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PEDIATRIC ORTHOPEDICS

OSTEOTOMY AT THE BASE OF FEMORAL NECK AND OSTEOPLASTY FOR THE TREAMENT OF SCFE

OSTEOTOMIA NA BASE DO COLO FEMORAL E OSTEOPLASTIA PARA O TRATAMENTO DA EPIFISIOLISTESE

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ABSTRACT

Objective: To compare the clinical outcomes between patients with moderate and severe slipped capital femoral epiphysis (SCFE) treated with osteotomy at the base of neck and osteoplasty and with healthy individuals. Methods: Comparative cohort with 12 patients (14 hips) with moderate and severe SCFE who underwent osteotomy at the base of neck and osteoplasty between 2007 and 2014. The mean age at surgery was 13.3 ± 2.5 years and the mean follow-up was 3.8 ± 2.2 years. We assessed the level of hip pain by the visual analog scale (VAS) and anterior impingement test (AIT); the level of function using the Harris Hip Score (HHS) and 12-Item Short Form Health Survey (SF-12), the range of motion (ROM) by goniometry and Drehmann sign, and the hip muscular strength by isokinetic and Trendelenburg sign. Results: The level of pain was slightly higher in the SCFE cohort compared with healthy hips (VAS, 0.8 ± 1.4 vs 0 ± 0, 0.007; AIT, 14% vs 0%, p = 0.06; respectively). No differences were observed between the SCFE and control cohort for the functional scores (HHS, 94 ± 7 vs 100 ± 1, p = 0.135); except for ROM, with increased internal rotation (37.3º ± 9.4º vs 28.7º ± 8.2º, p < 0.001), and strength, with decreased abduction torque (75.5 ± 36.9 Nm/Kg vs 88.5 ± 27.6 Nm/Kg, p = 0.045) in the SCFE cohort. Conclusion: The osteotomy at the base of neck and the osteoplasty restored the hip motion and muscle strength, except for the abductor strength, to near normal levels, representing a viable option for the treatment of moderate and severe SCFE. ***Level of Evidence III, Ambidirectional Cohort Study.***

Keywords: Slipped Capital Femoral Epiphyses. Femoroacetabular Impingement. Osteotomy. Hip Joint. Muscle Strength Dynamometer. Joint Deformities, Acquired.

RESUMO

Objetivo: Comparar resultados clínicos de pacientes com escorregamento epifisário proximal do fêmur (EEPF) moderado e grave tratados com osteotomia basocervical e cervicoplastia com indivíduos saudáveis. Métodos: Coorte comparativa com 12 voluntários saudáveis e 12 pacientes (14 quadris) com EEPF moderado e grave submetidos à osteotomia basocervical e cervicoplastia entre 2007 e 2014. A média de idade na cirurgia foi de 13,3 ± 2,5 anos e o seguimento médio de 3,8 ± 2,2 anos. Avaliou-se nível de dor no quadril utilizando a escala visual analógica (EVA) e o teste de impacto anterior (TIA); nível de função usando o Harris Hip Score (HHS) e o 12-Item Short Form Health Survey (SF-12); amplitude de movimento (ADM) com goniometria e sinal de Drehmann; e força muscular do quadril com dinamômetro isocinético e sinal de Trendelenburg. Resultados: O nível de dor foi ligeiramente maior na coorte de EEPF comparado a quadris saudáveis (EVA, 0,8 ± 1,4 vs 0 ± 0, 0,007; TIA, 14% vs 0%, p = 0,06; respectivamente). Não foram observadas diferenças entre os grupos EEPF e controle para os escores funcionais (HHS, 94 ± 7 vs 100 ± 1, p = 0,135), exceto para ADM, com aumento da rotação interna (37,3º ± 9,4º vs 28,7º ± 8,2º, p < 0,001), e força, com diminuição do torque de abdução (75,5 ± 36,9 Nm/Kg vs 88,5 ± 27,6 Nm/Kg, p = 0,045), para o grupo EEPF. Conclusão: A osteotomia basocervical e a cervicoplastia restauraram o movimento do quadril e a força muscular, com exceção da força abdutora, a níveis próximos do normal, representando uma opção viável para o tratamento de EEPF moderado e grave. ***Nível de Evidência III, Estudo de Coorte Ambidirecional.***

