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Clinical and Radiological Outcomes of the Morscher Osteotomy in Adolescent and Young Adult Patients with Abductor Lever Arm Shortening and Limping Due to Sequelae of Childhood Hip Disease: A Retrospective Case Series

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Abstract

Objective

Sequelae of childhood hip disease can lead to femoral neck shortening, relative elevation of the greater trochanter, and shortening of the abductor lever arm. The clinical, biomechanical, and radiological outcomes of the Morscher osteotomy were evaluated.

Methods

A single-center retrospective case series included 23 patients who underwent Morscher osteotomy for a shortened abductor lever arm and limping and who completed at least 12 months of follow-up. All procedures were performed by the same surgeon with the patient supine. The greater trochanter was fixed with a tension band or cannulated screws according to the individual case. The Harris Hip Score (HHS), visual analog scale (VAS), hip range of motion, leg length discrepancy, Trendelenburg sign, and limping were assessed. Abduction torque was normalized to body weight, and the limb symmetry index (LSI) was calculated. The alpha angle, neck-shaft angle, articulotrochanteric distance (ATD), lateral center-edge angle (LCEA), extrusion index, and femoral offset were measured radiologically.

Results

HHS rose from 58.0 ± 7.9 to 89.0 ± 4.5, abduction torque from 0.88 ± 0.14 to 1.38 ± 0.18 Nm/kg, and LSI from 55.2 ± 7.6% to 87.2 ± 4.6%; VAS fell from 7.0 to 2.0 and leg length discrepancy from 2.46 ± 0.53 cm to 0.63 ± 0.33 cm (Holm-adjusted $p < 0.001$ for all). The neck-shaft angle, ATD, and femoral offset improved significantly. The alpha angle, LCEA, and extrusion index showed no significant change after Holm correction. The Trendelenburg sign and limping resolved in every patient. No complications occurred.

Conclusion

In selected adolescents and young adults with sequelae of childhood hip disease, the Morscher osteotomy was associated with better abductor function, hip function, and proximal femoral geometry at short-term follow-up.

INTRODUCTION

Limping or a Trendelenburg gait is the main complaint that brings patients with Legg-Calvé-Perthes disease (LCPD) to medical attention; pain increases during and after physical activity [1]. The disease is an idiopathic avascular necrosis of the femoral head that distorts head morphology and produces joint incongruity [2]. Residual head deformity and joint congruency are graded with the Stulberg classification,

and the main determinants of surgical outcome are age at onset and initial disease severity [3]. The reported global incidence ranges from 0.2 to 19.1 per 100,000 children under 15 years of age [4]. Frequency is low in equatorial regions and highest in Northern Europe, and the poorest households are affected four times more often than the wealthiest [5]. Onset occurs between 3 and 12 years of age, most often at 5 to 7 years, and boys are affected three to five times more often than girls [1]. Head deformity persisting beyond stage IIIb is permanent, so treatment is directed mainly at the sequelae; premature closure of the capital physis leads to a short femoral neck (coxa brevis) and relative elevation of the trochanter [5]. In these patients the arthroplasty rate is 7%, and the complication rate after arthroplasty is 22.9% [4].

In the sequela stage, coxa vara and trochanteric elevation cause painful restriction of motion and gluteal insufficiency; the Morscher osteotomy aims to normalize gait by restoring neck length and the abductor lever arm [6]. The evidence in this field, however, is entirely retrospective; patient ages span a wide range, no study has performed a post hoc power analysis, variation in the reporting of functional scores has made formal meta-analysis impossible, and one of the scales used has not yet been validated in the pediatric LCPD population [7]. In small case series, the sound way to convey estimation precision is to report an effect size and confidence interval for each comparison rather than observed power, and that is the approach followed here. Gait studies in unoperated children attribute the Trendelenburg pattern to abductor weakness, debate whether trunk lean truly unloads the hip, and repeatedly point to the lack of assessment of the sound side as a shortcoming [8]. An objective, side-to-side measurement of abductor strength remains a gap in this picture.

The Morscher osteotomy lengthens the neck in a true sense by lateralizing the femoral shaft and shifts the elevated greater trochanter distally. We reasoned that this correction, by rebuilding the shortened abductor lever arm, could translate into a strength gain measurable with a dynamometer. We also expected the gain to be reflected in pain, functional score, range of motion, leg length discrepancy, the Trendelenburg sign, and limping. On the radiological side, we anticipated improvement in the articulotrochanteric distance (ATD), the neck-shaft angle, and femoral offset, whereas acetabular coverage and head-neck parameters were expected to remain unchanged because the procedure stays extra-articular. In patients with a shortened abductor lever arm and limping due to sequelae of childhood hip disease, the clinical, biomechanical, and radiological outcomes of the procedure were examined together with its complications. Strength gain was quantified with the sound side as an internal control, and the intraobserver and interobserver agreement of torque and radiological measurements was tested separately. Determinants of the torque gain were examined as exploratory analyses.

METHODS

Study Population

This study is a retrospective case series conducted at a single center. Patients who underwent Morscher osteotomy between January 1, 2019 and January 1, 2024 for a shortened abductor lever arm and

limping due to sequelae of a childhood hip disease were screened. The upper limit of the surgical period was set at January 1, 2024 so that all patients could be followed for at least 12 months by the date of data collection. Patients in whom the femoral head deformity had become permanent, in other words in whom the disease had reached the sequela stage, were included; no predefined lower or upper limit was applied to age at surgery. Patients without at least 12 months of follow-up, with incomplete records, or with a concurrent additional hip procedure were excluded. Twenty-three patients met these criteria and were included.

Age at surgery, sex, affected side, height, body weight, and follow-up duration were recorded. The severity of the hip deformity was graded on preoperative radiographs with the Stulberg classification, and accompanying degenerative changes with the Tönnis grading.

Study Procedures

All patients were examined preoperatively and at the final visit with the same standard assessment protocol. The primary outcome was body weight-normalized abduction torque on the operated side. The remaining clinical, biomechanical, and radiological measurements were treated as secondary outcomes.

Functional status was assessed with the Harris Hip Score (HHS) and pain intensity with a visual analog scale (VAS). Hip range of motion was measured in degrees with a standard goniometer in flexion, abduction, internal rotation, and external rotation. Leg length discrepancy was recorded clinically in centimeters, and the presence of the Trendelenburg sign and of limping was also assessed.

Abductor muscle strength was measured with the patient in the lateral decubitus position and a handheld dynamometer placed over the lateral femoral condyle. The patient was asked to perform maximal isometric hip abduction; the measurement was repeated three times, and the mean of the three trials was used in the analyses. Abduction torque was calculated as the product of the force measured with the dynamometer and the moment arm between the point of application and the greater trochanter. The resulting torque was divided by body weight and expressed in Nm/kg. The limb symmetry index (LSI) was calculated as the ratio of operated-side torque to sound-side torque multiplied by 100.

