Original Article

Hardware Impingement Is Associated With Shorter Screw Length in Patients Treated With In Situ Screw Fixation for Slipped Capital Femoral Epiphysis: An In Vivo Arthroscopic Evaluation

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Purpose: To determine the incidence of screw impingement on dynamic exam during hip arthroscopy in patients undergoing treatment for femoroacetabular impingement after previous slipped capital femoral epiphysis fixation and to evaluate screw characteristics with hardware impingement. **Methods:** A retrospective review from 2008 to 2020 was performed of slipped capital femoral epiphysis (SCFE) patients that underwent arthroscopy for symptoms of hip impingement. Patients underwent a dynamic exam under direct arthroscopic visualization to assess for sources of impingement, including bony anatomy and fixation hardware. Slip angle was calculated on lateral radiographs prior to arthroscopy, and screw length was noted in the initial operative reports at treatment of SCFE and reported in millimeters. Normality of data was assessed using Shapiro-Wilk tests, with statistical analysis performed using independent sample *t*-tests, Mann-Whitney *U*-nonparametric tests, and multivariable logistic regression. An alpha level of <0.05 was used to indicate statistical significance. **Results:** Thirty-nine hips were included, with 13 (33.3%) having screw impingement on dynamic exam. Slip angle was found to be increased in the screw impingement group (42.4° vs 35.5°; $P = .11$). Screw length was noted to be significantly shorter in the screw impingement group (53.1 vs 61.6 mm; $P = .021$). The presence of screw impingement was found to be associated with shorter screw length ($\beta = -0.172$, $R^2 = 0.329$; $P = .036$). **Conclusions:** Shorter screws (55 mm or less) are at greater risk of causing hardware hip impingement after in situ SCFE fixation. When considering hip arthroscopy for the treatment of femoroacetabular impingement in patients with a previous SCFE, hardware impingement and subsequent hardware removal should be considered in hips with shorter screws and in hips that show objective hardware impingement on dynamic exam. **Level of Evidence:** Level IV, therapeutic case series.

Introduction

Slipped capital femoral epiphysis (SCFE) is a common condition in children and adolescents, with an incidence of 10.8 per 100,000 in the United States.[1,2] This condition is typically seen in obese males between 9 and 16 years of age,[1-3] and is additionally seen more frequently in both Black and Hispanic patients compared to their Caucasian counterparts.[4] Prompt treatment of SCFE is required to minimize further deformity and mitigate the risk of subsequent avascular necrosis (AVN) and osteoarthritis, especially in moderate to severe slips.[5] Current treatment of a SCFE centers around percutaneous pinning with in situ fixation of the slipped proximal femur,[6] with this approach showing favorable outcomes regarding long-term sequelae, such as AVN and chondrolysis,[7,8] in addition to showing improved patient function scores.[9]

Although in situ pinning has been shown to have good functional outcomes both in short- and long-term studies and is indicated in most cases of stable slips,[10,11] there exists a risk of subsequent deformity of the proximal femur. This deformity, having been demonstrated in both slipped hips and prophylactically pinned

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hips, often appears similar in nature to idiopathic cam lesion formation of the proximal femur and can contribute to hip impingement similar to that of femoroacetabular impingement (FAI).[12-17] Previous research has shown an incidence as high as 75% of patients treated for SCFE slips with percutaneous in situ pinning subsequently develop radiographic evidence of cam morphology in the proximal femur.[18] Symptomatic FAI syndrome following SCFE occurs less frequently than the incidence of radiographic deformity alone, but it has still been demonstrated to be quite common following SCFE pinning, with research showing up to 31% of patients experiencing this condition.[15] Hip arthroscopy has become increasingly used for the treatment of impingement in the post-SCFE patient and provides a minimally invasive and relatively safe method, albeit technically challenging, to address hip impingement in these patients,[19] with much treatment centering on labral repair, acetabular rim resection, and femoral osteochondroplasty.[20]

Although the clinical picture of hip impingement is well documented in this patient population, the presence of screw hardware impingement after SCFE in situ pinning has significantly less investigation, with information primarily coming from case series and cadaveric work.[21,22] Given this knowledge gap regarding hardware impingement in patients having undergone previous in situ fixation and development of subsequent impingement symptoms, the clinical significance of hardware impingement is unclear. Additionally, with the increased utilization of hip arthroscopy for treatment of impingement in this patient population, this provides a minimally invasive method for hardware removal if indicated and can be assessed on dynamic exam under anesthesia at the time of arthroscopy.

The purposes of this study were to determine the incidence of screw impingement on dynamic exam during hip arthroscopy in patients undergoing treatment for femoroacetabular impingement after previous slipped capital femoral epiphysis fixation and to evaluate screw characteristics with hardware impingement. Our hypotheses were that screw impingement would be a relatively common occurrence in this patient population and that larger slip angles and shorter screw length would be associated with the presence of screw impingement on dynamic exam.

