



## Changes in the lengths of the gluteus medius and gluteus minimus muscles with trochanteric transfer following pelvic support osteotomy: a biomechanical study

*Yeni bir pelvik destek osteotomisinde gluteus medius ve minimus kaslarında meydana gelen uzunluk değişimlerinin incelenmesi: Biyomekanik çalışma*

Muharrem İNAN, <sup>1</sup> Andrew MAHAR, <sup>2</sup> Troy SWIMMER, <sup>3</sup> Tucker TOMLINSON, <sup>4</sup> Dennis R WENGER <sup>2</sup>

<sup>1</sup>Inönü University Department of Orthopaedics and Traumatology; <sup>2</sup>Children's Hospital, San Diego, CA;

<sup>3</sup>University of California, San Diego, CA; <sup>4</sup>Duke University, Raleigh, NC

**Amaç:** Sentetik kemik modelinde trokanterik osteotomi ve pelvik destek osteotomi (PDO) kombinasyonunu uyguladıktan sonra gluteus medius ve minimus kaslarının uzunluklarında meydana gelen değişimleri inceledik ve sonuçları klasik PDO tekniğiyle karşılaştırdık.

**Çalışma planı:** İki adet sentetik pelvis ve dört femur üzerinde, gluteus medius ve minimus kaslarının uzunlukları dört ayrı durumda ve kalça eklemi nötral ve 45° fleksiyon pozisyonundayken ölçüldü: (i) Normal pozisyon; (ii) kalça eklemi disloke; (iii) trokanter minörün 2.5 cm aşağısından osteotomi uygulanarak femur proksimali 45° abdukte pozisyonda eksternal fiksatorle tespit edildi; (iv) üçüncü durumdaki pozisyon korunurken trokanterik osteotomi uygulanarak kasların yapışma noktası 2 cm laterale ve 1 cm distale alındı.

**Sonuçlar:** Pelvik destek osteotomisi uygulanan grupta, kas uzunluğu disloke pozisyona göre artış gösterdi ( $p<0.0001$ ). Trokanterin lateral ve distale transferinden sonra kas uzunlukları normal kalçaya göre kısaldı ( $p<0.001$ ) ancak PDO uygulananlara göre anlamlı olarak artmıştı ( $p<0.002$ ). Kalça 45° fleksiyonda iken yapılan ölçümler nötral pozisyonadaki ölçümlerle benzerlik gösterdi. Hiçbir işlemde normal kas uzunluğu elde edilemedi.

**Çıkanmlar:** Kemik model üzerinde PDO ile kombine olarak uyguladığımız trokanterin lateral ve distale transferinin abduktör moment kolunu klasik osteotomiye göre daha fazla uzattığı görüldü.

**Anahtar sözcükler:** Biyomekanik; eksternal fiksator; femur/fizyopatoloji/cerrahi; kalça çıkığı, doğuştan/cerrahi; kalça eklemi; kas/anatomi ve histoloji; osteotomi/yöntem.

**Objectives:** Using a synthetic bone model, we investigated changes in the muscle length of the gluteus medius and gluteus minimus following trochanteric osteotomy and pelvic support osteotomy (PSO) and compared the results with those of traditional PSO.

**Methods:** On two pelvises and four femurs, the lengths of the gluteus medius and gluteus minimus were measured in the following circumstances, with the hips in neutral position and in 45 degrees of flexion: (i) alignment of the hip joint with normal congruency; (ii) dislocated hip joint; (iii) following an osteotomy 2.5 cm below the lesser trochanter and stabilization with an angulation of 45 degrees of abduction; (iv) the insertion point was then moved 2 cm distally and 1 cm laterally, simulating a translation osteotomy of the greater trochanter.

**Results:** The muscle lengths increased with PSO compared to those of the dislocated hips ( $p<0.0001$ ). Following distal and lateral translation osteotomy, the lengths significantly exceeded those obtained with traditional osteotomy ( $p<0.002$ ), but were significantly less than those in the neutral position ( $p<0.001$ ). Measurements in 45 degrees of flexion yielded similar results. Normal lengths could not be obtained in any of the procedures.

**Conclusion:** Distal and lateral translation osteotomy following traditional PSO seems to increase the length of the abductor moment arm more than that obtained by traditional PSO alone.

**Key words:** Biomechanics; external fixators; femur/physiopathology/surgery; hip dislocation, congenital/surgery; hip joint; muscles/anatomy & histology; osteotomy/methods.