Radiological assessment covered the alpha angle, neck-shaft angle, ATD, lateral center-edge angle (LCEA), extrusion index, and femoral offset. Angles were expressed in degrees, distances in millimeters, and the extrusion index as a percentage. To illustrate the radiological changes, preoperative and 18-month postoperative anteroposterior pelvic radiographs of the same patient were presented together (Figures 1A and 1B).

To assess measurement reliability, all abduction torque measurements and radiological parameters were evaluated by two independent observers. One observer repeated all measurements after an interval of 15 days to allow estimation of intraobserver reliability.

To reduce selection bias, all consecutive patients meeting the criteria during the study period were included. To limit measurement bias, torque and radiological measurements were performed by two

independent observers with a standard protocol, and reliability was assessed with the intraclass correlation coefficient (ICC). Because the implants were visible on the radiographs, blinding the observers to preoperative versus postoperative status was not possible.

Surgical Technique

All patients underwent Morscher osteotomy. Patients were positioned supine, and all procedures were performed by the same surgeon. The operation was carried out to lengthen the shortened femoral neck effectively by lateralizing the femoral shaft and to transfer the relatively elevated greater trochanter distally. The correction was intended to restore the lever arm and tension of the abductor muscles.

Osteotomy levels were marked under intraoperative fluoroscopy with Kirschner wires placed on the greater trochanter and the femoral neck. The planned osteotomy lines were verified fluoroscopically before the osteotomy was started (Figure 2A).

The greater trochanteric osteotomy was then performed. After the osteotomy parallel to the superior border of the femoral neck and the distal transverse osteotomy were completed, the lateral cortical segment between these two lines was removed (Figure 2B). Once the segment was removed, the femoral shaft was lateralized, the femoral neck was effectively lengthened, and the elevated greater trochanter was transferred distally.

In the representative case, the removed lateral cortical segment was reused as autogenous bone graft, and its position was verified with intraoperative fluoroscopy (Figure 2C).

The main osteotomy line was fixed with a lateral plate and screws. Fixation of the distally transferred greater trochanteric fragment, in other words the abductor lever arm, was achieved with a tension band technique or cannulated screws according to the characteristics of the case. A representative fluoroscopic view of trochanteric fixation with cannulated screws is presented in Figure 2D. All reduction and fixation steps were checked with intraoperative fluoroscopy (Figures 2A–D).

On the first postoperative day, patients were mobilized without weight bearing on the operated limb. Hip range of motion exercises for the operated limb were started in the same period. Partial weight bearing was permitted from the fourth postoperative week. From the third month onward, patients were allowed to mobilize with full weight bearing on the operated limb.

Complications during follow-up, including infection, nonunion, implant failure, and the need for revision surgery, were recorded.

Statistical Analysis

The distribution of continuous variables was examined with the Shapiro–Wilk test. Normally distributed variables are presented as mean ± standard deviation (SD) and non-normally distributed variables as median and interquartile range (IQR).

For preoperative to postoperative comparisons, the paired samples t test was used for continuous variables with normally distributed within-patient differences. When the normality assumption was not met, the exact version of the Wilcoxon signed-rank test was applied. Effect size was reported as Cohen dz for the paired t test and as the rank-biserial correlation coefficient (r) for the Wilcoxon test. For variables analyzed with the t test, 95% confidence intervals (CIs) of change were based on the t distribution of within-patient differences; for nonparametric variables, the Hodges–Lehmann estimate and its CI were calculated.

Paired binary outcomes were compared with the exact McNemar test. Continuous determinants of the change in abduction torque were assessed with the Spearman rank correlation coefficient, with CIs calculated by Fisher z transformation. Subgroup comparisons were performed with the exact Mann–Whitney U test, and the effect was reported as the between-group Hodges–Lehmann difference. Determinant analyses were regarded as exploratory.

Measurement reliability was evaluated with the ICC. A two-way mixed-effects model [ICC (3,1)] was used for intraobserver agreement and a two-way random-effects model [ICC (2,1)] for interobserver agreement. Both analyses were based on absolute agreement and single measurements. ICC values were interpreted according to the lower bound of the 95% CI rather than the point estimate.

Correction for multiple comparisons was carried out over two independent test families. Preoperative to postoperative comparisons of the primary and secondary outcomes formed a single family of 17 tests, and the exploratory analyses of determinants of torque change formed a separate family of 11 tests. The Holm method was used in both families. Because sound-side abduction torque served as an internal control, it was not included in the correction.

Statistical significance was set at $p < 0.05$. No a priori sample size calculation was performed; all consecutive patients meeting the criteria were analyzed. Instead of a post hoc power calculation, estimation precision was judged from the effect sizes and 95% CIs reported for each comparison. In a sensitivity analysis, with 23 patients, two-sided $\alpha = 0.05$, and 80% power, the smallest detectable effect was $dz = 0.61$ for paired comparisons and approximately Cohen $d = 1.2–1.5$ for subgroup comparisons.

Analyses were performed with IBM SPSS Statistics version 29.0 (IBM Corp., Armonk, NY, USA). The Exact Tests module was used for exact tests. Hodges–Lehmann estimates and CIs, the rank-biserial correlation coefficient, Cohen dz, and Holm corrections were additionally calculated in a spreadsheet environment. The sensitivity analysis was run with G*Power version 3.1.9.7 (Heinrich Heine University, Düsseldorf, Germany). Because patients with incomplete records were excluded, all analyses were complete-case; no data imputation was applied. As patients without at least 12 months of follow-up were not included, no patient in the analysis was lost to follow-up.

Ethical Considerations

This study was approved by the Harran University Non-Interventional Clinical Research Ethics Committee (Protocol No: HÜ-GOEK-2026-00305; approval date: August 5, 2026). Given the retrospective design of the study, the requirement for informed consent was waived by the ethics committee. Because of the retrospective design, the ethics committee reviewed and approved a waiver of informed consent and permitted use of the patient data under this condition. All patient data were anonymized before analysis.

RESULTS

Patient characteristics

Twenty-three patients were included. Median age at surgery was 16 years (IQR, 15–18), with a range of 13–24 years. Eleven patients were female (47.8%) and 12 male (52.2%). The affected side was right in 11 patients (47.8%) and left in 12 (52.2%). Mean height was 165.9 ± 8.5 cm (148–183 cm) and mean body weight 59.7 ± 10.3 kg (42–82 kg). Mean follow-up was 22.5 ± 7.6 months, ranging from 12 to 43 months. On preoperative radiological classification, 5 patients were Stulberg II (21.7%) and 18 were Stulberg III (78.3%). The Tönnis grade was 0 in 17 patients (73.9%) and 1 in 6 (26.1%). None of the analyzed variables had missing data in the 23 included patients (Table 1).