Descritores: *Escorregamento das Epífises Proximais do Fêmur. Impacto Femoroacetabular. Osteotomia. Articulação do Quadril. Dinamômetro de Força Muscular. Deformidades Articulares Adquiridas.*

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INTRODUCTION

Slipped capital femoral epiphysis (SCFE) is a common hip disorder that affects adolescents, and whose long-term outcomes are associated with pain,[1,2] limited motion[3-5] and weakness.[6-8] In moderate and severe SCFE, residual deformities may predispose femoroacetabular impingement, cartilage damage and

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The study was conducted at Hospital das Clínicas of Ribeirão Preto Medical School, Universidade de São Paulo.
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osteoarthritis.[9,10] The deformity correction may involve compensating osteotomies at the trochanteric region,[11,12] at the base of femoral neck,[13] with or without osteoplasty,[8,14-16] and the capital realignment performed at the growth plate level.[17]
The capital realignment represented by the modified Dunn procedure is able to restore the proximal femur anatomy; however, the rate of avascular necrosis (AVN) is controversial, varying from 14% to 50% in unstable SCFE.[10,18-21] A low rate of AVN has been reported following compensating femur osteotomies for moderate and severe stable SCFE.[8,13,16,19,22] Recently, the association of osteotomy at the base of the femoral neck and osteoplasty has been shown to partially restore the function of abduction in SCFE.[8] However, limited evidence estimates the level of functional restoration following the compensating osteotomy at the base of the femoral neck with osteoplasty.[8] Our study evaluated clinical outcomes of osteotomy at the base of femoral neck and osteoplasty for the treatment of moderate and severe SCFE by assessing the level of hip pain, clinical scores, range of motion and muscle strength after a minimum follow-up of two years. Later, we compared the results with those from healthy individuals.

METHODS

This is a prospective study approved by the Institutional Review Board (HCRP 942.952 and 2.357.360). All subjects and their parents signed the informed consent form for this research. Between 2007 and 2014, 45 patients were diagnosed with moderate and severe SCFE. Four patients were lost to follow-up, 13 patients underwent the modified Dunn procedure, and 16 were not included because they had not undergone dynamometry. We enrolled 12 patients (14 hips) who underwent osteotomy at the base of the femoral neck associated with neck osteoplasty with a mean ± standard deviation (SD) age at surgery of 13.2 years (range, 7.4 to 17.6 years), and a mean ± SD follow-up of 3.8 ± 2.1 years (range, 2.0 to 9.9 years). The osteotomy at the base of femoral neck and osteoplasty was performed according to a previously described surgical technique (Figure 1).[8] No patients evolved to AVN. Twelve healthy volunteers without a clinical history of hip disease were invited to compose the control cohort (Table 1).
For unilateral SCFE, a restricted non-weight bearing protocol with crutches was recommended during the first six weeks, followed by protected partial weight bearing for another four weeks. On the first postoperative day, patients underwent passive mobilization and isometric strengthening exercises. Active hip motion started at three to four weeks after surgery. Following the osteotomy healing, patients were encouraged to walk and perform the muscle strengthening exercises.[8]
We assessed the demographic data composed of age, sex, and SCFE characteristics, including acuity, severity and stability, length of postoperative follow-up, and body mass index (BMI) (Table 1). One pediatric orthopedic surgeon (with 12 years of experience) assessed the pre- and postoperative Southwick angles.[11]

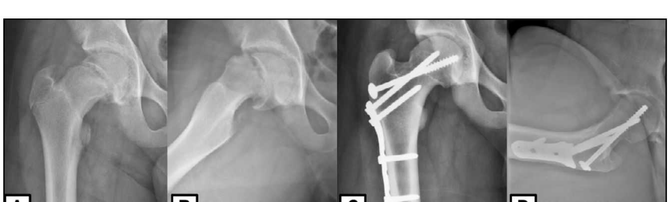

Figure 1. Anteroposterior and lateral radiographic images of a patient before (A and B) and two years after (C and D) osteotomy at the base of neck and osteoplasty.

Table 1. Demographic and radiographic data from a cohort of patients with slipped capital femoral epiphysis and from a healthy cohort. Values refer to mean ± standard deviation (range), median and interquartile range (P25th-P75th) or frequency and percentages of hips.

