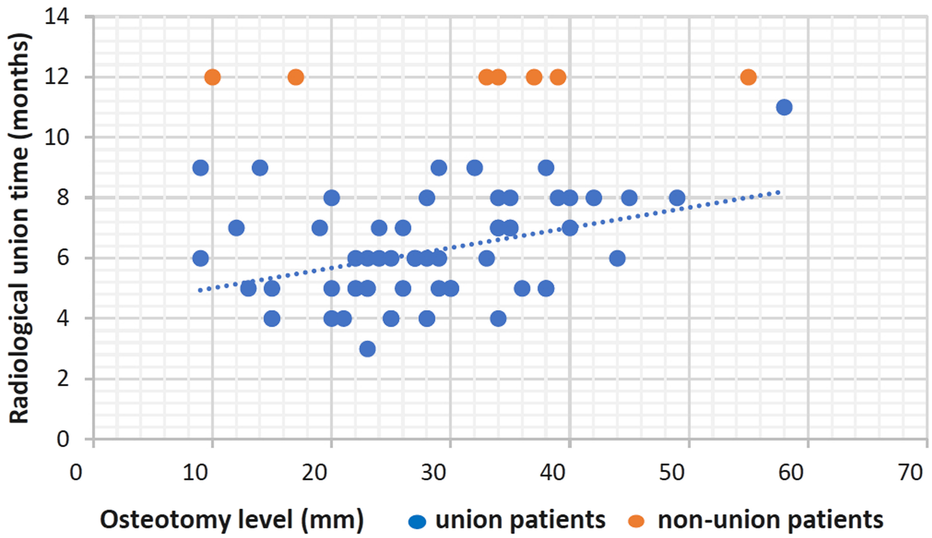

Figure 2. Scatter plot showing the correlation between osteotomy level and radiological union time. Red plots show non-union patients ($r=0.385$, $P=.003$).

$P=.226$). The mean osteotomy level-stem end distance was 101.1 ± 20.3 mm. There was no significant correlation between the mean osteotomy level-stem end distance and radiological union time ($r=-0.227$, $P=.087$), unsupported loading time ($r=-0.074$, $P=.579$), and Harris hip score ($r=-0.012$, $P=.930$).

Non-union rate showed no statistically significant differences among the 3 groups ($P > .05$). Group III had longer radiological union time than group II (Table 1).

DISCUSSION

The most important finding of this study is that the optimal osteotomy level distance should be within the 20-30 mm range from the lesser trochanter to reduce osteotomy site union problems. As the osteotomy level moves away from the lesser trochanter, the radiological union time increases consequently. Many studies on subtrochanteric shortening osteotomy were focused on its biomechanical aspect and clinical applications for stability assessment and complication rate reduction.[4,10-13]

Some authors have reported that transverse femoral osteotomy has a high complication rate, especially non-union or delayed union, due to the low bone contact area and provision of less rotational stability.[14] In contrast, the transverse osteotomy is technically simple and allows the correction of torsional deformities.[6,15,16] Sofu

Table 2. Descriptive Statistics of the Patients and Study Parameters

Demographics		Minimum–maximum	Median	Mean ± SD or n (%)
Age (years)		25.0-70.0	49.0	47.6 ±10.4
Sex	Female			61 (93.8%)
	Male			4 (6.2%)
Follow-up period (months)		36.0-156.0	62.0	75.9 ± 32.0
Non-union	(−)			58 (89.2%)
	(+)			7 (10.8%)
Incision	Lateral			24 (36.9%)
	Posterior			41 (63.1%)
Radiological union time (months)		3.0-24.0	6.0	6.5 ± 2.9
Unsupported loading time (weeks)		4.0-24.0	12.0	12.2 ± 5.7
Osteotomy level (mm)		9.0-58.0	28.0	28.5 ± 10.4
Osteotomy level-stem end distance (mm)		58.0-156.0	101.0	101.1 ± 20.3
Harris hip score		45.0-97.0	82.0	80.1 ± 11.7

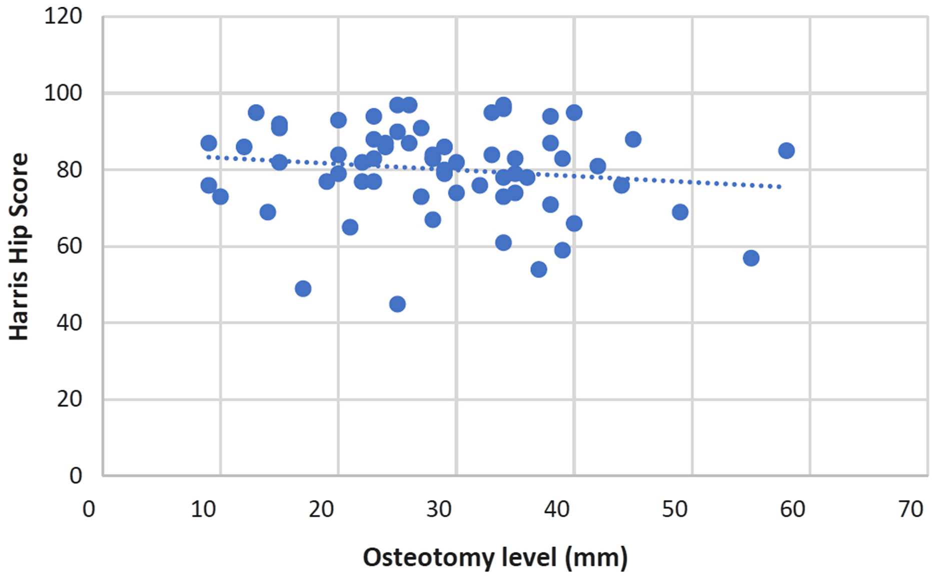

Figure 3. Scatter plot showing the correlation between osteotomy level and Harris hip score ($r=-0.150$, $P=.262$).