Clinical and functional outcomes

HHS rose from 58.0 ± 7.9 preoperatively to 89.0 ± 4.5 at the final visit. Mean within-patient change was +30.9 points (95% CI, +28.4 to +33.5) with a very large effect size ($dz = 5.25$; $p < 0.001$; Holm-adjusted $p < 0.001$). Median VAS fell from 7.0 (IQR, 5.0–8.0) to 2.0 (IQR, 1.0–2.0). The Hodges–Lehmann estimate of change was −5.0 (95% CI, −5.5 to −4.5) ($r = -1.00$; $p < 0.001$; Holm-adjusted $p < 0.001$) (Table 2).

Hip range of motion improved significantly in every direction assessed. Median flexion rose from 109.0° (IQR, 100.5–113.0) to 119.0° (IQR, 112.0–122.5), with a Hodges–Lehmann change of +9.0° (95% CI, +7.5 to +12.5) ($r = +1.00$; $p < 0.001$). Abduction increased from 25.1 ± 3.7° to 40.6 ± 3.9°, a mean within-patient change of +15.5° (95% CI, +14.2 to +16.7) ($dz = 5.39$; $p < 0.001$). Median internal rotation rose from 12.0° (IQR, 8.0–14.0) to 17.0° (IQR, 14.5–20.0) and median external rotation from 33.0° (IQR, 27.5–37.5) to 39.0° (IQR, 35.0–44.0). Within-patient changes were +5.5° (95% CI, +5.0 to +6.5) and +6.0° (95% CI, +5.0 to +8.0), respectively, with $r = +1.00$ and Holm-adjusted $p < 0.001$ for both (Table 2).

Leg length discrepancy decreased from 2.46 ± 0.53 cm preoperatively to 0.63 ± 0.33 cm at the final visit. Mean within-patient change was −1.82 cm (95% CI, −1.98 to −1.67) ($dz = -5.13$; $p < 0.001$; Holm-adjusted $p < 0.001$). A positive Trendelenburg sign and limping, present in all 23 patients (100.0%) preoperatively, were seen in none at the final visit; both findings resolved in 23/23 patients (100.0%) ($p < 0.001$ for both; Holm-adjusted $p < 0.001$) (Table 2).

Abductor muscle strength and limb symmetry

Body weight-normalized abduction torque on the operated side rose from 0.88 ± 0.14 Nm/kg preoperatively to 1.38 ± 0.18 Nm/kg at the final visit. The mean within-patient increase was +0.51 Nm/kg

(95% CI, +0.45 to +0.57) (dz = 3.57; p < 0.001; Holm-adjusted p < 0.001), and the increase was observed in all 23 patients. Sound-side abduction torque was 1.60 Nm/kg (IQR, 1.48–1.72) at both assessments; the Hodges–Lehmann change estimate was 0.00 Nm/kg (0.00–0.00), and the difference was not statistically significant (p = 0.500). As the sound side served as an internal control, it was not entered into the Holm correction.

LSI rose from 55.2 ± 7.6% preoperatively to 87.2 ± 4.6% at the final visit. The mean increase in patient-level LSI was +32.0 percentage points (95% CI, +28.9 to +35.0) with a large effect size (dz = 4.54; p < 0.001; Holm-adjusted p < 0.001) (Table 2).

Radiological outcomes

Preoperative and 18-month postoperative anteroposterior pelvic radiographs of a representative patient are shown in Figure 1. The preoperative image shows the short femoral neck and elevated greater trochanter, and the postoperative image shows distalization of the greater trochanter and proximal femoral remodeling after osteotomy (Figure 1). The paired presentation of preoperative and postoperative radiographs, made in line with reviewer suggestions, allows visual appraisal of the radiological changes.

Parameters reflecting femoral geometry improved markedly. The neck-shaft angle rose from 110.6 ± 9.5° to 126.8 ± 5.7°, a mean within-patient change of +16.3° (95% CI, +14.1 to +18.4) (dz = 3.22; p < 0.001; Holm-adjusted p < 0.001). ATD rose from −18.7 ± 5.0 mm preoperatively to 12.1 ± 4.0 mm at the final visit. The mean change was +30.7 mm (95% CI, +29.0 to +32.5), the largest effect size among the parameters examined (dz = 7.53; p < 0.001; Holm-adjusted p < 0.001). Femoral offset rose from 26.6 ± 5.2 mm to 33.5 ± 5.2 mm, a mean change of +6.9 mm (95% CI, +5.9 to +7.9) (dz = 3.04; p < 0.001; Holm-adjusted p < 0.001) (Table 2; Figure 1).

In contrast, the alpha angle, LCEA, and extrusion index showed no statistically significant change after Holm correction. Median alpha angle went from 53.0° (IQR, 48.0–63.0) to 52.0° (IQR, 49.0–64.5); the Hodges–Lehmann estimate was −0.5° (95% CI, −1.5 to +0.5), and the difference was not significant (r = −0.28; p = 0.294; Holm-adjusted p = 0.294). LCEA rose from 28.9 ± 5.2° to 29.4 ± 5.2°, a mean change of +0.5° (95% CI, −0.1 to +1.1) (dz = 0.36; p = 0.097; Holm-adjusted p = 0.193).

The extrusion index was 17.0% (IQR, 14.5–24.0) preoperatively and 18.0% (IQR, 14.0–23.0) at the final visit. The paired patient-level Hodges–Lehmann change estimate, however, was −1.0 percentage point (95% CI, −1.0 to 0.0) (r = −0.59). The uncorrected p value was 0.039, but significance was not maintained after Holm correction (p = 0.116). At the patient level, the extrusion index decreased in 12 patients (52.2%), increased in 4 (17.4%), and did not change in 7 (30.4%) (Table 2).

Complications

No surgical complication occurred in any patient during follow-up. Infection, nonunion, implant failure, and the need for revision surgery were each recorded as 0/23 (0.0%), and the overall complication rate

was 0/23 (0.0%) (Table 2).

Determinants of the change in abduction torque

None of the continuous variables examined was significantly associated with operated-side torque gain after Holm correction of the 11 comparisons. A weak positive correlation was observed between the change in femoral offset and the change in torque (ρ = +0.316; 95% CI, −0.111 to +0.644; p = 0.142; Holm-adjusted p = 1.000). A similar relation was found for the change in ATD (ρ = +0.363; 95% CI, −0.058 to +0.674; p = 0.089; Holm-adjusted p = 0.801). The change in neck-shaft angle correlated negatively with torque gain, and the correlation was significant in the uncorrected analysis (ρ = −0.453; 95% CI, −0.729 to −0.050; p = 0.030) but lost significance after Holm correction (p = 0.329).