	Osteotomy at the base of femoral neck and osteoplasty (14 hips)	Control (24 hips)	Adjusted p value
Age at surgery (years)	13 ± 3 (7-18)		
Age at evaluation (years)	17 ± 2 (13-21)	17 ± 2 (13-20)	p = 1.00
Sex (boys:girls)	10:4 (71%:29%)	12:12 (50%:50%)	p = 0.21
Body mass index, (kg/m^2)	28 ± 6 (20-38)	22 ± 5 (16-34)	
Percentile by age of body mass index			p < 0.001
Normal weight (≤ 85th)	6 (43%)	22 (92%)	
Overweight (85th to 95th)	3 (21%)	0	
Obese (≥ 95th)	5 (36%)	2 (8%)	
Follow-up (years)	3.8 ± 2.1 (2.0-9.9)		
Acuity			
Acute (< 3 weeks)	0		
Chronic (> 3 weeks)	10 (71%)		
Acute on chronic (> 3 weeks with acute pain exacerbation)	4 (29%)		
Severity			
Mild (Southwick angle ≤ 30º)	0		
Moderate (Southwick angle > 30º and < 60º)	6 (43%)		
Severe (Southwick angle ≥ 60º)	8 (57%)		
Stability			
Stable (able to walk)	10 (71%)		
Unstable (not able to walk, even with crutches)	4 (29%)		
Preoperative Southwick angle (º)	63 ± 19 (34-100)		
Postoperative Southwick angle (º)	18 ± 12 (2-41)		

The mean ± SD age of the SCFE cohort at the final evaluation was 17.0 years ± 2.2 (range, 12.8 to 20.7 years). Clinical outcomes were estimated using the visual analog scale of pain, anterior impingement test, Harris Hip Score (HHS)[23] and 12-Item Short Form Health Survey (SF-12).[24] The hip motion was evaluated using goniometry[25] and the Drehmann sign. The patient was positioned supine to measure the range of flexion, adduction and abduction; in lateral decubitus for extension, and in the sitting position with 90° of hip flexion for rotations. The hip muscle strength was determined using the isokinetic dynamometry of hip[8,26] and Trendelenburg test. One of two trained observers (physical therapists with nine and four years of experience) performed the clinical evaluation at final follow-up. The concentric isokinetic hip strength was assessed using the dynamometer Biodex Multi-joint System 4 Pro (Biodex Medical Systems, Shirley, NY, USA). Flexion and extension strength was measured in supine position;[26] and adduction and abduction strength, in lateral decubitus.[8] The maximum strength was assessed in five consecutive repetitions with an angular speed of 60°/s.[8]

Statistical analysis

For statistical analysis, a linear regression model with mixed effects was performed. Mean values of peak torque were normalized by body mass, since our cohorts had different mean BMI, and body mass has been shown to influence to muscle strength.[27] Variations of baseline demographic parameters were controlled within the statistical model using adjustments for the presence or absence of SCFE bilaterality and sex. Post hoc analysis included the Tuckey correction to adjust for multiple testing. SAS Statistical Software (version 9.3; SAS Institute, Inc. Cary. North Carolina) and R Core Team (2016, Foundation for Statistical Computing, Vienna, Austria) were used, and p-values < 0.05 were considered significant.

RESULTS

At final follow-up, the level of pain following osteotomy at the base of neck and osteoplasty was slightly higher compared with normal hips (0.8 ± 1.4 vs 0 ± 0, p = 0.007). Ten of 14 hips (71%) were free of pain (VAS = 0) following the base of neck osteotomy. With the numbers available, the base of neck osteotomy showed no difference in prevalence of positive anterior impingement test (14% vs 0%, p = 0.06) and HHS (93.5 ± 7.3 vs 99.8 ± 0.6, p = 0.135) compared with healthy hips. Twelve (86%) of 14 hips submitted to osteotomy at the base of neck and osteoplasty had good or excellent HHS outcomes (> 80). Base of neck osteotomy and healthy individual cohorts showed similar SF-12 physical (53 ± 4 vs. 57 ± 2, p = 0.325) and mental scores (57 ± 4 vs. 54 ± 6, p = 0.533) (Table 2).

The range of motion was similar between the base of neck osteotomy and normal hips, except for increased internal rotation in the SCFE cohort (37°±9° in osteotomy at base of neck vs. 29°±8° in normal hips, p < 0.001). The Drehmann sign was absent in all hips treated with base of neck osteotomy and in normal hips from control cohort (Table 2).