et al performed the first cut distal to the lesser trochanter, which was approximately 10 cm below the tip of the greater trochanter. Mutlu et al have performed the osteotomy at 2 cm distal to the lesser trochanter. Moreover, Kawai et al recommended that osteotomy should be performed just below the lesser trochanter.[11,13,17] However, there is no consensus on the most suitable level for osteotomy. According to our results, the optimal osteotomy level should be within the range of 20-30 mm.

It has been reported that, in the fracture line located more closely to the diaphyses, union problems will also increase according to the metaphyseal segment.[18] Even though the femur is the same bone, the implants used could vary. For fracture management, we use nail implants, but for osteotomy fixation, we use femoral stems for the same area. Given that we are using different types of implants, the healing process may vary for each patient group. According to our results, if the osteotomy line is more distal, the radiological union time also increases even if the unsupported loading time is not statistically different. At the final follow-up, the Harris hip score of all the groups was similar, which may be because the union process has been completed since the patients had long-term follow-ups.

If the osteotomy level was between 20 and 30 mm, no non-union cases were observed. The possible reason for the non-union of distal osteotomy could be related to the diaphyseal segment biologic properties. It is well known that the metaphyseal union is easily completed according to the diaphyses.[18] However, 2 patients who had the osteotomy level at 0-20 mm had non-union. Thus, we considered that if the osteotomy was performed too proximal, the stability of the proximal part will be lost, which could potentially result in non-union. The distal part of the bone has a biological disadvantage, whereas the proximal part of the bone has a biomechanical disadvantage. Thus, we considered that the best results were obtained if the osteotomy is performed at a distance between 20 and 30 mm from the lesser trochanter.

Mutlu et al[17] have demonstrated that the femoral stem end bypassed the osteotomy level for at least 5 cm. Kawai et al[13] recommended that the femoral stem end should bypass the osteotomy level at least 7 cm. However, our results showed that the femoral stem end bypass distance of our patients was greater compared with the abovementioned recommendations. Thus, we could not show the effect of femoral stem end distance bypassing the osteotomy line on the union process.[6,13-17]

One important point to note is that deformity correction surgeries or trauma surgeries for the proximal femur were performed using nails. A nail has a smooth surface and does not have osteointegration properties. Moreover, there is no biological reaction between the implant and bone. Thus, for a successful union, callus bridging of 3 of the 4 cortices is essential.[9] However, in some THA patients who had femoral designs with osteointegration properties, no complaints were reported at the 2-year follow-up even if the radiological union was not observed. Moreover, in our study, 1 patient showed callus bridging of only the lateral cortex. At the 2-year follow-up, the medial, anterior, and posterior cortices showed no signs of callus bridging, but there was no problem due to femoral stem osteointegration found. In these patients, the ingrowth process was completely different from that of trauma patients due to implant properties. Thus, the treatment options may also be different for delayed union or non-union. We recommend that subtrochanteric osteotomy patients with severely dislocated hips should wait before undergoing femoral revision or non-union procedures even if callus bridging could not be observed.

Another important point to note is the entry of the cable to the osteotomy line. Even though resected segments are placed symmetrically to the osteotomy line during tensioning of the cable graft, they can still glide from the first position. Moreover, on the other side of the bone, the cable may enter the osteotomy line, which is a potential cause of union problems.

This study has several limitations. One of the study's main limitations was the small number of patients in the non-union group. Second, the femoral stems could not be standardized. Even if only the metaphyseal press-fit stems were included, while the tapered designs were excluded, the stems were from different manufacturing companies. Third, some of the patients underwent plate fixation. We could not confirm whether the plate was used to restore osteotomy line instability or as additional support even if the osteotomy line was stable. Thus, all patients with a plate fixation were excluded, which decreased the number of the study. Future prospective studies involving a single type of femoral stem and with a larger number of samples are warranted to confirm our findings.

In conclusion, according to the results of the current study, the optimal level for transverse subtrochanteric femoral shortening osteotomy in severely dysplastic patients is between 2 and 3 cm distal from the lesser trochanter. Early revision should be avoided for patients with union problems due to the surface properties of the femoral stem. Moreover, to prevent non-union, the cable should be well controlled so as not to enter into the osteotomy line after the tensioning.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Health Science University Baltalimanı Metin Sabancı Bone Diseases Education and Research Hospital (date: December 10, 2018, number: 39-274).