Change in abduction range of motion (ρ = +0.142; 95% CI, −0.287 to +0.523; p = 0.519; Holm-adjusted p = 1.000), change in HHS (ρ = −0.114; 95% CI, −0.503 to +0.313; p = 0.604; Holm-adjusted p = 1.000), age (ρ = −0.021; 95% CI, −0.430 to +0.394; p = 0.923; Holm-adjusted p = 1.000), and follow-up duration (ρ = +0.002; 95% CI, −0.411 to +0.414; p = 0.994; Holm-adjusted p = 1.000) showed no significant association with torque gain (Table 3).

None of the subgroup comparisons was significant after Holm correction. Median torque change was 0.60 Nm/kg (IQR, 0.41–0.65) in female and 0.47 Nm/kg (IQR, 0.40–0.53) in male patients, with a between-group Hodges–Lehmann difference of +0.05 Nm/kg (p = 0.347; Holm-adjusted p = 1.000). Torque change was 0.49 Nm/kg (IQR, 0.44–0.61) for the right side and 0.46 Nm/kg (IQR, 0.40–0.63) for the left, a Hodges–Lehmann difference of +0.01 Nm/kg (p = 0.880; Holm-adjusted p = 1.000).

Median torque change was 0.47 Nm/kg (IQR, 0.38–0.60) in the Stulberg II group and 0.49 Nm/kg (IQR, 0.41–0.63) in the Stulberg III group; the Hodges–Lehmann difference was −0.03 Nm/kg (p = 0.638; Holm-adjusted p = 1.000). In the Tönnis 0 group, torque change was 0.47 Nm/kg (IQR, 0.38–0.50), and in the Tönnis 1 group 0.62 Nm/kg (IQR, 0.62–0.65). The between-group Hodges–Lehmann difference, Tönnis 0 minus Tönnis 1, was −0.16 Nm/kg. The uncorrected p value was 0.044, but the difference was not significant after Holm correction (p = 0.438) (Table 3).

Measurement reliability

Measurement reliability of abduction torque and the radiological parameters was assessed with intraobserver and interobserver ICCs. For operated-side abduction torque, the intraobserver ICC was 0.96 (95% CI, 0.89–0.99) and the interobserver ICC 0.91 (95% CI, 0.81–0.96). Corresponding values for the sound side were 0.97 (95% CI, 0.92–0.99) and 0.94 (95% CI, 0.86–0.98).

For the radiological measurements, intraobserver ICCs ranged from 0.84 to 0.95 and interobserver ICCs from 0.80 to 0.91. Agreement was highest for ATD (intraobserver ICC = 0.95; 95% CI, 0.88–0.98; interobserver ICC = 0.91; 95% CI, 0.82–0.96) and lowest for the extrusion index (ICC = 0.84; 95% CI, 0.73–0.92 and ICC = 0.80; 95% CI, 0.68–0.89, respectively) (Table 4).

DISCUSSION

We evaluated the clinical, biomechanical, and radiological outcomes of the Morscher osteotomy in adolescents and young adults with a shortened abductor lever arm and limping due to sequelae of childhood hip disease. Alongside functional scores, dynamometric torque measurement and the LSI were used to capture the change in abductor muscle function objectively. At the final visit, pain had decreased, hip range of motion had increased, and leg length discrepancy had narrowed markedly. Operated-side abduction torque rose while the sound side showed no significant change. A positive Trendelenburg sign and limping, present in every patient preoperatively, were seen in none at the final visit. Radiologically, the neck-shaft angle, ATD, and femoral offset improved significantly, whereas the alpha angle, LCEA, and extrusion index showed no significant change after Holm correction. No infection, nonunion, implant failure, or need for revision occurred during follow-up.

Operated-side abduction torque in our series rose from 0.88 to 1.38 Nm/kg, the increase occurred in all 23 patients, and the sound side showed no statistically significant change. The value of this finding lies in showing that the gain in abductor function after Morscher osteotomy can be measured objectively. Abductor function has mostly not been measured at this level of detail in the literature. Albers and colleagues graded strength with the Medical Research Council scale; the proportion of hips with M5 strength rose from 17% to 91%, and limping fell from 76% to 9% [9]. In the review by Ghaffari and colleagues, the success rate in converting a preoperatively positive Trendelenburg sign to negative in 101 hips averaged 65% (29–100%), and an increase in abductor strength was reported in roughly two thirds of patients [10]. The same review reported a lowest success rate of 30%, offered the higher mean age in that study (34 versus 20 years) as a possible explanation, and proposed that strength may be regained more readily in younger patients [10]. The median age of 16 years in our patients may have contributed to the high rate of clinical recovery observed in our series. In 15 patients treated with isolated distal transfer of the greater trochanter, only three achieved freedom from pain with strenuous activity and late conversion of the Trendelenburg sign to negative, while the abductor lever arm ratio and the abductor moment in single-leg stance did not change [11]. The contrast suggests that true neck lengthening may produce a mechanical result different from isolated trochanteric transfer. A study in healthy young adults, by contrast, found no significant relation between normalized abductor torque and frontal-plane pelvic motion during the Trendelenburg test, and agreement between the clinician's visual assessment and three-dimensional motion analysis remained poor ($\kappa = 0.22–0.25$). The authors state that this caution applies to individuals without intra-articular hip pathology [12]. For this reason we did not treat the clinical disappearance of the Trendelenburg sign and limping in all patients as a sufficient indicator of strength on its own. The LSI of 87.2 ± 4.6% at the final visit indicates that, despite clear clinical recovery, full side-to-side symmetry of abductor strength was not reached.

Gains in hip range of motion in our series were not distributed evenly across the planes of movement. The largest increase occurred in abduction (+ 15.5°), while flexion gained + 9.0° and internal and external rotation + 5.5° and + 6.0°, respectively. Our abduction results agree closely with the change from 26.5° to 42.4° reported in a series applying the same osteotomy to Stulberg II–III deformity through a surgical hip

dislocation approach with osteochondroplasty [13]. The separation appeared in rotation: internal rotation in that series rose from 19.4° to 32.4°, and in another study combining osteochondroplasty with relative neck lengthening, internal rotation in flexion reached 42.6° from 7.75° and flexion 116.9° from 50.7° [14]. Both series involved direct intervention at the head-neck junction; our procedure remained extra-articular. Leaving the cam morphology untouched fits the lack of a significant change in the alpha angle after Holm correction and may have contributed to the more limited gains in flexion and internal rotation; anterolateral impingement is indeed described as a distinct late sequela, and trimming of the head or head-neck junction is presented as a possible treatment option [6].