Stability is necessary in the hip joint for the treatment of clinical symptoms like limping and pain in patients with developmental dysplasia of the hip. Schanz has described the pelvic support osteotomies (PSO) for this objective. In this technique, the mechanical axis is moved laterally by the abduction osteotomy performed in the proximal part of femur and proximal femur is pushed towards the lateral wall of the pelvis.<sup>[1,2]</sup> The objectives are to provide stability, to lengthen the lever arm by moving the attachment of the abductor muscles laterally and distally and to reduce the abductor insufficiency. The key factor in moving the trochanter laterally and distally is the abduction angle calculated for the proximal femur.<sup>[3]</sup> Despite the fact that the maximum abductor force would be acquired when this angle is as close to 90 degrees as possible, in practice it may never be obtained. The reason is that, in case the abduction angle is larger than the lateral pelvic wall angle, motion in the hip joint would be limited.<sup>[1,4]</sup>

In our study, we have performed trochanteric osteotomy and PSO combination on a synthetic model, believing that this method would increase the abductor lever arm without causing limitation in movements, and compared the changes in gluteus medius and minimus muscles with the classical PSO technique.

### Materials and method

Two synthetic pelvises and four synthetic femur structures were used for the study. On the lateral wall of the iliac wing, three points were marked to indicate the origins of the gluteus medius muscle and one point for the gluteus minimus muscle. Attachment areas for both muscles were considered to be the most lateral part of the major trochanter (Figure 1). On the bone models, the following measurements were performed: (i) when the hip joint is in normal position (Figure 2a); (ii) when the hip joint is dislocated (Figure 2b); (iii) when the proximal femur is fixed with an external fixator at 45° abduction after an osteotomy was performed 2.5 cm below the minor trochanter (Figure 2c); (iv) while preserving item (iii), when the insertion point of the muscles were moved 2 cm laterally and 1 cm distally after a trochanteric osteotomy (Figure 2d).

The lengths of the muscles were measured when the hip joint is in the neutral position and at 45° flex-

ion, using a 2.0 ethibond suture. All measurements were performed three times and recorded (Figure 1).

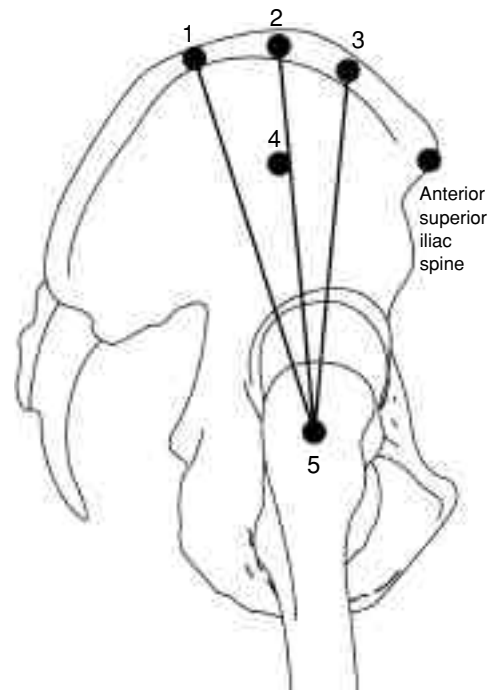
All measurements for every test were evaluated using a one-way variance analysis (ANOVA).

### Results

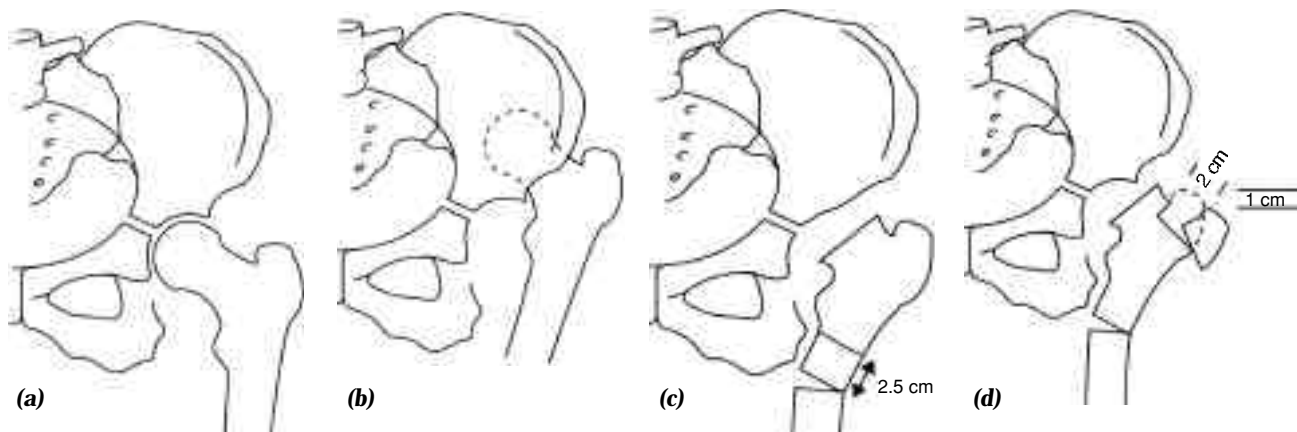
As expected, the muscle length was shortest when measured at the dislocated position ( $p < 0.001$ ). In the group where pelvic support osteotomy was performed, muscle lengths increased as compared to the dislocated position ( $p < 0.0001$ ). After lateral and distal transfer of the trochanter, muscle lengths were shorter compared to normal ( $p < 0.001$ ), but were significantly increased in those with PSO ( $p < 0.002$ ) (Figure 3). Measurements performed when the hip is in 45° flexion were similar to those at neutral position. Although classical osteotomy was found to increase muscle length in all measurements, the maximum increase was obtained when trochanteric osteotomy was combined with the surgical procedure ( $p < 0.001$ ) (Figure 4).