Methods

Cohort Selection

Following Institutional Review Board approval (no. 71733), a retrospective query of the senior author's (S.K.A.) surgical cases was performed from January 1, 2008, to December 31, 2020, to identify patients who underwent hip arthroscopy for symptoms of hip impingement and had a previous SCFE diagnosis. All patients were evaluated clinically and radiographically and were subsequently treated by the senior author for symptoms consistent with femoroacetabular impingement syndrome (FAIS). Inclusion criteria were 1) patients who were undergoing hip arthroscopy for impingement and 2) patients who were previously diagnosed and subsequently treated for SCFE. Exclusion criteria were 1) lack of screw hardware at time of hip arthroscopy and 2) no screw length noted in initial operative report from treatment of SCFE. Patient demographic characteristics were captured from the electronic medical record and included age in years at the time of hip arthroscopy, patient sex, body mass index (BMI), and operative hip side. Operative notes were also reviewed to identify reported screw length at time of initial SCFE surgery.

Operative Protocol and Dynamic Exam Under Anesthesia

After induction under general anesthesia and application of sufficient traction force to produce adequate hip distraction, anteromedial and anterolateral portals were placed followed by completion of an interportal capsulotomy to allow for appropriate visualization during arthroscopy. Central compartment work was performed prior to addressing the peripheral compartment. Prior to the femoral osteochondroplasty, patients underwent a dynamic exam of the operative hip. The

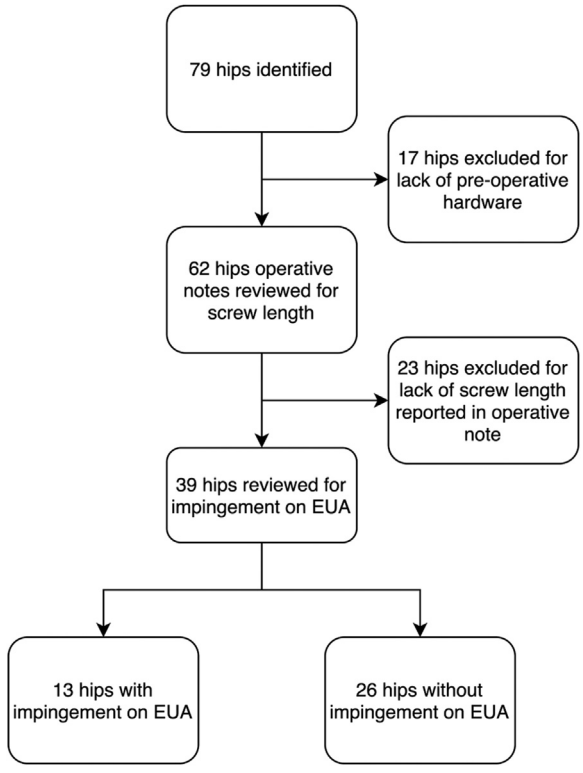

Fig 1. Flow diagram showing cohort selection. EUA, exam under anesthesia.

Table 1. Demographics of Impingement and No Impingement Groups

Variable	Total Cohort	Impingement on Dynamic Exam	No impingement on Dynamic Exam	*P* Value
Age, years, mean (SD)	16.1 (1.8)	16.5 (1.7)	15.9 (1.9)	.393
Time from pinning to arthroscopy, mean (SD)	3.0 (1.9)	2.9 (1.3)	3.1 (2.2)	.741
Patients, *n*	36	13	23	.651
Female, *n*	19	7	12	
Male, n	17	6	11	
BMI, mean (SD)	30.9 (6.5)	31.6 (5.5)	30.5 (7.0)	.653
Hips, *n*	39	13	26	.496
Right, *n*	21	8	13	
Left, *n*	18	5	13	

hip was ranged in flexion up to 90°, as limited by patient positioning and draping. Screw impingement was assessed under direct arthroscopic visualization and was noted postoperatively with all screws being removed by the senior author regardless of impingement status. Retrospective review of operative reports was completed to identify patients with hardware impingement.

Slip Angle and Screw Length

Slip angle was calculated prior to hip arthroscopy for hip impingement by one of three study authors (D.C.L., A.K.M., D.L.F.), using established methods for calculation of the Southwick slip angle.[23] Lateral radiographs prior to arthroscopy were accessed through the institution's picture archiving and communication system (PACS) IntelliSpace (Phillips, Amsterdam, Netherlands) to determine the slip angle at the time of hip arthroscopy. First, a line was drawn connecting the medial and lateral aspects of the proximal femoral physis or physeal scar, as indicated on the basis of on patient skeletal maturity. A line at a right angle was subsequently drawn to this first line (referred to as "right-angle line"). Another line was established along the central axis of the femoral diaphysis, with the angle between this line and the right-angle line calculated as the slip angle. Screw length was collected from operative reports at the time of treatment for initial SCFE slip and was reported in millimeters.