Functional outcomes improved markedly. HHS rose from 58.0 to 89.0; the two series we compared reported postoperative means of 89.5 and 89.4 [13,14]. Similar postoperative HHS values across series despite different baseline values suggest that the absolute gain observed may depend on preoperative functional level. The 5-point drop in VAS cannot be compared directly, because pain was not measured with VAS in those series; Elmarghany et al. reported a postoperative mean Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score of 4.6 [14]. The reduction in leg length discrepancy from 2.46 to 0.63 cm is almost identical to the result of Baraka et al. (2.52 to 0.63 cm); true neck lengthening compensates for the leg length discrepancy while correcting the abductor lever arm [6,13]. These gains, however, come from a retrospective design without a control group and a mean follow-up of 22.5 months. Follow-up in the series we compared averaged 4.5 years in one and had a median of 27.7 months in the other, whereas the relevant systematic review used a lower limit of 5 years and a mean follow-up of 9.6 years [3,13,14]. Our series also consists only of Stulberg II–III and Tönnis 0–1 patients; Stulberg II–III hips have been reported to improve more than IV–V hips, although the difference did not reach statistical significance ($p = 0.1104$) [14]. Direct generalization of our results to patients with more advanced deformity or degeneration is therefore not appropriate.

Proximal femoral geometry in our series changed in the direction targeted by surgery. ATD rose from −18.7 to 12.1 mm, the neck-shaft angle increased by 16.3°, and femoral offset by 6.9 mm, and all three retained statistical significance after Holm correction. A similar repositioning has been reported in relative femoral neck lengthening series. Verhaegen et al. measured a preoperative centro-trochanteric distance of − 18.7 ± 6.7 mm and brought it to 1.9 ± 9.0 mm after the procedure; in the same series, ATD rose from 1.5 ± 9.7 mm to 22.8 ± 10.4 mm and became indistinguishable from the sound hip (22.4 ± 4.8 mm; $p = 0.8$) [15]. Because that procedure was applied as a first stage before arthroplasty in patients with a mean age of 38.1 ± 11.4 years and advanced arthrosis at Tönnis grade 2, the series is not directly comparable in population terms with our Tönnis 0–1 cohort of adolescents and young adults. Nor does the numerical closeness sit at the parameter level: our value of − 18.7 mm refers to ATD, their identical figure to the centro-trochanteric distance, and the preoperative ATD in that series is + 1.5 mm. Osterholt et al. reported an ATD of 18.0 ± 5.7 mm in the skeletally mature sound hips of unilateral LCPD patients; our postoperative mean sits at the lower edge of that range [16]. In the same study, only 31.8% of cases treated with trochanteric epiphysiodesis were rated optimal by this criterion, so full anatomical normalization is not the rule even with less invasive, growth-guiding procedures. Because the measurement conventions do not overlap exactly, the comparison should be read as approximate.

The alpha angle, LCEA, and extrusion index, in contrast, showed no statistically significant change after Holm correction for multiple comparisons. The finding fits a procedure whose main effect is confined to proximal femoral geometry; an extra-articular femoral osteotomy would not be expected to produce a distinct change in acetabular coverage. Gharanizadeh et al. obtained a 29.3° improvement in LCEA and a 32.8% improvement in the extrusion index only by adding a periacetabular osteotomy to femoral head reduction osteotomy, and that gain was achieved in dysplastic hips with a preoperative LCEA of 2.8 ± 12.7°, whereas at our baseline of 28.9° there was no coverage deficit to correct [17]. The uncorrected statistical significance in the extrusion index ($p = 0.039$) disappeared after Holm correction ($p = 0.116$), and patient-level change remained heterogeneous: a decrease in 12 patients, an increase in 4, and no change in 7. No clinical meaning should therefore be attached to the − 1.0 percentage point Hodges–Lehmann change. The absence of a significant change in the alpha angle likewise agrees with our expectation that the surgery does not act directly on femoral head-neck morphology.

No infection, nonunion, implant failure, or need for revision occurred in our series. The observation should not be read as an absence of complication risk for the procedure. Verhaegen et al. reported trochanteric nonunion in 7.1% and one deep infection, and Gourineni et al. found two osteotomy nonunions and four cases of femoral head ischemia in their 79-hip series, giving a major complication rate of 7.59% [15,18]. Ischemia in the latter series was attributed to combining relative neck lengthening, in which the hip is dislocated surgically and the posterior retinacular flap is raised completely, with a proximal femoral osteotomy; the same authors state that the true neck lengthening described by Morscher is performed without dislocating the hip and without raising the flap [18]. This technical difference may partly explain the complication-free course in our series. A sample of 23 patients and a follow-up of 12–43 months, however, are not sufficient to assess rare complications reliably; our finding should therefore be read only as an absence of observed complications during follow-up in the current series.

Analyses of the determinants of torque gain were exploratory, and no variable remained statistically significant after Holm correction of the 11 comparisons. Correlations of torque gain with change in femoral offset ($\rho = +0.316$; Holm-adjusted $p = 1.000$) and change in ATD ($\rho = +0.363$; Holm-adjusted $p = 0.801$) were weak, though their direction matched the biomechanical expectation. Such weakness may itself be an expected result. A reduction in offset markedly lowers the abductor and external rotator moment arms ($R > 0.5$), and the optimal range that increases the abductor moment arm without costing other muscle groups more than 5% is reported as only 2.3–2.9 mm [19]. Expecting a strong, linear correlation within so narrow a range may not be appropriate. A missing relation between proximal femoral geometry and abductor strength also appears in the literature: in children with increased femoral anteversion, normalized abductor strength did not differ from controls ($p = 0.14$), and no correlation was found between peak stance-phase hip adduction and strength ($r = − 0.198$; $p = 0.44$) [20]. The change in neck-shaft angle showed a negative correlation with torque gain in the uncorrected analysis ($\rho = −0.453$; $p = 0.030$) but lost significance after Holm correction ($p = 0.329$). We therefore regarded this relation as hypothesis-generating in biomechanical terms and did not interpret it as an independent determinant. In the subgroup analyses, similarly, the difference between the Tönnis 0 and Tönnis 1 groups had an

uncorrected p of 0.044 that rose to 0.438 after Holm correction, so no independent group effect should be drawn from this finding either.

The highest ICC values were obtained for the dynamometric abduction torque measurements. Intraobserver and interobserver ICCs were 0.96 and 0.91 on the operated side and 0.97 and 0.94 on the sound side. Among the radiological parameters, one of the lowest values occurred for the alpha angle, with an intraobserver ICC of 0.86 and an interobserver ICC of 0.80. For the extrusion index, the corresponding values were 0.84 and 0.80. The alpha angle is known to be a difficult measurement: interobserver ICCs obtained with different circle types have remained between 0.494 and 0.645 [21]. The ICCs of 0.80–0.86 for the alpha angle in our series exceed those values but fall below most of the other measurements in our study. When the 95% CI rather than the point estimate is taken as the basis, our torque measurements fall into the good to excellent range; against the criterion of at least 30 subjects and three raters recommended by the same guideline, however, we worked with 23 patients and two observers [22]. Force measured with a dynamometer has also been reported to vary with body size, sex, and age, different normalization formulas are in use, and no consensus exists on which is superior, so caution is needed when comparing the absolute Nm/kg values in our study with different populations and measurement protocols [20].