### Discussion

In the beginning of the twentieth century, PSO introduced by Lorenz and Schanz for the treatment



**Figure 1.** Reference points determined for measuring the lengths of the gluteus medius (1,2,3) and minimus (4) muscles.



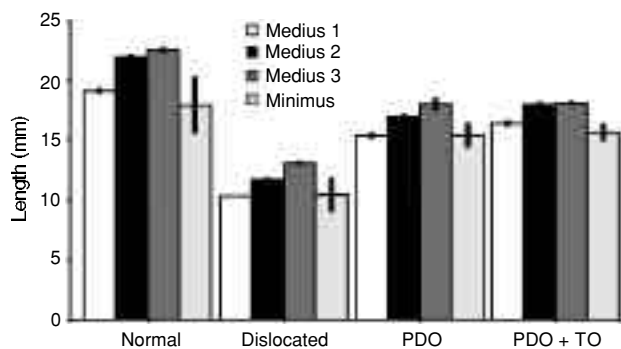
**Figure 2.** References for measurements used in the study. (a) Normal hip joint; (b) dislocated hip; (c) pelvic support osteotomies; (d) pelvic support osteotomies and trochanteric osteotomy.

developmental dysplasia of the hip in older children were modified by Milch, Haas and Ilizarov in the later years.<sup>[1,4-6]</sup> The most important factor determining adequacy of pelvic support osteotomies is reported to be the abduction angle applied to the proximal femur and several methods were proposed to measure the abductor angle which would lengthen the abductor lever arm without causing limited motion.<sup>[4,7,8]</sup>

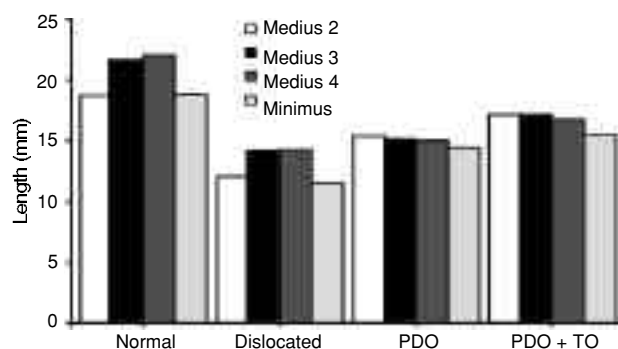
In a postmortem study, Milch<sup>[4]</sup> measured the mean pelvic lateral wall angle as 20-25 degrees and the maximum abduction angle to be acquired as 15-20 degrees. However, Haas<sup>[5]</sup> proposed that this angle could be as high as 30-40 degrees in unilateral dislocated hips. Wardle who has developed the measurement technique currently used, indicated that the affected extremity should be provided with the angle equal to the highest adduction angle<sup>[7]</sup>. Afterwards Catagni et al<sup>[8]</sup> made a preoperative planning using the angle determined from the radiograph taken at maximum adduction and Trendelenburg

position; and indicated that the correction amount should be 15-20 degrees higher than the adduction degree at the Trendelenburg position. In conclusion, considering that the maximum adduction degree is 30 degrees even in the normal hip, the maximum abduction provided would be 45-50 degrees. This means that, only half of the highest possible increase in power could be achieved in terms of muscular strength. Although the muscle length in the normal hip could not be acquired with combined osteotomy we have performed on a bone model in order to increase the muscular strength, the superiority of this technique over the classical osteotomy is promising.

