Review Article

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Conversion Total Hip Arthroplasty after Sliding Hip Screw and Cephalomedullary Nail Failures: A Systematic Comparative Review and Meta-analysis

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With the exception of revision osteosynthesis, conversion total hip arthroplasty (CTHA) following sliding hip screw (SHS) and cephalomedullary nail (CMN) failure in intertrochanteric fractures (ITF) is the most commonly used treatment option. This review determined the relative risk of medical and orthopedic complications, including periprosthetic femoral fractures (PFF), following CTHA in failed SHS and CMN fixation of ITF, as well as the Harris hip score (HHS). Major electronic databases were searched for studies and reports on CTHA after SHS and CMN fixation failures in ITF. To assess the risk of bias, the studies were analyzed using the Joanna Briggs Institute critical appraisal tool for cohort studies. Three studies pooled 327 cases and 353 cases of CTHA from failed CMN and SHS in ITF. The relative risk of medical and orthopedic complications and PFF in the SHS group as compared to the CMN group was 0.87 [0.39, 1.90], 1.64 [1.18, 2.29], and 1.92 [0.81, 4.56], respectively. The mean difference in HHS was –0.72 [–1.47, 0.02] between failed SHS and CMN groups. The included studies were of retrospective study design with a more than 20% loss of follow-up and a high risk of bias. There is 64% more risk of orthopedic complications with CTHA in SHS failures than CMN failures. There is no difference in relative risk of medical complications and PFF between CTHA in both SHS and CMN failure. After CTHA, the benefits in function are similar in both groups.

Keywords: Total hip replacement, Complications, Intramedullary nailing, Intertrochanteric fractures, Periprosthetic fracture

INTRODUCTION

Cephalomedullary nails (CMN) and sliding hip screws (SHS) are both utilized in the surgical treatment of intertrochanteric fractures (ITF). Recently, there has been an increase in the use of CMN devices over SHS for treating ITF[1]. Despite this, there is no confirmed advantage of CMN over SHS[2]. Although patient outcomes for revision osteosynthesis after SHS failure look promising, they are mostly based on extensive case series[3,4]. Conversion total hip arthroplasty (CTHA) serves as an alternative for addressing failed SHS and CMN fixations in ITF[5]. Due to the presence of previous implants, changes in the geometry of the proximal femur, and compromised bone and soft tissues, performing a CTHA after failures of SHS and CMN is especially complex[6]. Frequency of reported complications vary although post-CTHA hip function differences between the two groups may not be significant[6-8]. There are variations in research results, with some studies revealing more orthopedic complications and periprosthetic femoral fractures (PFF) after

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CTHA following SHS failures while others report the opposite[6-8]. After CTHA for SHS and CMN failure, the reported incidence of orthopedic complications ranges from 5% to 37% and 10% to 30%, respectively[6-8]. Between SHS and CMN groups, this number ranges from 6% to 16% and 3% to 10%, respectively, for PFF[6-8]. This review aims to estimate the relative risk (RR) of complications (orthopedic and medical) between CTHA after failed SHS and CMN for ITF.

MATERIALS AND METHODS

We registered this review with the International Prospective Register of Systematic Reviews, PROSPERO (CRD42024534958). The review followed Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines[9].

1. Eligibility Criteria

1) Inclusion criteria

Studies published in English comparing complications (orthopedic and medical complications for this review) between a CMN group (CTHA after failed CMN) and an SHS group (CTHA after SHS failure) were included in this review.

2) Exclusion criteria

Mixed studies involving diverse proximal femur fracture types (intertrochanteric, subtrochanteric, and neck femur) were excluded. Studies during which participants received mixed treatment methods (hemiarthroplasty or total hip arthroplasty) were excluded. For this review, follow-up duration was categorised as short-term (<5 years), mid-term (5-10 years), and long-term (>10 years).

3) Definition of PFF

PFF, for the purpose of this review, refers to fractures occurring during or after CTHA in the included cohort studies.

2. Search Strategy and Sources

The electronic databases (Cochrane Library, DOAJ [Directory of Open Access Journals], Embase, PubMed, and Scopus) were searched up to February 2024. Studies related to CTHA in failed CMN and SHS fixation for ITF in adults were searched. Supplementary Material 1 details the search strategy for electronic databases in this review. The references from the studies were hand-searched for full text. Reports from the conference proceedings, trial registries, books, and dissertations were excluded.