The retrospective design and the absence of a comparison group make it difficult to attribute all of the observed changes causally to the surgical procedure. The limited number of patients is a particular constraint in the subgroup analyses. According to the sensitivity analysis, only effects of roughly Cohen d = 1.2–1.5 could be detected with 80% power in subgroup comparisons with the current sample; the lack of statistically significant differences between the Stulberg and Tönnis groups should therefore not be read as equivalence. Follow-up is also relatively short. The long-term success of a joint-preserving procedure has to be judged by arthrosis progression, hip survival, and the need for arthroplasty. The absence of complications in this series likewise does not mean that rare events can be excluded with the current sample and follow-up. Restriction of the series to Stulberg II–III and Tönnis 0–1 patients limits the generalizability of the findings to hips with more advanced deformity and degeneration. The wide age range of 13–24 years is a further source of heterogeneity; the muscular adaptation and functional recovery potential of an adolescent who has just reached skeletal maturity and of a young adult may not be the same.

A strength of the study is that abductor function was not assessed only as clinically present or absent but was quantified with body weight-normalized torque and the LSI. Treating the sound side as an internal control allowed the change on the operated side to be interpreted in a side-to-side context. Performance of the torque and radiological measurements by two independent observers, with separate assessment of intraobserver repeatability, provided additional information on measurement reliability. Reporting effect sizes together with 95% CIs for the primary and secondary continuous outcomes also allows the results to be judged by the magnitude of effect and the precision of estimation rather than by statistical significance alone. Confirmation of these findings will require prospective studies with longer follow-up, suitable comparison groups, and objective gait analysis. Defining the relation between the

optimal amount of trochanteric distalization and abductor strength gain, in particular, could make surgical planning more objective.

Conclusion

In adolescents and young adults with a shortened abductor lever arm and limping due to sequelae of childhood hip disease, the Morscher osteotomy was associated with marked short-term improvement in clinical and biomechanical outcomes. Pain decreased, hip range of motion increased, and leg length discrepancy narrowed. The rise in abduction torque on the operated side, with no significant change on the sound side, supports the view that the observed torque gain arose on the operated side. Although full limb symmetry was not reached, no patient had a positive Trendelenburg sign or limping at the final visit. The neck-shaft angle, ATD, and femoral offset improved significantly, whereas the alpha angle, LCEA, and extrusion index showed no significant change after Holm correction. No complication occurred in this series, but the sample size and follow-up duration do not allow the risk of rare complications to be excluded. The findings support the possibility that the Morscher osteotomy can improve abductor function and hip function in properly selected adolescents and young adults.

Abbreviations

ATD: articulotrochanteric distance

CI: confidence interval

HHS: Harris Hip Score

HL: Hodges–Lehmann

ICC: intraclass correlation coefficient

IQR: interquartile range

LCEA: lateral center-edge angle

LCPD: Legg-Calvé-Perthes disease

LSI: limb symmetry index

ROM: range of motion

SD: standard deviation

VAS: visual analog scale

WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index

Declarations

Ethics approval and consent to participate:

This study was approved by the Harran University Non-Interventional Clinical Research Ethics Committee (Protocol No: HÜ-GOEK-2026-00305; approval date: August 5, 2026). Given the retrospective design of the study, the requirement for informed consent was waived by the ethics committee. All procedures performed in this retrospective study were conducted in accordance with relevant guidelines and regulations and the principles of the Declaration of Helsinki.

Consent for publication:

Written informed consent for publication of the anonymized clinical and radiographic images was obtained from the patient(s) or, where applicable, from their parent(s) or legal guardian(s).

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Author Contribution

M.M.A. contributed to the conceptualization, investigation, data collection, and preparation of the original draft. V.K. contributed to the study design, methodology, data interpretation, supervision, and writing and critical revision of the manuscript. A.L. contributed to the surgical procedures, clinical evaluation, data interpretation, and critical revision of the manuscript. E.M.K. contributed to radiological evaluation, data validation, visualization, and critical revision of the manuscript. All authors reviewed and approved the final version of the manuscript.

Data Availability

The datasets generated and/or analysed during the current study are not publicly available due to patient confidentiality but are available from the corresponding author on reasonable request, subject to applicable ethical and institutional requirements.

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Tables

Table 1. Demographic characteristics, anthropometric measurements, and preoperative radiological classifications (n = 23)

Parameter	Value
Age (years), median (IQR)	16 (15–18)
Age range (min–max)	13–24
Sex, n (%)	Female 11 (47.8); Male 12 (52.2)
Affected side, n (%)	Right 11 (47.8); Left 12 (52.2)
Height (cm), mean ± SD (range)	165.9 ± 8.5 (148–183)
Body weight (kg), mean ± SD (range)	59.7 ± 10.3 (42–82)
Follow-up (months), mean ± SD (range)	22.5 ± 7.6 (12–43)
Stulberg class, n (%)	II: 5 (21.7); III: 18 (78.3)
Tönnis grade, n (%)	0: 17 (73.9); 1: 6 (26.1)

IQR: interquartile range; SD: standard deviation. Age was not normally distributed on the Shapiro–Wilk test ($p = 0.029$); height, weight, and follow-up duration were normally distributed ($p > 0.05$).

Table 2. Preoperative versus final follow-up comparison (clinical, biomechanical, and radiological)

Parameter	Preoperative	Final follow-up	Change (95% CI)	Effect size	p	Adjusted p*
Clinical						
HHS, mean ± SD	58.0 ± 7.9	89.0 ± 4.5	+30.9 (+28.4 to +33.5)	dz = 5.25	<0.001	<0.001
VAS, median (IQR)	7.0 (5.0–8.0)	2.0 (1.0–2.0)	−5.0 (−5.5 to −4.5)	r = −1.00	<0.001	<0.001
Flexion (°), median (IQR)	109 (100.5–113)	119 (112–122.5)	+9.0 (+7.5 to +12.5)	r = +1.00	<0.001	<0.001
Abduction (°), mean ± SD	25.1 ± 3.7	40.6 ± 3.9	+15.5 (+14.2 to +16.7)	dz = 5.39	<0.001	<0.001
Internal rotation (°), median (IQR)	12 (8–14)	17 (14.5–20)	+5.5 (+5.0 to +6.5)	r = +1.00	<0.001	<0.001
External rotation (°), median (IQR)	33 (27.5–37.5)	39 (35–44)	+6.0 (+5.0 to +8.0)	r = +1.00	<0.001	<0.001
Leg length discrepancy (cm), mean ± SD	2.46 ± 0.53	0.63 ± 0.33	−1.82 (−1.98 to −1.67)	dz = −5.13	<0.001	<0.001
Positive Trendelenburg, n (%)	23 (100)	0 (0)	23/23 (100) resolved	–	<0.001	<0.001
Limping, n (%)	23 (100)	0 (0)	23/23 (100) resolved	–	<0.001	<0.001
Biomechanical						
Abduction torque, operated side (Nm/kg), mean ± SD	0.88 ± 0.14	1.38 ± 0.18	+0.51 (+0.45 to +0.57)	dz = 3.57	<0.001	<0.001
Abduction torque, sound side (Nm/kg)†, median (IQR)	1.60 (1.48–1.72)	1.60 (1.48–1.72)	0.00 (0.00–0.00)	–	0.500	–
LSI (%), mean ± SD	55.2 ± 7.6	87.2 ± 4.6	+32.0 (+28.9 to +35.0)	dz = 4.54	<0.001	<0.001
Radiological						