Statistical Analysis

All statistical analysis was completed using Microsoft Excel version 16.54 (Microsoft, Redmond, WA) and SPSS version 27 (IBM, Armonk, NY). Descriptive statistics for cohort demographics were calculated. Normality of data was assessed using Shapiro-Wilk tests, with statistical analysis performed using independent samples *t*-tests, Mann-Whitney U nonparametric tests, chi-square tests, and multivariable logistic regression. A goal of at least 10 patients per variable was used to estimate adequate power for the regression model.[24] An alpha level of <0.05 was used to indicate statistical significance.

Table 2. Evaluation of Screw Characteristics and Impingement

Variable	Percentage
Impinged screws ≤55 mm	92.3
Screws ≤55 mm that impinged	48.0
Screws ≥60 mm that did not impinge	92.9

Results

Initial review of the senior author's surgical cases along our study timeline identified 79 potential hips for study inclusion, with 17 hips excluded for lack of pre-arthroscopy hardware and 23 excluded for lack of a screw length reported in the initial operative note from the time of SCFE treatment. This resulted in 39 hips being included in our analysis, with 13 hips (33.3%) demonstrating screw impingement on dynamic exam and 26 hips (66.7%) without evidence of screw impingement on dynamic exam (Fig 1). Patient age, BMI, and sex were similar across our two groups ($P >$ .05; Table 1). The time from initial pinning to hip arthroscopy for impingement was a mean of 3.0 ± 1.9 years and was not statistically different between groups ($P = .741$).

Characterization of screw length and impingement status revealed the majority of impinged screws were 55 mm in length or less, with 92.3% of impinged screws fitting this criterion (Table 2). Additionally, our results showed that 92.9% of screws 60 mm or greater did not demonstrate evidence of impingement. Total screws 55 mm or less in length in our cohort demonstrated impingement on dynamic exam at a rate of 48.0%.

Comparison of the mean slip angle and screw length between our two groups revealed notable differences (Fig 2 and 3). Analysis of the mean slip angle demonstrated a larger angle in the impingement group, although this did not achieve statistical significance (42.4 ± 11.2 vs 35.5 ± 13.0°; $P = .115$). Mean screw length was noted to be significantly shorter in the hardware impingement group when compared to the no hardware impingement group (53.1 ± 3.3 vs 61.6 ±

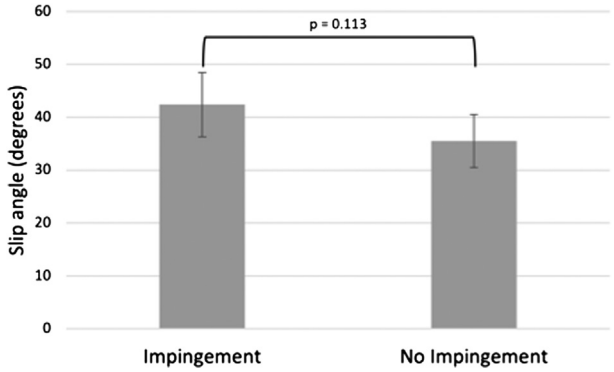

Fig 2. Results of independent samples *t*-test of measured slip angle in our Impingement and No Impingement groups. The Impingement group was found to have an increased slip angle, though this was not statistically significant ($P = .113$). The height of the bars represents the mean value for each group, while the whiskers represent the 95% confidence interval of the standard error of the mean.

12.3; $P = .021$). Logistic regression analysis (Table 3) revealed a significant association with decreased screw length and presence of screw impingement on dynamic exam ($\beta = -0.172$; $P = .036$). Slip angle demonstrated an association with increased slip angle and presence of screw impingement on dynamic exam, although this was notably not statistically significant ($\beta = 0.053$; $P = .113$).

Discussion

Our results provide further characterization regarding screw hardware impingement in SCFE individuals undergoing hip arthroscopy for the treatment of FAI. We have demonstrated hardware impingement is relatively common in these individuals at 33.3% in our study population and have additionally established a relationship with decreased screw length and impingement, specifically that screws 55 mm or less or at an increased risk of hardware impingement following in situ fixation of SCFE.