3. Selection Process

Search results were managed by Rayyan AI, a systematic review website. Review authors (A.R. and D.C.) screened titles and abstracts for potentially eligible studies. Full-text reports were obtained when appropriate. Independent study selection was done by A.R. and D.C., with resolution of disagreements by S.K.N.

4. Data Items Recorded

Characteristics of CMN and SHS groups recorded from included reports were:

1) Complications

Medical and orthopedic complications were recorded. The medical complications included: acute renal failure, pulmonary embolism, atrial fibrillation, and urinary tract infection. The orthopedic complications included: PFF, dislocation, infection, aseptic loosening, nerve palsy, heterotopic ossification, and abductor tendon deficiency.

2) Harris hip score (HHS)

3) Demographic information (age, sex, time to CTHA, and follow-up after operation)

5. Risk of Bias Assessment

The risk of bias was assessed by the Joanna Briggs Institute (JBI) critical appraisal checklist for cohort studies[10].

6. Effect Measures

Continuous variables were summarized using mean, standard deviation, or median with interquartile range. Using RR as an effect estimate, forest plots were constructed for medical, orthopedic and overall complications between the SHS and CMN groups. Between the groups, the subgroup analysis was conducted for PFF with risk ratio as an effect estimate. Mean difference in HHS after CTHA in both the groups was represented on the forest plot. The random-effects model pooled effect estimates. Chi-square and I^2 tests were used to assess heterogeneity and inconsistency. The funnel plot was not constructed as an insufficient number of studies were included in the analysis. The review author (S.K.N.) performed the statistical assessments.

RESULTS

1. Qualitative Analysis

1) Selection of studies

After a review of 7,317 titles, 189 abstracts were selected for potential inclusion. Twenty-two articles were identified that reported on CTHA after failed CMN and SHS[6-8,11-29]. However, only three studies directly compared the outcomes of CTHA after failed CMN and SHS[6-8]. The characteristics of the included and excluded studies are shown respectively in Supplementary Table 1 and 2. Fig. 1 shows the PRISMA flow diagram for the screening and inclusion process of the studies[30]. From three studies, we pooled data from 680 patients/hips who underwent CTHA after CMN (n=327) or SHS (n=353) failures[6-8]. There were 160/167 and 182/171 males/females in CMN and SHS groups, respectively. The mean age of the participants was 67.24±13.10 years and 66.38±11.66 years in CMN and SHS groups, respectively. The mean follow-up reported by two of the included studies was 39.84 months and 40.46 months in CMN and SHS groups, respectively[7,8]. All included studies were retrospective chart reviews. The researchers enrolled participants from the arthroplasty register. Two studies compared failed proximal femoral nail surgeries[6,8], while one InterTAN nail[7] surgery was compared with SHS for CTHA. Time to CTHA was 11 months (range, 3-16 months) in one study[8]. Another study reported time to surgery as 11 months (range, 0.6-23 months) for SHS and 7 months (range, 0.6-19 months) for CMN[7]. While one study did not report the cause of ITF fixation failure[6], others