Following the compensating osteotomy at the base of neck and osteoplasty, the muscular strength was similar to normal hips for flexion, extension and adduction. However, we observed a reduction in the abduction torque in the SCFE cohort compared with normal hips (76 ± 37 Nm.kg in base of neck osteotomy vs. 89 ± 28 Nm.kg in normal hips; p = 0.045). A low proportion of Trendelenburg sign was observed in the SCFE cohort (7% in base of neck osteotomy vs 0% in controls, p = 0.194) (Table 2).

Table 2. Functional and clinical evaluation of individuals who underwent base of neck osteotomy and osteoplasty and control individuals. Values refer to mean ± standard deviation (range) or frequency and percentages of hips.

	Osteotomy at the base of femoral neck and osteoplasty (14 hips)	Control (24 hips)	95%CI; p-value
Pain and clinical scores			
VAS	0.8 ± 1.4	0.0 ± 0.0	–1.4 to –0.2; 0.01
Anterior impingement test	2 (14%)	0	0.0 to 0.3; 0.06
HHS	93.5 ± 7.3	99.8 ± 0.6	–13.0 to 1.8; 0.14
SF-12 PCS	53.1 ± 4.3	56.6 ± 2.0	–7.2 to 2.5; 0.33
SF-12 MCS	57.0 ± 3.7	54.4 ± 5.6	–4.7 to 9.0; 0.53
Range of motion (°)			
flexion	106.1 ± 7.2	111.1 ± 4.2	–7.5 to 1.7; 0.22
extension	15.1 ± 7.1	14.2 ± 2.3	–2.0 to 5.1; 0.38
adduction	26.4 ± 7.1	23.4 ± 2.7	0.6 to 8.2; 0.03
abduction	32.0 ± 4.6	32.3 ± 5.2	–4.5 to 4.1; 0.94
internal rotation	37.3 ± 9.4	28.7 ± 8.2	5.3 to 17.8; < 0.001
external rotation	36.7 ± 9.3	35.5 ± 5.5	–4.8 to 6.8; 0.73
Drehmann sign	0	0	–0.2 to 0.2; 1.0
Mean of torque peak (Nm/kg)			
abduction	75.5 ± 36.9	88.5 ± 27.6	–36.2 to –0.4; 0.045
adduction	125.2 ± 53.5	130.6 ± 29.6	–13.9 to 36.2; 0.38
flexion	130.5 ± 55.8	140.4 ± 41.8	–44.8 to 6.5; 0.14
extension	162.1 ± 69.8	179.6 ± 55.9	–15.6 to 61.9; 0.24
Trendelenburg test	1 (7%)	0	–0.0 to 0.2; 0.19

DISCUSSION

The treatment of moderate and severe slip deformities is controversial, and the literature evaluating clinical outcomes of compensating osteotomy at the base of the femoral neck and osteoplasty is scarce.[8] In our study, we evaluated the clinical outcomes of the osteotomy at the base of the femoral neck in association with neck osteoplasty for the treatment of moderate and severe SCFE at a minimum follow-up of two years. The level of pain, clinical scores, range of motion and muscle strength were compared with the outcomes obtained from normal hips. We found that the osteotomy at the base of femoral neck and osteoplasty was associated with most of the clinical parameters of this study comparable to the level of healthy individuals, except for abduction strength.

Patients with moderate and severe SCFE may experience significant pain preceding the progression of osteoarthritis, as a consequence of intra-articular disease such as proximal femur deformity, femoroacetabular impingement and labral damage.[16] Treatment for femoroacetabular impingement with osteoplasty, associated or not with surgical hip dislocation and femoral osteotomy has been suggested to decrease pain in SCFE.[8,14,15] In our study, 71% of hips were free of pain at short to midterm. Furthermore, no pain was trigged by the anterior impingement test in 86% of hips following the base of femoral neck osteotomy and osteoplasty. We believe that the compensating realignment provided by the osteotomy, enhanced by the benefits of the osteoplasty in mitigating femoroacetabular impingement conflicts, reduces the intra-articular disease and the level of pain. Theoretically, the anatomical realignment by the modified Dunn procedure would minimize the presence of residual femoroacetabular impingement signs. However, Ziebarth et al.[28] reported negative anterior impingement test in 61% of hips with mild to severe slip following modified Dunn procedure and minimum of

10 years of follow-up. This finding could be explained by a potential femoral neck thickening following the anatomical realignment.[28] In our study, the association of osteoplasty was possibly the main factor for the low prevalence of impingement sign.

