Intraarticular hip preservation procedures in healed Perthes disease: a systemic review and meta-analysis

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ABSTRACT

Background:
There is limited data about surgical options in treatment of healed Perthes disease. The authors conducted this systematic review and meta-analysis to compare two newly described surgical techniques: femoral head reduction osteotomy (FHRO) and relative femoral neck lengthening (RFNL) in the management of healed Perthes disease in terms of efficacy and complications.

Methods:
This systematic review and meta-analysis examined controlled and noncontrolled studies that compared FHRO and RFNL. The authors searched the Medline database via PubMed, EMBASE, and Cochrane Library for studies published between January 2000 and February 2021.

Results:
Fourteen studies that assessed RFLN and five studies that assessed FHRO were examined. The FHRO group demonstrated better improvement in the Harris Hip Score (HHS) than RFLN. The RFNL group showed better improvement than the FHRO group regarding flexion and internal rotation degree. The incidence of postoperative pain and postoperative stiffness was higher in the FHRO group than in the RFNL group. In the FHRO group, 28 patients with postoperative complications were reported (59.5%) versus 72 patients in the RFNL (16.4%).

Conclusion:
FHRO and RNFL are effective and safe modalities for post-Perthes sequelae. However, the postoperative clinical outcomes were observed to be in favor of RFNL, with less incidence of postoperative complication, compared to the FHRO. Moreover, the FHRO group needed more secondary acetabular procedures than the RFNL group. On the other hand, FHRO showed observed greater improvements in radiographic coverage indices.

Level of Evidence:
Level III.

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Key Words
Legg-Calve-Perthes, femoral head reduction osteotomy, relative femoral neck lengthening, meta-analysis

INTRODUCTION

Ischemic injury in LCPD leads to osteonecrosis, chondronecrosis, focal ossification, and delayed bone formation, as well as femoral head deformity[1] eventually. In return, patients can present with insidious onset of limping, mostly unilateral, and localized or diffuse pain.[2]

While conservative and surgical approaches have achieved notable improvements over the past few decades in addressing LCPD, patients with LCPD can still suffer from a wide range of sequelae due to hip morphological changes leading to femoroacetabular impingement (FAI) and degenerative arthritis.[3] Nearly one-third of the patients with post-Perthes sequelae develop symptoms due to deformities, such as degenerative pain and limited range of motion. Such deformities are mainly in the form of coxa vara, coxa plana or magna, and overriding greater trochanter.[4] Thus, several surgical approaches were proposed to correct the post-Perthes sequelae and preserve the hip according to the severity and location of the deformity, including hip dislocation, resection of the aspherical part of the femoral head, and valgus-flexion osteotomy.[5] However, those techniques revealed limited benefit in the setting of complex deformities.[6]

Relative femoral neck lengthening (RFNL) is a widely utilized procedure in many orthopaedic centers for the correction of femoral deformities and FAI. The technique is based on osteochondroplasty of the femoral head and neck concurrently to extend the greater trochanter, while maintaining the neck vascularity through safe hip dislocation and soft tissue flap.[7] According to previous case series and retrospective reviews, RFNL has demonstrated significant reduction in postoperative pain and improvement in hip function.[8] More recently, femoral head reduction osteotomy (FHRO) has been proposed as an alternative technique that aims to restore the sphericity of the head by reducing its size, hence improving the longevity of the femoral head. This approach is based on the Ganz technique that helps maintain the femoral head's vascularity during dislocation.[9] Previous reports showed that the FHRO achieved promising postoperative results and significantly improved hip function and motion.[10]

However, limited data are available regarding the comparative effectiveness and safety of FHRO versus RFNL in the management of post-Perthes sequelae. Thus, the authors conducted the present systematic review and meta-analysis to compare FHRO and RFNL in the management of post-Perthes sequelae in terms of postoperative hip function and complications. The authors hypothesized that RFNL would have an equal clinical outcome to FHRO with fewer potential risks and complications.