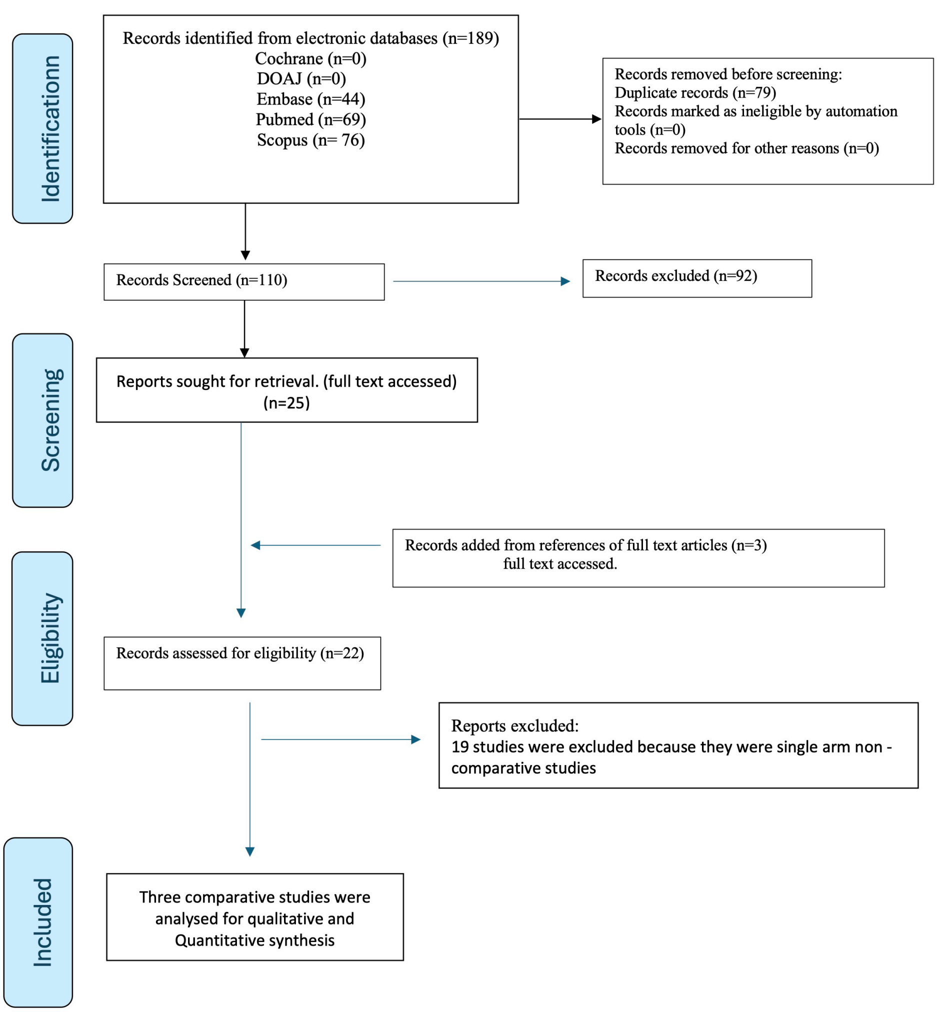

Fig. 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) flow diagram for the review[30]. DOAJ: Directory of Open Access Journals.

reported non-union and implant cut-out as the most common causes[7,8]. Other less frequent causes for CTHA after implant failure were infection, inadequate fixation, and avascular necrosis. The types of CTHA stem and cup varied among the included studies. One study did not specify the choice of CTHA stem and cup[8]. Another study used cementless stems and cups for all participants[7]. One study used cemented/cementless/hybrid combinations[6]. One study included participants based on bone mineral density scores lower than –2.5 at the normal proximal femur and used direct anterior and posterolateral approaches for the hip surgery[7]. A different study used both anterior and posterior approaches[8]. There was substantial heterogeneity in complication reporting between the studies included in this review. While one study[6] combined medical and orthopedic complications and reported them as perioperative complications, another study[7] described perioperative, medical and orthopedic complications separately. One study[8] summated orthopedic and medical complications and reported them as total complications. A summary estimate of medical and orthopedic complications as overall complications is reported in Table 1. PFF was described both during and after CTHA by one study[6]. PFF was reported postoperatively by one study[8] whereas a separate study[7] did not report when CTHA occurred.

2) Assessment of ROB

One study[7] included participants based on age and bone mineral density, while another[8] included participants based on age and a minimum follow-up of 3 years. All included studies had short-term follow-up periods. Confounding factors were not identified or otherwise addressed. Two studies reported a loss to follow-up of more than 20%[7,8]. Xu et al.[7] reported a 30% loss of follow-up in SHS and CMN groups. Another study[8] reported a 23% loss of follow-up. Neither study reported on strategies to deal with incomplete follow-ups. All studies used appropriate statistical analysis plans, but failed to report sample size calculations to detect differences.

2. Meta-analysis

Fig. 2 and 3 display the RR of medical and orthopedic complications in the SHS group compared to the CMN group. RR was 0.87 [0.39, 1.90] and 1.64 [1.18, 2.29], respectively. In Fig. 4, subgroup analysis of PFF RR between SHS and CMN groups was 1.92 [0.81, 4.56]. One of the studies[7] had more influence on the pooled risk for orthopedic complications and PFF because it had more weight (48% and 42%) than the other two[6,8]. Due to this, a sensitivity analysis was performed that excluded the more influential former study to estimate the revised pooled RR for both outcomes. In a comparison between the SHS group and the CMN group, sensitivity analysis showed an RR of orthopedic complications and PFF of 1.26 [0.79, 2.00] and 1.68 [0.31, 8.95], respectively. Shown in Fig. 5, the mean difference in HHS between SHS and CMN groups was –0.72 [–1.47, 0.02]. We estimated 35%, 85%, and 37% heterogeneity for medical and orthopedic complications and PFF. The heterogeneity for mean difference in HHS between both groups was 0%.