It is widely known that trochanteric osteotomies are used to treat the abductor insufficiency due to the cranial malposition of the trochanter after various reasons. For this purpose, different osteotomy techniques were defined and in order to increase the abductor power, lateral transfer of the trochanter is more important than its distal transfer.<sup>[3,9,10]</sup> Considering this opin-



**Figure 3.** Muscle lengths measured with the hip joint is in neutral position.



**Figure 4.** Muscle lengths measured with the hip joint is in 45° flexion.

ion, we have applied Wagner's technique<sup>[9]</sup> for lateral and distal transfer of the major trochanter without performing bone resection in order to increase trochanteric lateral transfer.

Combination of the trochanteric osteotomy technique with PSO may be considered to create technical difficulties for the surgical procedure and increase the procedure time. However osteotomy may be performed through the same incision made for femoral head resection and fixation may be performed with cortical screws or Schanz screws used for PSO. The mean period required for union is reported to be six weeks.<sup>[9]</sup> The period indicated is not longer than the period required for union of other osteotomies, therefore total treatment duration will not be elongated. However, to protect reduction, three weeks are required until complete weight-bearing and walking are allowed. This problem may be solved by providing a stable fixation.

In this study, we have chosen the gluteus medius and minimus muscles among the abductor muscles since they provide most of the abductor power.<sup>[11,12]</sup> Fascia lata and the anterior bundles of the gluteus maximus muscle, only have a complementary role. During subluxation and after the osteotomy, not knowing the real function of the accessory muscles, which otherwise have no function in the normal hip, and the inability to demonstrate this situation on the bone model are the major drawbacks of this study.

Being the preferred treatment modality for hip dislocations in older children, PSO causes long-term limitation in daily activities. At the end of this long period, patient's expectations for the outcome of treatment are also high. Two recently performed studies reported that the failure rate of PSO in treating abductor insufficiency was 18% and 21% respectively.<sup>[13,14]</sup> Five of the 15 patients (%30) we have treated are still limping due to abductor insufficiency (unpublished data). With these results in mind, new techniques are required in elongating the

abductor lever arm in order to increase the success rate of the procedure. Trochanteric lateral and distal transfer combined with PSO on the bone model create a better elongation of the abductor lever arm as compared to the classical osteotomy. However, despite theoretical success, this technique should be tested clinically and should be supported by other studies.

## References

1. Milch H. The postosteotomy angle. *J Bone Joint Surg [Br]* 1943;25:394-400.
2. Milch H. The "pelvic support" osteotomy. 1941. *Clin Orthop* 1989;(249):4-11.
3. Paley D. Hip joint consideration. In: *Principles of deformity correction*. 1st ed. Berlin: Springer-Verlag; 2002. p. 689-94.
4. Milch RA. Roentgenographic study of the inclination of the lateral pelvic wall and the interacetabular distance in normal adult pelvis. *J Bone Joint Surg [Am]* 1954;36:533-8.
5. Hass J. A subtrochanteric osteotomy for pelvic support. *J Bone Joint Surg [Am]* 1943;25:281-91.
6. Ilizarov GA. Treatment of disorders of the hip. In: Green SA, editor. *Transosseous osteosynthesis*. 1st ed. Berlin: Springer-Verlag; 1992. p. 668-96.
7. Wardle EN. Displacement osteotomy of the upper end of the femur. *J Bone Joint Surg [Br]* 1955;37:568-75.
8. Catagni MA, Malzev V, Kirienko A. Treatment of hip disorders. In: Maiocchi AB, editor. *Advances in Ilizarov apparatus assembly*. 1st ed. Milan: Il Quadratino; 1994. p. 119-22.
9. Tachdjian MO, Kelikian AS. Distal and lateral advancement of the greater trochanter. In: Tachdjian MO, editor. *Congenital dislocation of the hip*. 2nd ed. New York: Churchill Livingstone; 1982. p. 721-39.
10. Maquet P. Importance of the position of the greater trochanter. *Acta Orthop Belg* 1990;56(PtB):307-22.
11. Gottschalk F, Kourosh S, Leveau B. The functional anatomy of tensor fasciae latae and gluteus medius and minimus. *J Anat* 1989;166:179-89.
12. Neumann DA, Cook TM. Effect of load and carrying position on the electromyographic activity of the gluteus medius muscle during walking. *Phys Ther* 1985;65:305-11.
13. Manzotti A, Rovetta L, Pullen C, Catagni MA. Treatment of the late sequelae of septic arthritis of the hip. *Clin Orthop* 2003;(410):203-12.
14. Kocaoglu M, Eralp L, Sen C, Dincyurek H. The Ilizarov hip reconstruction osteotomy for hip dislocation: outcome after 4-7 years in 14 young patients. *Acta Orthop Scand* 2002; 73:432-8.