MATERIALS AND METHODS

Ethical Review & Study Design

The authors followed the standards recommended by the Cochrane Collaborative Group[11] and PRISMA checklist[12] to prepare this systematic review and meta-analysis. Eligibility criteria included studies published in English that recruited patients with LCPD irrespective of age or gender. Both controlled and noncontrolled studies that compared FHRO and RFNL were included, whether they were prospective or retrospective. Eligible studies were required to have included one of the following outcome measurements to be considered in this systematic review: visual analogue scale (VAS) score, hip functional scores, hip range of movement (ROM), radiographic assessment of osteoarthritic changes, and postoperative complications or need for revision surgery. Duplicate datasets, cadaveric studies, review articles and other forms of nonoriginal publications were excluded, as were theses. The research ethics committee at Ain Shams University approved (#FMASU MS154/ 2021) this study.

Data Collection

The authors searched the Medline database via PubMed, EMBASE, and Cochrane Library for studies between January 2000 and February 2021 using the following keywords: "Legg-Calve-Perthes," "Perthes disease," "femoral head reduction," "osteotomy," "hip preservation surgery," "surgical hip dislocation in Perthes," and "relative neck lengthening." They put all search results into an Endnote X8 program (Thompson Reuter, USA) for duplicates removal and construction of a screening sheet. The screening of the unique records passed through two stages: titles and abstracts screening, and full-text screening of the abstracts deemed eligible for the present review. Each step was done by two reviewers independently, according to the predetermined criteria. Disagreements at any stage were resolved by consensus. The online search was complemented by manual searching of the references of eligible studies.

Two reviewers independently extracted the following data from eligible studies' data collection forms: study design, level of evidence, the sample size in each intervention, demographic characteristics, age at index procedures, follow-up duration, functional outcomes, postoperative radiographic findings, need for revision surgery, and postoperative complications.

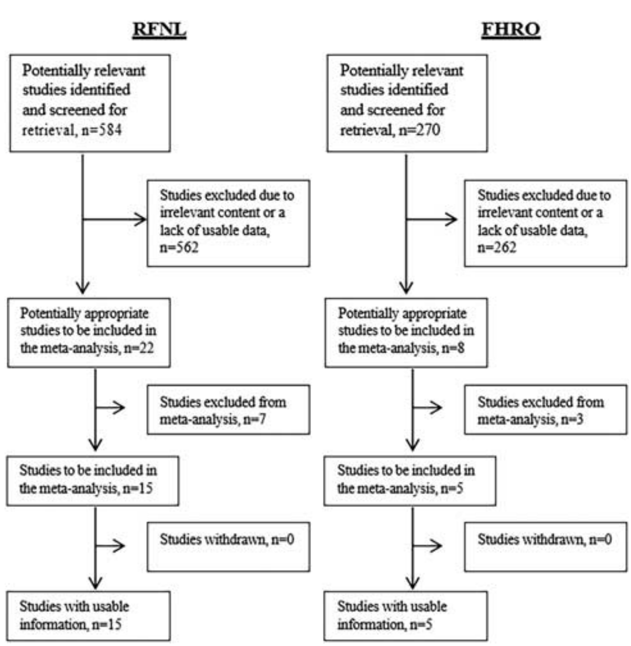

FIGURE 1. Search methodology.

Statistical Analysis

Binary outcomes were expressed as a proportion. Continuous outcomes were expressed as standardized mean difference (SMD). Estimates from included studies were pooled using the random-effects (REM) model according to the absence or presence of heterogeneity. Review Manager (RevMan, Cochrane Collaboration; version 5.3) was used to pool studies. I square value and its *P* value were used to quantify heterogeneity. *P* value >0.05 was considered statistically significant. The random-effect model was used when the I-square value was more than 50%.

RESULTS

Using the search criteria, 584 articles were initially identified for RFNL, and 14 studies met inclusion criteria. While 270 articles were initially identified for FHRO, five studies met inclusion criteria (Figure 1).