Table 1. Comparative Overview of Complications in Cephalomedullary Nail versus Sliding Hip Screw Failure Groups after Conversion Total Hip Arthroplasty

Group	CMN (n=327)	SHS (n=353)
Overall complications between groups	95	147
Patients affected	72/327 (22.0)	104/353 (29.5)
Medical complications	31	33
Patients affected	29/327 (8.9)	28/353 (7.9)
Atrial fibrillation	5	5
Pulmonary embolism	3	4
Acute renal failure	4	3
GI bleed	1	0
UTI	18	20
CVA	0	1
Orthopedic complications	63	114
Patients affected	43/327 (13.1)	76/353 (21.5)
Dislocation	12	15
Abductor tendon deficiency	6	6
Heterotopic ossification	10	18
Nerve injury	6	5
Implant loosening	9	27
Periprosthetic infection	4	7
Periprosthetic fracture	12	28
Acetabular abrasion*	2	4
Limb length disparity >2.5 cm†	1	2
Prosthetic instability†	1	2

Values are presented as number only or number (%).
CMN: cephalomedullary nail, SHS: sliding hip screw, GI: gastrointestinal, UTI: urinary tract infection, CVA: cerebrovascular accident.
*One study[7]. †One study[8].

DISCUSSION

1. Summary of Evidence

The chance of PFF increases by twofold with CTHA

Study or Subgroup	SHS Events	SHS Total	CMN Events	CMN Total	Weight	Risk ratio M-H, Random, 95% CI
Pui et al.	2	60	4	31	18.1%	0.26 [0.05 , 1.33]
XU et al.	21	223	22	224	58.6%	0.96 [0.54 , 1.69]
zeng et al.	5	70	3	72	23.2%	1.71 [0.43 , 6.90]
Total (95% CI)		**353**		**327**	**100.0%**	**0.87 [0.39 , 1.90]**
Total events:	28		29			

Heterogeneity: Tau² = 0.19; Chi² = 3.09, df = 2 (P = 0.21); I² = 35%
Test for overall effect: Z = 0.36 (P = 0.72)
Test for subgroup differences: Not applicable

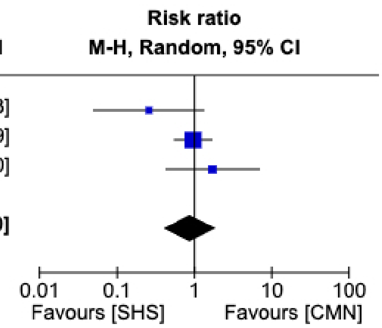

Fig. 2. Relative risk of medical complications between sliding hip screw and cephalomedullary nail groups for conversion total hip arthroplasty in intertrochanteric fractures. SHS: sliding hip screw, CMN: cephalomedullary nail, M-H: Mantel-Haenszel, CI: confidence interval.

Study or Subgroup	SHS Events	SHS Total	CMN Events	CMN Total	Weight	Risk ratio M-H, Fixed, 95% CI
Pui et al.	5	60	9	31	26.0%	0.29 [0.11 , 0.78]
XU et al.	45	223	22	224	48.1%	2.05 [1.28 , 3.30]
zeng et al.	26	70	12	72	25.9%	2.23 [1.22 , 4.06]
Total (95% CI)		**353**		**327**	**100.0%**	**1.64 [1.18 , 2.29]**
Total events:	76		43			

Heterogeneity: Chi² = 13.45, df = 2 (P = 0.001); I² = 85%
Test for overall effect: Z = 2.92 (P = 0.003)
Test for subgroup differences: Not applicable

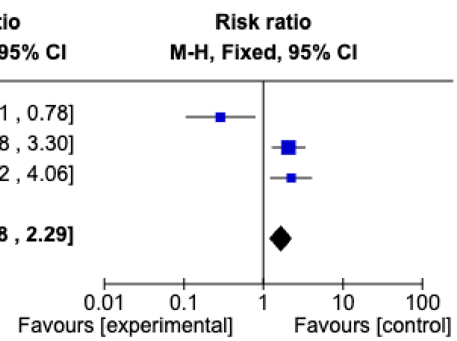

Fig. 3. Relative risk of orthopedic complications between sliding hip screw and cephalomedullary nail groups for conversion total hip arthroplasty in intertrochanteric fractures. SHS: sliding hip screw, CMN: cephalomedullary nail, M-H: Mantel-Haenszel, CI: confidence interval.