Alpha angle (°), median (IQR)	53 (48–63)	52 (49–64.5)	−0.5 (−1.5 to +0.5)	r = −0.28	0.294	0.294
Neck-shaft angle (°), mean ± SD	110.6 ± 9.5	126.8 ± 5.7	+16.3 (+14.1 to +18.4)	dz = 3.22	<0.001	<0.001
ATD (mm), mean ± SD	−18.7 ± 5.0	12.1 ± 4.0	+30.7 (+29.0 to +32.5)	dz = 7.53	<0.001	<0.001
LCEA (°), mean ± SD	28.9 ± 5.2	29.4 ± 5.2	+0.5 (−0.1 to +1.1)	dz = 0.36	0.097	0.193
Extrusion index (%), median (IQR)	17 (14.5–24)	18 (14–23)	−1.0 (−1.0 to 0.0)	r = −0.59	0.039	0.116
Femoral offset (mm), mean ± SD	26.6 ± 5.2	33.5 ± 5.2	+6.9 (+5.9 to +7.9)	dz = 3.04	<0.001	<0.001
Complications, n/N (%)	–	0/23 (0)	–	–	–	–

ATD: articulotrochanteric distance; CI: confidence interval; HHS: Harris Hip Score; IQR: interquartile range; LCEA: lateral center-edge angle; LSI: limb symmetry index; SD: standard deviation; VAS: visual analog scale. *Holm correction across 17 comparisons. †Sound side served as internal control and was not included in the correction family. Paired t test for normally distributed data; Wilcoxon signed-rank test for non-normal data (shown as IQR); McNemar test for categorical variables. Extrusion index decreased in 12 patients, increased in 4, and was unchanged in 7.

Table 3. Determinants of the change in abduction torque (n = 23)

Continuous determinant	Spearman ρ (95% CI)	p	Adjusted p*
Change in femoral offset (mm)	+0.316 (−0.111 to +0.644)	0.142	1.000
Change in ATD (mm)	+0.363 (−0.058 to +0.674)	0.089	0.801
Change in neck-shaft angle (°)	−0.453 (−0.729 to −0.050)	0.030	0.329
Change in abduction ROM (°)	+0.142 (−0.287 to +0.523)	0.519	1.000
Change in HHS	−0.114 (−0.503 to +0.313)	0.604	1.000
Age (years)	−0.021 (−0.430 to +0.394)	0.923	1.000
Follow-up (months)	+0.002 (−0.411 to +0.414)	0.994	1.000

Subgroup	Torque change (Nm/kg), median (IQR)	n	HL difference (first − second)	p	Adjusted p*
Female / Male	0.60 (0.41–0.65) / 0.47 (0.40–0.53)	11 / 12	+0.05	0.347	1.000
Right / Left side	0.49 (0.44–0.61) / 0.46 (0.40–0.63)	11 / 12	+0.01	0.880	1.000
Stulberg II / III	0.47 (0.38–0.60) / 0.49 (0.41–0.63)	5 / 18	−0.03	0.638	1.000
Tönnis 0 / 1	0.47 (0.38–0.50) / 0.62 (0.62–0.65)	17 / 6	−0.16	0.044	0.438

*Holm correction across 11 exploratory comparisons (none remained significant). ATD: articulotrochanteric distance; CI: confidence interval; HHS: Harris Hip Score; HL: Hodges–Lehmann (exact Mann–Whitney U test); IQR: interquartile range; ROM: range of motion. Continuous variables analyzed with Spearman correlation.

Table 4. Measurement reliability (ICC) (n = 23)

Measurement	Intraobserver ICC (95% CI)	Interobserver ICC (95% CI)
Abduction torque, operated side (Nm/kg)	0.96 (0.89–0.99)	0.91 (0.81–0.96)
Abduction torque, sound side (Nm/kg)	0.97 (0.92–0.99)	0.94 (0.86–0.98)
Alpha angle (°)	0.86 (0.75–0.93)	0.80 (0.68–0.89)
Neck-shaft angle (°)	0.93 (0.85–0.97)	0.89 (0.79–0.95)
ATD (mm)	0.95 (0.88–0.98)	0.91 (0.82–0.96)
LCEA (°)	0.92 (0.84–0.96)	0.87 (0.77–0.93)
Extrusion index (%)	0.84 (0.73–0.92)	0.80 (0.68–0.89)
Femoral offset (mm)	0.94 (0.87–0.98)	0.91 (0.83–0.96)

Intraobserver agreement: ICC(3,1) (two-way mixed, absolute agreement, single measurement). Interobserver agreement: ICC(2,1) (two-way random, absolute agreement, single measurement). ATD: articulotrochanteric distance; CI: confidence interval; ICC: intraclass correlation coefficient; LCEA: lateral center-edge angle.