Table 1 shows the preoperative characteristics of the 19 included studies. The majority of studies were retrospective chart reviews ($n=14$). The total number of patients in the studies assessing FHRO was 47 (hips $n=47$), compared with 438 (hips $n=460$) in the studies assessing RFNL. In the FHRO arm, the mean age at index procedure was 13.66 ± 0.4, and the mean follow-up was 33.7 ± 15.5 mo. In the RFNL arm, the mean age at index procedure was 19.9 ± 3.6, and the mean follow-up was 45.7 ± 20 mo.

The studies showed notable variations in the radiographic angles used for assessment; however, the majority used sphericity index, extrusion index, lateral center edge angle (LCEA), and acetabular index for the radiographic evaluation. In the FHRO arm, additional procedures were performed in 23 patients, commonly periacetabular and pelvic osteotomies. On the other hand, 45 patients underwent additional procedures in the RFNL arm, mainly periacetabular and intertrochanteric osteotomies. The Harris Hip Score (HHS) was the most commonly utilized functional score in both interventions' arms.

TABLE 1. Preoperative characteristics of the included studies

Authors	Main procedure	Type	LOE	N	Hips	Mean age at index procedures (yr)	Mean follow-up (mo)	Additional procedures	Functional score
Paley[13]	FHRO	Retrospective cohort	IV	20	21	14	32.4	Pelvic osteotomy (5 patients) Valgus intertrochanteric osteotomy (1 patient)	N/A
Siebenrock *et al.*[14]	FHRO	Retrospective cohort	IV	11	11	13	60	triple osteotomy (2 patients) PAO (2 patients)	Merle d'Aubigne-Postel score
Georgiev *et al.*[15]	FHRO	Prospective cohort	III	4	4	13.7	19	Femoral VDO (1 patient)	HHS
Clohisy *et al.*[16]	FHRO	Retrospective cohort	IV	6	6	13.6	39.6	PAO (6 patients)	mHHS, WOMAC
Fürnstahl *et al.*[17]	FHRO	Retrospective pilot study	IV	6	6	14	17.5	PAO (6 patients)	N/A
Rebello *et al.*[18]	RFNL	Retrospective cohort	IV	15	16	19.3	41.6	Intertrochanteric osteotomy (6 patients) Trapdoor procedure (1 patient) Acetabular rim osteoplasty (1 patient)	WOMAC
Anderson *et al.*[19]	RFNL	Retrospective cohort	IV	21	23	15.7	15.1	Subcapital osteotomy (2 patients) Distraction hip arthroplasty (2 patients)	N/A
Shore *et al.*[8]	RFNL	Retrospective cohort	IV	14	14	19.6	45	PAO (2 patients)	HHS
Albers *et al.*[6]	RFNL	Retrospective cohort	IV	50	50	21	61.2	Acetabular redirection osteotomy (2 patients) Excision of heterotopic ossifications (1 patient)	Merle d'Aubigne-Postel score
Nassif *et al.*[20]	RFNL	Prospective cohort	III	88	104	N/A	40.8	Hip arthroscopy for labral tear (4 patients) Capsulotomy at the time of index procedure (1 patient)	mHHS
Albers *et al.*[7]	RFNL	Retrospective cohort	IV	40	41	24	96	1. Varus intertrochanteric osteotomy (1 patient) 2. Combined triple osteotomy with valgus intertrochanteric osteotomy (1 patient)	Merle d'Aubigne-Postel score
Clohisy *et al.*[21]	RFNL	Retrospective cohort	IV	16	16	22	40	Hip arthroscopy (1 patient)	mHHS
Eid[22]	RFNL	Prospective cohort	III	12	12	15.9	24	N/A	HHS
Guindani *et al.*[23]	RFNL	Retrospective cohort	IV	15	16	14.2	36	Pelvic osteotomy (1 patient)	mHHS, NAHS
Madan *et al.*[24]	RFNL	Retrospective cohort	IV	34	34	26	72	N/A	Merle d'Aubigne-Postel score
Kim *et al.*[25]	RFNL	Retrospective cohort	IV	20	21	17.3	67.2	Pelvic osteotomy (4 patients) Valgus osteotomy (4 patients)	mHHS
Risto *et al.*[26]	RFNL	Retrospective cohort	IV	39	39	21	47	PAO (11 patients)	mHHS, NAHS, VAS
Elmarghany *et al.*[27]	RFNL	Prospective cohort	III	30	30	26.4	27.7	N/A	WOMAC, mHHS
Nabil *et al.*[28]	RFNL	Prospective cohort	III	15	15	20.1	36	PAO (2 patients)	HHS