While hip impingement is a recognized potential downstream sequela of in situ pinning for treatment of SCFE, the majority of research focus has been on bony impingement and FAI, with little characterization of the incidence and contribution of screw impingement in this population. A study by Howse et al. suggested a method for arthroscopic screw removal in patients previously treated for SCFE and subsequently presenting with hip impingement, although they did not remark on the number of patients that exhibited screw impingement in their study or how this was assessed clinically.[22] An additional study regarding hip impingement in SCFE patients by Leunig et al. advocated for SCFE deformity correction at initial pinning to reduce the subsequent incidence of impingement, though notably this study did not comment on subsequent screw impingement and was further hampered in its clinical applicability due to limited follow-up and a small sample size.[16] Our study provides an improved sample size from previous reports and additionally evaluates the incidence of screw impingement in this patient population, demonstrating that this may be a relatively common occurrence and should be considered when treating these patients for symptoms of impingement about the hip. Understanding impingement resulting from screw hardware is important as this can contribute to labral and cartilage damage around the hip, as has been shown in previous SCFE studies,[25] and this source of impingement should be considered when undergoing hip arthroscopy in these patients.

Our study demonstrated significant associations with screw length, specifically that shorter screws were associated with an increased likelihood of hardware impingement on hip arthroscopy dynamic exam. Our data suggest an increased level of suspicion for screw impingement in the prearthroscopy setting should be considered with screws 55 mm or less in length. A parameter of 55 mm or less in screw length demonstrated increased sensitivity when compared to specificity for hardware impingement in this patient population, as 92.3% of screws that impinged were 55 mm or less in length but less than half of the screws 55 mm or less in length demonstrated hardware impingement. Our data also suggest potential caution when selecting screw length in the initial treatment of SCFEs and that it may be best to avoid screws of shorter lengths. A study by Goodwin et al. presented a case report and subsequent cadaveric model regarding screw

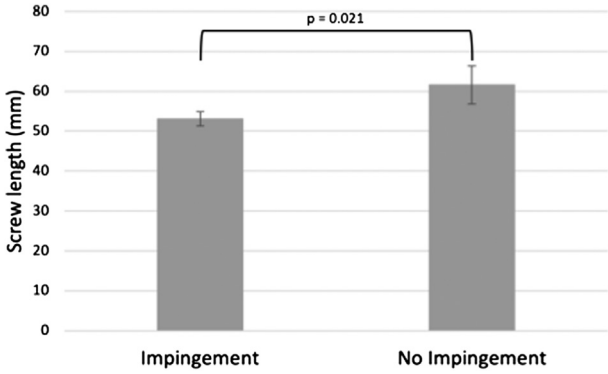

Fig 3. Results of Mann-Whitney *U*-test of the reported screw length in the operative notes in our Impingement and No Impingement groups. The Impingement group was found to have a decreased screw length when compared to the No Impingement group ($P = .021$). The height of the bars represents the mean value for each group, while the whiskers represent the 95% confidence interval of the standard error of the mean.

Table 3. Logistic Regression Results Comparing Association With Slip Angle and Screw Length Versus Impingement Status

Variable	β	OR (95% CI)	R^2	*P* Value
Slip angle	0.053	1.054 (0.988, 1.126)	0.329	.113
Screw length	−0.172	0.842 (0.716, 0.989)		.036

impingement in this patient population demonstrated that placement of a screw head lateral to the intertrochanteric line in moderate to severe SCFEs had a lower risk of impingement, which may be important with regard to optimal screw placement at initial pinning.[21] Combining the findings of Goodwin et al. and our study may help to serve as a guide to optimize reduction of the incidence of screw hardware impingement in this patient population.

Our study also demonstrated an association with increased slip angle and hardware impingement; however, this correlation did not achieve statistical significance in our patient population. This aligns with findings from Goodwin et al. that screw head impingement occurred at lower degrees of flexion in severe SCFE than in moderate SCFE. However, more research is necessary to confirm this correlation and further characterize how the degree of SCFE slip impacts hardware impingement. This association could be additionally useful in the prearthroscopy risk assessment for sources of impingement if found to be significant.

Limitations

There are several limitations of the current study that warrant consideration. First, measurement of Southwick slip angle was difficult using available prearthroscopy radiographs, as most of these patients were skeletally mature with closed proximal femoral physes, limiting the precision of slip measurement. Second, we had considerable exclusion of our initially identified patients based on lack of screw length noted in the initial operative report, which may have provided additional insight regarding overall rates of screw impingement and screw length seen with impingement. Third, our study comprised patients who were treated at a single center by a single hip arthroscopic surgeon, which may affect generalizability of our results to a broader population. Fourth, the arthroscopic dynamic exam was limited to a flexion angle of 90° given limitations related to patient size, positioning on the traction table, and surgical draping. A dynamic exam at deeper flexion angles may demonstrate additional cases of hardware impingement.

Conclusion

Shorter screws (55 mm or less) are at greater risk of causing hardware hip impingement after in situ SCFE fixation. When considering hip arthroscopy for the treatment of FAI in patients with a previous SCFE, hardware impingement and subsequent hardware removal should be considered in hips with shorter screws and in hips that show objective hardware impingement on dynamic exam.

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