Informed Consent: Written informed consent was obtained from the patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – Y.A.; Design – Y.A.; Supervision – S.G.; Resources – K.A.; Materials – A.E.; Data Collection and/or Processing – M.B.K.; Analysis and/or Interpretation – Y.A.; Literature Search – D.A.; Writing Manuscript – Y.A.; Critical Review – Y.A.; Other – S.G.

Declaration of Interests: The authors declare that they have no competing interests.

Funding: The authors declared that this study has received no financial support.

REFERENCES

1. Rosenstein AD, Diaz RJ. Challenges and solutions for total hip arthroplasty in treatment of patients with symptomatic sequelae of developmental dysplasia of the hip. *Am J Orthop (Belle Mead NJ)*. 2011;40(2):87-91.
2. Cheng R, Zhang H, Kernkamp WA, et al. Relations between the Crowe classification and the 3D femoral head displacement in patients with developmental dysplasia of the hip. *BMC Musculoskelet Disord*. 2019;20(1):530. [CrossRef]
3. Yoshitani J, Kabata T, Kajino Y, et al. Morphometric geometrical analysis to determine the centre of the acetabular component placement in Crowe type IV hips undergoing total hip arthroplasty. *Bone Joint J*. 2019;101-B(2):189-197. [CrossRef]
4. Sanchez-Sotelo J, Berry DJ, Trousdale RT, Cabanela ME. Surgical treatment of developmental dysplasia of the hip in adults: II. Arthroplasty options. *J Am Acad Orthop Surg*. 2002;10(5):334-344. [CrossRef]
5. Muratli KS, Karatosun V, Uzun B, Celik S. Subtrochanteric shortening in total hip arthroplasty: biomechanical comparison of four techniques. *J Arthroplasty*. 2014;29(4):836-842. [CrossRef]
6. Kiliçoğlu Oİ, Türker M, Akgül T, Yazicioğlu O. Cementless total hip arthroplasty with modified oblique femoral shortening osteotomy in Crowe type IV congenital hip dislocation. *J Arthroplasty*. 2013;28(1):117-125. [CrossRef]
7. Zagra L, Bianchi L, Mondini A, Ceroni RG. Oblique femoral shortening osteotomy in total hip arthroplasty for high dislocation in patients with hip dysplasia. *Int Orthop*. 2015;39(9):1797-1802. [CrossRef]
8. Brinker MR. *Skeletal Trauma: Basic Science Management, and Reconstruction*. 3rd ed. Philadelphia: Saunders; 2003.
9. Vicenti G, Bizzoca D, Carrozzo M, et al. The ideal timing for nail dynamization in femoral shaft delayed union and non-union. *Int Orthop*. 2019;43(1):217-222. [CrossRef]
10. Talwar J, Agarwal S, Agarwal S, Krishna LG, Rustagi A. Step-cut subtrochanteric osteotomy combined with total hip arthroplasty for neglected traumatic hip dislocations. *Clin Orthop Surg*. 2022;14(2):205-212. [CrossRef]
11. Sofu H, Kockara N, Gursu S, Issin A, Oner A, Sahin V. Transverse subtrochanteric shortening osteotomy during cementless total hip arthroplasty in Crowe type-III or IV developmental sysplasia. *J Arthroplasty*. 2015;30(6):1019-1023. [CrossRef]
12. Tuncay I, Yıldız F, Bilsel K, et al. Biomechanical comparison of 2 different femoral stems in the shortening osteotomy of the high-riding hip. *J Arthroplasty*. 2016;31(6):1346-1351. [CrossRef]
13. Kawai T, Tanaka C, Ikenaga M, Kanoe H. Cemented total hip arthroplasty with Transverse subtrochanteric shortening osteotomy for Crowegroup IV dislocated hip. *J Arthroplasty*. 2011;26(2):229-235. [CrossRef]
14. Li C, Zhang C, Zhang M, Ding Y. Comparison of transverse and modified subtrochanteric femoral shortening osteotomy in total hip arthroplasty for developmental dysplasia of hip: a meta-analysis. *BMC Musculoskelet Disord*. 2014;15:331. [CrossRef]
15. Ozden VE, Dikmen G, Beksac B, Tozun IR. Total hip arthroplasty with step-cut subtrochanteric femoral shortening

osteotomy in high riding hip dislocated patients with previous femoral osteotomy. *J Orthop Sci*. 2017;22(3):517-523. [CrossRef]
16. Hotokebuchi T, Sonohata M, Shigematsu M, Mawatari M. A new device for a v-shaped subtrochanteric osteotomy combined with total hip arthroplasty. *J Arthroplasty*. 2006;21(1):135-137. [CrossRef]
17. Mutlu T, Çiçek H, Yalçin N, Kiliçarslan K, Tuhanioğlu Ü. How do different designs of femoral stem affect total hip arthroplasty applied to Crowe type III and type IV dysplastic hips. *Hip Int*. 2016;26(4):374-379. [CrossRef]
18. Bishop JA, Palanca AA, Bellino MJ, Lowenberg DW. Assessment of compromised fracture healing. *J Am Acad Orthop Surg*. 2012;20(5):273-282. [CrossRef]