Study or Subgroup	SHS group Events	SHS group Total	CMN groups Events	CMN groups Total	Weight	Risk ratio M-H, Random, 95% CI
Pui et al.	4	60	3	31	25.7%	0.69 [0.16 , 2.89]
XU et al.	13	223	6	224	42.7%	2.18 [0.84 , 5.62]
zeng et al.	11	70	3	72	31.5%	3.77 [1.10 , 12.95]
Total (95% CI)		**353**		**327**	**100.0%**	**1.92 [0.81 , 4.56]**
Total events:	28		12			

Heterogeneity: Tau² = 0.22; Chi² = 3.19, df = 2 (P = 0.20); I² = 37%
Test for overall effect: Z = 1.49 (P = 0.14)
Test for subgroup differences: Not applicable

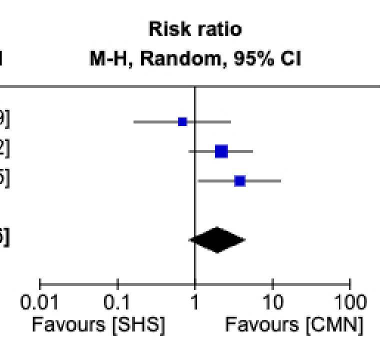

Fig. 4. Subgroup analysis of relative risk of periprosthetic femoral fractures between sliding hip screw and cephalomedullary nail groups for conversion total hip arthroplasty in intertrochanteric fractures. SHS: sliding hip screw, CMN: cephalomedullary nail, M-H: Mantel-Haenszel, CI: confidence interval.

Study or Subgroup	SHS group Mean	SHS group SD	SHS group Total	CMN group Mean	CMN group SD	CMN group Total	Weight	Mean difference M-H Random, 95% CI
Pui et al.	83.6	0	100	78.6	0	100		Not estimable
XU et al.	77.71	3.53	100	78.4	3.29	100	62.1%	-0.69 [-1.64 , 0.26]
zeng et al.	84.5	4.34	100	85.28	4.4	100	37.9%	-0.78 [-1.99 , 0.43]
Total (95% CI)			**300**			**300**	**100.0%**	**-0.72 [-1.47 , 0.02]**

Heterogeneity: Tau² = 0.00; Chi² = 0.01, df = 1 (P = 0.91); I² = 0%
Test for overall effect: Z = 1.90 (P = 0.06)
Test for subgroup differences: Not applicable

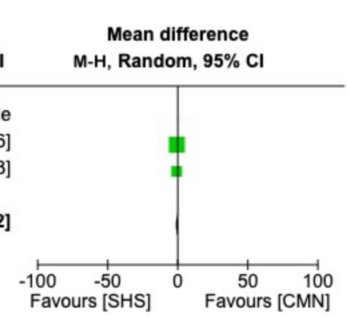

Fig. 5. Mean difference in Harris hip scores between sliding hip screw and cephalomedullary nail for conversion total hip arthroplasty in intertrochanteric fractures. SHS: sliding hip screw, CMN: cephalomedullary nail, SD: standard deviation, M-H: Mantel-Haenszel, CI: confidence interval.