We observed no differences in the HHS and SF-12 outcomes between osteotomy at the base of femoral neck and osteoplasty and control individuals. Good and excellent outcomes (HHS > 80) were observed in 86% of hips following base of neck osteotomy. Previously, Kramer, Craig, and Noel[13] reported poor results with definitive limping, limited range of motion and painful gait in 16% (9/55) of patients after the compensating osteotomy. Extracapsular base of neck osteotomy has been associated with 86% of satisfactory results, according to a modified Southwick criteria.[22] It has been suggested that osteoplasty in association with compensating Imhäuser osteotomy improves clinical outcomes,[19,29] showing greater Non-Arthritic Hip Scores in comparison with hips without osteoplasty.[15]

Range of motion was mostly restored to near normal levels following the osteotomy at the base of the neck with osteoplasty, except for increased internal rotation. Possibly, the anterosuperior bone wedge subtraction and improvement in articular clearance by osteoplasty may explain the increase in internal rotation.[30] Although the osteoplasty provides increased range of motion, this procedure may lead to increased risk of neck fracture,[31] which, in association with the risk of slip progression, lead us to insert a cannulated screw from the lateral cortex into the epiphysis. The screw was important to provide immediate *in situ* fixation of the epiphysis with further epiphysiodesis, and potentially protect the neck from fractures at the short-term postoperative period.

The increasing deformity assessed by the slip angle is correlated with decreasing muscle strength of hips with SCFE undergoing *in situ* epiphysiodesis.[6] Theoretically, the deformity correction of moderate and severe SCFE would be able to improve the hip biomechanics. Following the compensating correction with the base of neck osteotomy and osteoplasty, we did not observe weakness in flexion, extension and adduction. However, the abduction strength has not been completely restored. Angelico et al. suggested that the abduction strength was restored to the level of mild slips, but not to normal levels.[8] Femoral neck shortening following the osteotomy could reduce the abductor arm,[7,13] and the direct lateral approach may disturb the abductor muscles.[8] On the contrary, the improvement in the anatomical positioning of the greater trochanter in the transverse plane following the base of neck osteotomy may have positive biomechanical effects.[7] The Trendelenburg test was negative in 93% of our patients, which is in agreement with previous studies reporting negative Trendelenburg test in 80% and 87% of patients after base of neck osteotomy.[13,22] Further investigation is suggested to determine whether the torque is correlated with characteristics of the radiographic anatomy, such as the neck length or trochanteric height.

Our study has several limitations. First, we acknowledge that there are demographic differences related to sex and obesity rate in our cohorts. Second, although less than 15% of patients were lost to follow-up, we could not enroll more patients for dynamometry. As a consequence, the sample size of each cohort is small. Third, there is no comparison with SCFE treated with other surgical techniques, since our patients treated with the modified Dunn procedure presented unstable severe slips, making the comparison unbalanced due to a greater prevalence of avascular necrosis. Fourth, the minimum follow-up of two years is not enough to evaluate hip survival, osteoarthritis, and osteonecrosis. The osteonecrosis rate for stable SCFE has been reported to be as low as 0%,[32-35] and the overall incidence of chondrolysis is estimated at 7%.[36] In our series, we did not observe osteonecrosis nor chondrolysis in hips undergoing osteotomy at the base of neck and osteoplasty. Finally, there is a potential for measurement bias on the hip motion, which is relatively challenging for obese patients.

CONCLUSION

In conclusion, our results showed that the treatment of moderate and severe SCFE with the osteotomy at the base of femoral neck in association with neck osteoplasty restored the hip motion and muscle strength to normal levels, except for abductor strength. Functional scores showed that the osteotomy at the base of femoral neck and osteoplasty may provide good or excellent outcomes in more than 80% of moderate and severe SCFE in the short-term and a potentially low risk of avascular necrosis.

AUTHORS' CONTRIBUTIONS: Each author contributed individually and significantly to the development of this article. LMG, ACCA: study design, performed measurements, manuscript preparation; FSS: performed measurements and manuscript preparation; JBV: study design and manuscript preparation; DACM: study design, statistical analysis, manuscript preparation.

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