Figures

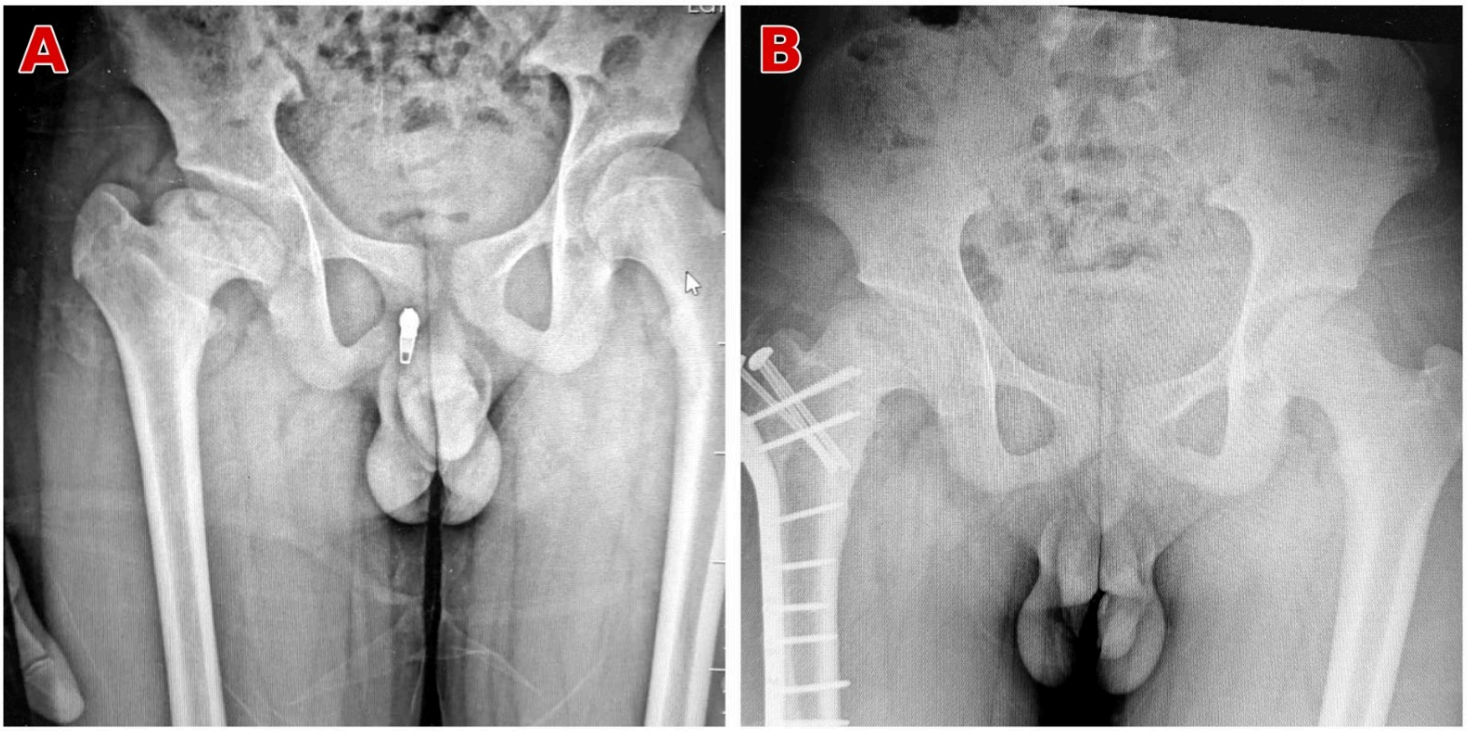


Figure 1

Preoperative (A) and 18-month postoperative (B) anteroposterior pelvic radiographs of a representative patient. (A) The right hip shows a short femoral neck, an elevated greater trochanter, and a negative articulotrochanteric distance. (B) The osteotomy line has united, the greater trochanter has been transferred distally and fixed with screws, and proximal femoral geometry has improved; femoral head morphology is unchanged.

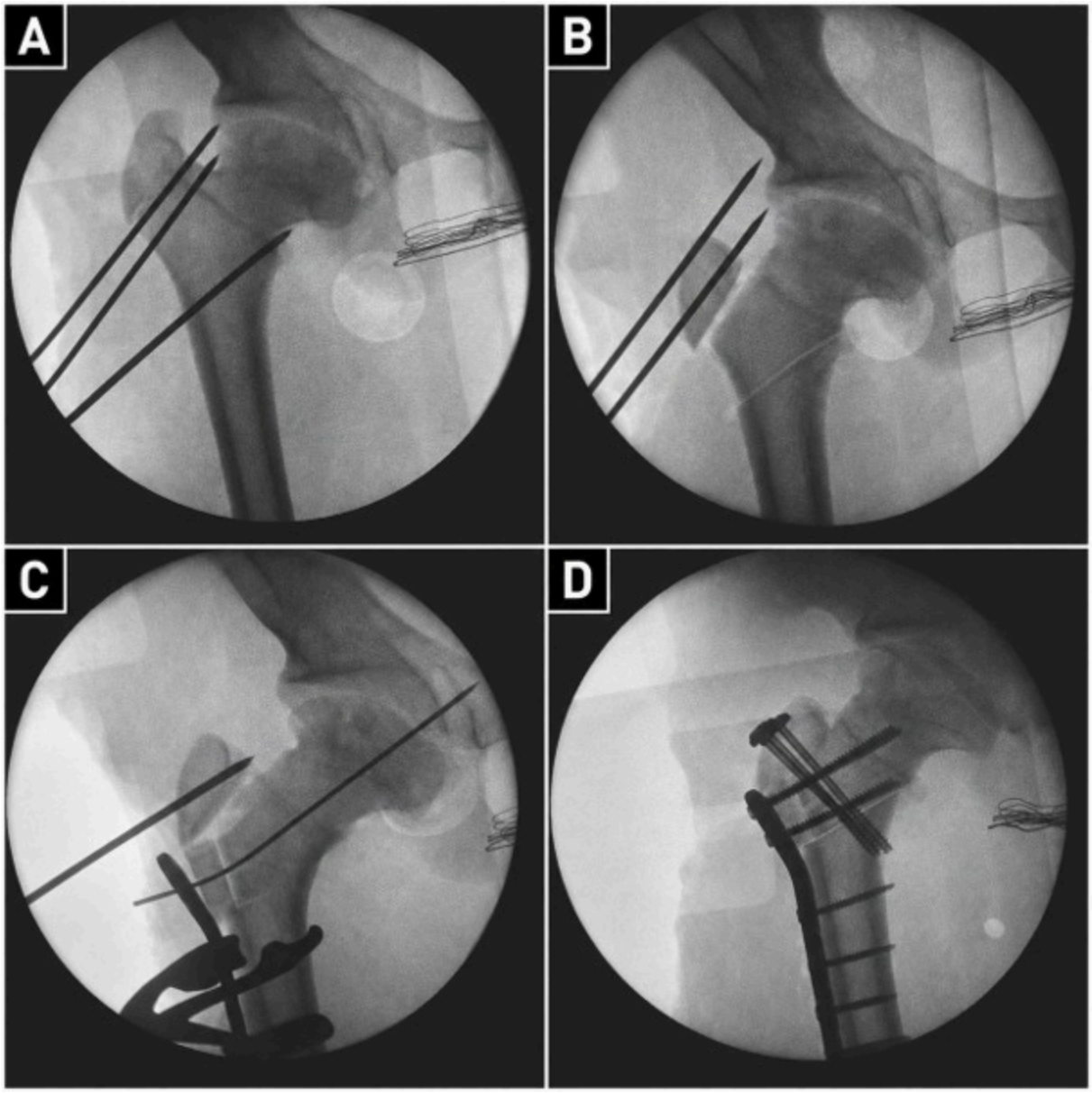


Figure 2

Sequential intraoperative fluoroscopy steps of the Morscher osteotomy. (A) Marking of the osteotomy levels with Kirschner wires. (B) Completion of the osteotomies and removal of the intervening lateral cortical segment. (C) Reuse of the removed segment as autogenous bone graft. (D) Fixation of the osteotomy with a plate and screws and of the distalized greater trochanter with screws.