FHRO, femoral head reduction osteotomy; HHS, Harris Hip Score; LOE, level of evidence; mHHS, modified Harris Hip Score; N, number of patients in the study; N/A, not applicable; NAHS, non-arthritic hip score; PAO, peri acetabular osteotomy; RFNL, relative femoral neck lengthening; VAS, visual analogue scale; VDO, varus derotational osteotomy; WOMAC, Western Ontario and McMaster Universities Arthritis Index.

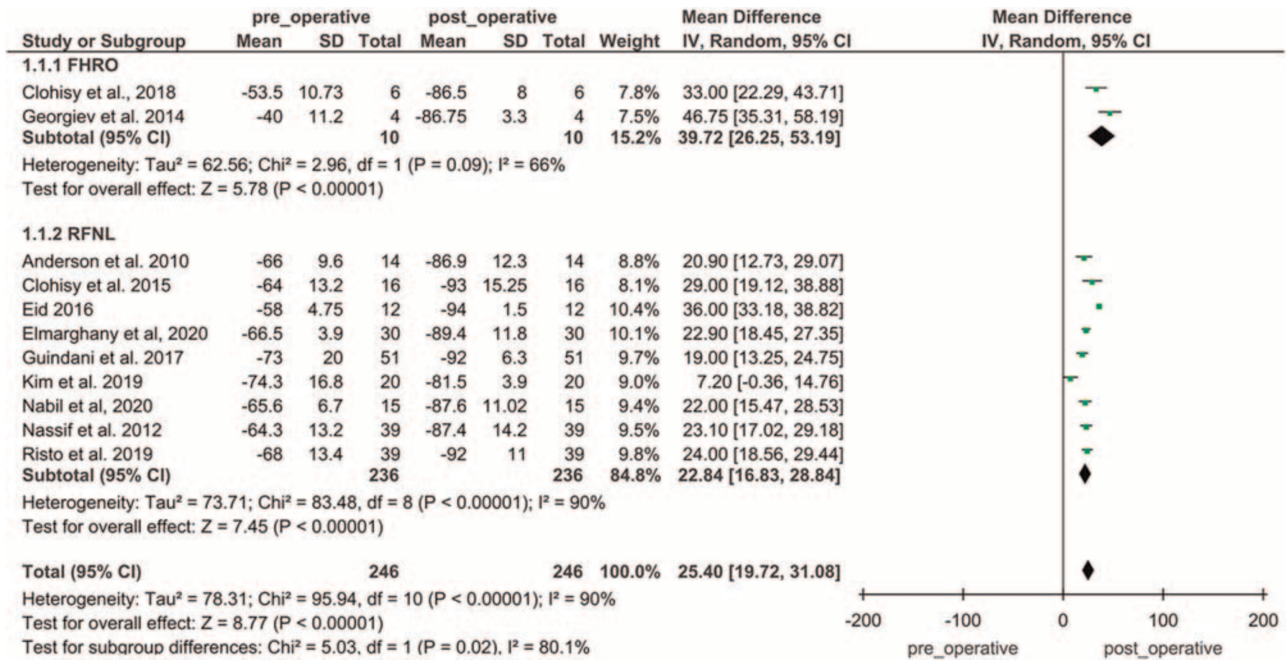

FIGURE 2. Forest plot for Harris Hip Score (HHS).