after unsuccessful SHS for ITF compared to failed CMN for ITF. However, due to the wide confidence interval, this result is uncertain. A higher rate of implant loosening in SHS group was noted in this review (Table 1). The design of the SHS implant may be responsible for more instances of implant loosening in CTHA following unsuccessful SHS as it engages seven or more cortices for screw anchorage. The stability of stem fixation, whether cemented or uncemented, may be compromised by the greater bone loss associated with cortical screws in SHS. The orthopedic complication rate is 64% higher with CTHA after failed SHS. However, the rate decreases to 26% after excluding the study with large effect size in the sensitivity analysis. We attribute the findings of the sensitivity analysis to more precise results (narrower confidence intervals) and large cohort size of the trial by Xu et al.[7]. Screw diameter may be the possible reason for more PFF with CTHA after SHS as the diameter is larger than the screw used in CMN. Other factors which are possible influences on the findings of this review include implant selection (stem length, neck geometry, and cementation), surgical technique (stress concentration, alignment and leg length, soft tissue damage), patient factors (bone quality, obesity, smoking, and lifestyle), falls and follow-up. The stress shielding from the side plate of SHS also makes this group more prone to PFF. These factors above were not compared between the groups in the included studies. The most common medical complications were cardiac and renal. However, they occurred rarely and evenly between the groups, so they could not be compared statistically.

Due to the heterogeneity between studies, the random effects model was chosen to get a cautious estimate of the RR of PFF and complications in this review. The fixed effects model would have inflated our estimation of RR for measured outcomes. In this review, the sources of methodical heterogeneity among the included studies were differences in reporting bone mineral density of the proximal femur, the type of CTHA implants (cemented, cementless, and mixed), and clinical variations between the participants. For PFF and orthopedic complications, we estimated 37% heterogeneity, which might not be significant, and 87% heterogeneity, which was considerable, by I^2 test. Moreover, the included studies were prone to a high risk of bias as they were all retrospective comparative chart reviews. Statistical heterogeneity was evident in noticeable overlapping confidence intervals yet variable point estimates from the included studies.

2. Limitations of the Review

The introduction of SHS and cemented CTHA occurred prior to the adoption of CMN for treating ITF and the use of cementless CTHA for repairs after CMN failure. Consequently, patients with unsuccessful SHS treatments were more likely to receive cemented CTHA. This disparity in the use of CTHA implants across the studies reviewed could hinder our understanding of the increased instances of PFF and other complications associated with CTHA following failed SHS procedures. Furthermore, cementless CTHA poses a higher threat of orthopedic complications. We found three studies that compared cemented to cementless CTHA in cases of failed ITF fixation over medium to long-term periods, specifically at 5 years and 10 years[15,19,25]. These studies show statistical differences in HHS when comparing these two types of CTHA (cemented/cementless). However, the actual HHS divergence is minimal, with standard deviations overlapping between the two groups. Hence, these differences might be statistically significant, but are lacking clinical relevance. Furthermore, hybrid CTHA has demonstrated a survival rate of 90%, as compared to 80% for cementless CTHA, at an average follow-up of 10 years[19]. The findings of this review cannot be generalized. More than 20% of the studies in this review lacked follow-up data. As indicated by our RR result of 1.92 with a wide confidence interval from 0.81 to 4.56 for PFF after CTHA in SHS, the study designs we included had a high risk of bias. Retrospective studies and chart reviews are often flawed by high dropout rates, bias, and poor design quality[31]. However, as it is not possible to do high-quality trials on CTHA after ITF fixation failure, we chose the best evidence of comparative retrospective chart reviews among case reports and extended case series. We also examined 19 other studies found during the review process[11-29]. These studies had weaker study designs due to lack of comparative data. Two studies reported CTHA outcomes in SHS failures[15,27]. However, neither study reported occurrence of PFF in follow-up.

CONCLUSION

In ITF, there is an increased risk of orthopedic complications (up to 64%) with CTHA following SHS as compared to CMN failures. There is no noted difference between the groups for medical complications and PFF. However, increased incidence of implant loosening in CTHA after SHS failure warrants additional research.

CTHA is a complex process. It necessitates precise assessment of the altered proximal femur anatomy and an awareness of the associated risk for orthopedic complications, including PFF. Although there is still some uncertainty regarding PFF, studies indicate that there are more orthopedic complications with SHS failures than with CMN when converted to CTHA. During surgery, PFF often occurs at the base of the greater trochanter in CMN cases. Whereas, for SHS, it frequently occurs postoperatively below the screw holes of the side plate[32]. An extensive examination of current literature reveals no significant clinical difference between cemented and cementless CTHA hip function. Nonetheless, the former is linked to a greater incidence of complications.

Reflecting on the results of this thorough analysis, it is our advice that patients with a failed SHS who undergo CTHA be made aware of the heightened risk for orthopedic complications.

Funding

No funding to declare.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Supplementary Materials

Supplementary data is available at https://hipandpelvis.or.kr/.

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