The pooled estimate for the postoperative HHS was marginally higher in the RFNL arm than FHRO (89.3 vs. 86.62, respectively). However, the mean preoperative HHS was lower in the FHRO group. Hence, the FHRO group demonstrated better improvement (mean difference [MD] = 40 points vs. 22 points, respectively; Figure 2). Regarding the degree of hip fixation, the RFNL group showed better improvement than the FHRO group regarding flexion degree (standardized MD [SMD] = 1.38 vs. 0.15, respectively.) Furthermore, the RFNL group showed better improvement than the FHRO group regarding internal rotation degree. The mean preoperative degree was 13 in FHRO, and 13.9 in the RFNL group. The mean postoperative degree increased to 15 in FHRO and 26 in the RFNL group.

Concerning the postoperative radiographic evaluation, the FHRO group showed better improvement than the RFNL group in postoperative LCEA. However, that was attributed to the performance of peri acetabular osteotomy (PAO) in 29.7% of cases. The mean preoperative angle was 8.6 degrees in FHRO and 20.7 degrees in the RFNL group. The mean postoperative angle increased to 32.95 degrees in FHRO and 28.35 degrees in the RFNL group (Figure 3A). However, both groups showed marginally equal improvement regarding alpha and Tönnis angle (Figure 3B and C). The FHRO group showed better improvement than the RFNL group. The mean preoperative Extrusion index was 41% in FHRO while it was 44% in the RFNL group. The mean postoperative index decreased to 6.86% in FHRO and to 57.5% in the RFNL group.

The postoperative pain was recorded according to the WOMAC score and reported by both groups. According to statistics results, the incidence of postoperative pain was higher in the FHRO group than in the RFNL group. The mean preoperative pain score was 60 points in the FHRO group and 18 points in the RFNL group, while the mean postoperative pain score increased to 89.1 points in the FHRO group and decreased to 4.3 points in the RFNL group. The incidence of postoperative stiffness was higher in the FHRO group compared to the RFNL group.

In total, 100 patients with postoperative complications were reported by both techniques, with a percent of 20.6% of the total number of patients (Table 2). In the FHRO group, 28 patients with postoperative complications were reported, with a percent of 59.5%. In the RFNL group, 72 patients with postoperative complications were reported, with a percentage of 16.4%.

DISCUSSION

Children with LCPD can suffer from a wide range of permanent deformities in late childhood and adulthood, which significantly affect their hip function and quality of life. In addition, such deformities can induce degenerative arthritis at an early age.[29] Thus, corrective surgery is usually needed in symptomatic patients to improve hip function and alleviate the associated pain. However, traditional extra-articular procedures may have limited benefits in patients with complex femoral deformities.[6] Since the introduction of the safe hip dislocation technique, the published literature showed a notable advance in the surgical approaches for the sequelae of LCPD, particularly with the description of the RFNL.[4] Additionally, FHRO offers the advantage of restoring the sphericity of the femoral head while maintaining the femoral head's vascularity during dislocation.[9] However, these two surgical procedures showed mixed results, despite the observed improvement in the clinical outcomes and hip ROM; overall, there are not many studies that compare the two treatments and recommend one over the other.[30] Thus, the authors conducted this systematic review and meta-analysis to compare FHRO and RFNL in the management of

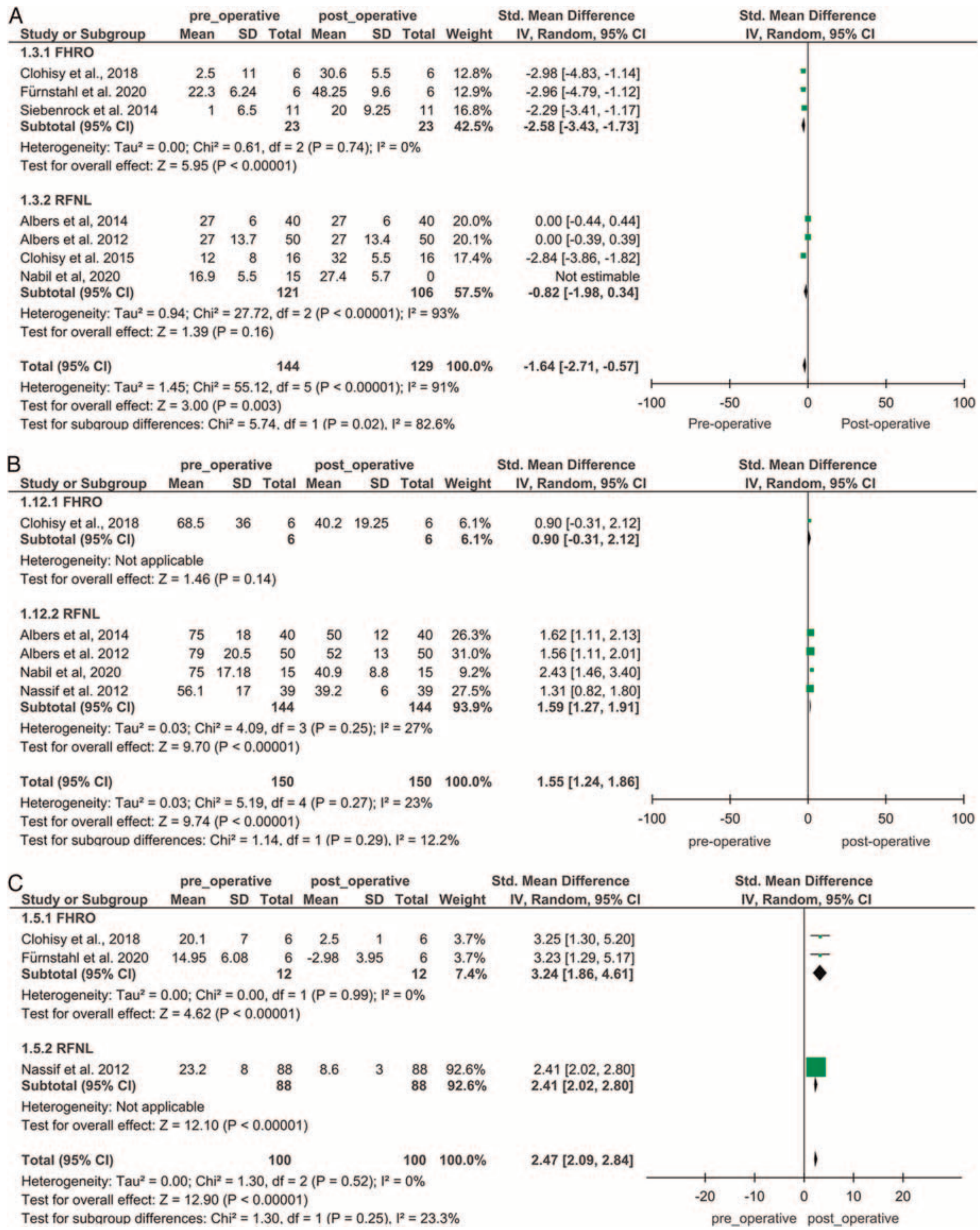

FIGURE 3. **A**, Lateral center edge angle (LCEA) forest plot. **B**, Alpha angle forest plot. **C**, Tönnis angle forest plot.

post-Perthes sequelae in terms of postoperative hip function and complications.

Although RFNL and FHRO have seemingly different indications in management of post-Perthes deformities, both techniques address the aspherical distortion of the femoral head. An ovoid head with anterolateral impinging bump is thought to be addressed better by RFNL, while FHRO is typically indicated for a saddle-shaped femoral head with a central necrotic portion. However, FHRO is more technically demanding, has a higher incidence of secondary procedures, and in many hips unable to fully excise the central necrotic portion, leaving behind a head that is not perfectly spherical with a portion of necrotic central segment.

TABLE 2. Summary of complications

Type of complication	Femoral head reduction osteotomy (FHRO) total number = 47	Relative femoral neck lengthening (RFNL) total number = 438
1. Pain	4 (8.5%)	5 (1.14%)
2. Wound infection (SSI)	1 (2.12%)	5 (1.14%)
3. Femoral neck fractures	2 (4.2%)	—
4. Heterotopic ossification	1 (2.12%)	2 (0.45%)
5. Avascular necrosis	2 (4.2%)	3 (0.6%)
6. Nerve palsy	—	3 (0.6%)
7. Osteonecrosis	1 (2.12%)	5 (1.14%)
8. Failure (reoperation)	15 (31.9%)	20 (4.5%)
9. Postoperative adhesions (stiffness)	2 (4.2%)	9 (2.05%)
10. Osteoarthritis	—	20 (4.5%)
Total	28 (59.5%)	72 (16.4%)

SSI, surgical site infection.

The impact of LCPD on hip function has been well established by much published literature. Previous reports showed that the LCPD significantly impacted hip abductor function and limited hip ROM.[31] It also has been noted that patients with LCPD had significantly lower functional scores, such as HHS.[32] The post-Perthes limitation in hip function is thought to arise from the combined effects of femoral deformities (FAI) and painful hip movements. Moreover, proper surgical intervention in the prearthritic stage restores function and protects the young hip from early degenerative changes.[22] Thus, one primary goal of the surgical management of post-Perthes sequelae is to restore normal hip function and reduce pain.[4] In this systematic review and meta-analysis, the authors found that the RFNL and FHRO significantly improved the postoperative HHS, with the FHRO group demonstrating better improvement. Regarding ROM, the RFNL showed a significant improvement in the clinical outcomes, with less incidence of persistent pain and postoperative stiffness. The better improvement in the RFNL compared to the FHRO may be attributed to the fact that the FHRO needs careful attention during soft tissue handling and should be performed by a highly experienced orthopedic surgeon.[13] FHRO usually needs secondary procedures – like acetabular osteotomy – to improve clinical outcomes. Additionally, Anderson *et al.*[30] noted that the trochanteric distalization combined with surgical dislocation and hip osteochondroplasty allows for safe examination and treatment of intraarticular cartilage and labral disease while improving hip biomechanics. To the best of the authors' knowledge, no comparative studies directly compared the clinical outcomes of RFNL versus FHRO. However, their results were in line with recent reports showing a significant improvement in hip function, ROM, and postoperative pain following RFNL and FHRO.[17,27] The authors recommend interpreting those results cautiously because the follow-up duration within the studies was limited. A sufficiently long follow-up is crucial to ensure the continuity of the excellent early results and determine whether these procedures will alter the natural history of the disease.[33] Thus, future large-scale studies should directly compare the change in the clinical outcomes between RFNL and FHRO.

The radiographic angles LCE angle and extrusion index showed better improvement in FHRO group, and the Tönnis angle and alpha angle were marginally equal.

Limitations and Future Perspectives

The authors acknowledge the presence of some limitations. The majority of studies were retrospective chart reviews, which could increase the risk of misclassification and information biases. The current findings also resulted from single-arm clinical trials. They could only be regarded as observations since formal statistical tests for significance between the two groups could not be conducted. The inconsistencies in radiographic assessment and evaluation of the clinical outcomes among the included studies were major limitations of the pooled estimates of the present study. Lastly, all studies had limited follow-up duration to investigate whether the RFNL and FHRO altered the disease's natural history and reduced the risk of osteoarthritis. Future randomized controlled studies comparing both techniques with a large number of participants should be conducted to substantiate the findings of the current study.

CONCLUSION

This systematic review and meta-analysis finds that FHRO and RNFL are effective and safe modalities for post-Perthes sequelae. However, the postoperative clinical outcomes were observed to be in favor of RFNL, which had less incidence of postoperative complication, compared to the FHRO. Moreover, the FHRO group needed more secondary acetabular procedures than the RFNL group. On the other hand, FHRO showed more improvements in radiographic indices. Further comparative studies between both techniques, with more patients and longer follow-up periods, are recommended.

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