Lateral Condylar Prominence, Post Corrective Osteotomy of Cubitus Varus: A Study Using Three-Dimensional Reverse Engineering Technique

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Lateral condylar prominence is a common problem after corrective osteotomy of the cubitus varus, which is believed to result from unequal opposing cut surfaces of lateral-based wedge osteotomy using a medial hinge. This study investigated this issue using a 3-dimensional CT data set consisting of images of the deformed elbow and the normal elbow of a patient with cubitus varus deformity who was scheduled for corrective osteotomy. A CT scan was performed with 3mm slice thickness and a reconstruction was done with 1mm interpolated slice thickness on both the left and right humerus. The CT-data set was then manipulated using reverse engineering software. Three-dimensional models of both the deformed and normal humeri were studied. Several locations or levels of medial hinge placement, each with 4-degree-tilt wedge osteotomy cut options, were then virtually performed and evaluated. The degree of correction was determined from the varus angle plus the normal carrying angle of the normal side. From the study, it was found that the degree of lateral condylar prominence is directly proportional to the distance of placement of the medial hinge above the joint. Differences in the lengths of the osteotomy surfaces have no effect on condylar prominence; only the step-off phenomenon affects condylar prominence. According to our findings, placement of the medial hinge close to the joint with a 10-degree distal osteotomy cut just above the olecranon fossa will result in optimal minimization of condylar prominence or the step-off phenomenon.

Keywords: *Cubitus varus, Corrective osteomy*

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Cubitus varus is a relatively common, yet problematic orthopedic complication resulting from the malunion of the pediatric supracondylar fracture of the humerus[1,2]. This deformity, which is usually easily, visually identifiable, does not normally cause the patient significant functional impairment (Fig. 1).

There are many published articles concerning treatment methods to correct this type of deformity[3-17]. In osteotomies that employ the use of a lateral based wedge, a lateral condylar bump usually results. It is believed that this residual appearance results from a radial shift of the distal fragment of the humerus, relative to the humeral shaft axis, thus causing a prominence of the lateral condyle (Fig. 2)[4,13,16,18-22].

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Fig. 1 Cubitus varus of the patient's left elbow (A) and radiographs of both elbows (B).

As a result, the authors performed a study using reverse engineering methods and computer simulation techniques to evaluate the factors that may contribute to lateral condylar prominence.

Material and Method

The present study used a 3-dimensional CT

data set to investigate the deformed and normal elbows of a 19-year-old female presenting with cubitus varus deformity, and who was scheduled for corrective osteotomy. A CT scan was performed with 3 mm slice thickness and reconstructed with 1 mm interpolated slice thickness on both the left and right humerus. The CT-data set was then manipulated using reverse engineering software. Three-dimensional models of both the deformed and normal humeri were studied. Six locations or levels of medial hinge placement above the joint, with 1 cm intervals, were evaluated in this study. The degree of correction was determined from the varus angle plus the normal carrying angle of the normal side (Fig. 3).

At each medial hinge level location, four different angle planes of distal osteotomy cut were simulated including, parallel to the joint line, 5 degrees, 10 degrees, and 15 degrees of medial tilting relative to the joint plane. The corresponding wedge osteotomies for the correction of cubitus varus deformity were then virtually performed, as previously mentioned (Fig. 4).

The authors used the lateral prominence index (LPI) described by Wong et al[18] to measure the degree of prominence of the lateral condyle of the humerus. The LPI was calculated on the affected side as the difference between the measured medial and lateral widths of the bone from the longitudinal mid-humeral axis (Fig. 5)[18].

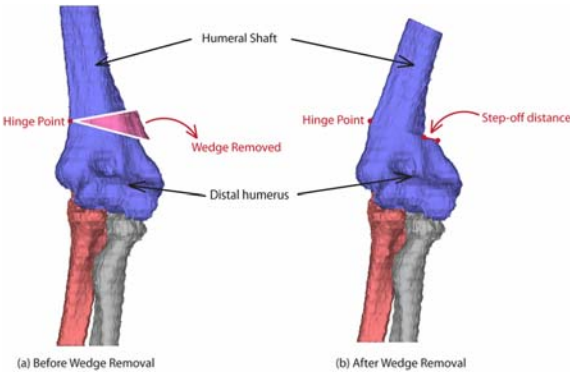

Fig. 2 The above images illustrate lateral-base wedge osteotomy (A) that will create lateral condylar prominence at the step-off of the opposing osteotomy surface (B).

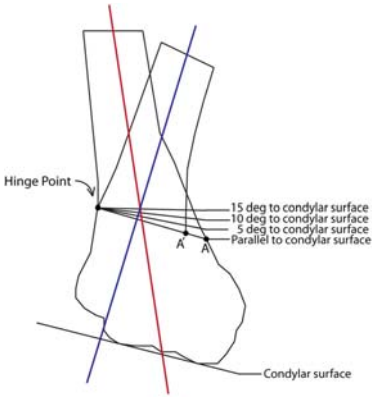

Fig. 4 Four different distal osteotomy surface planes for the location of the medial hinge were used for the study.

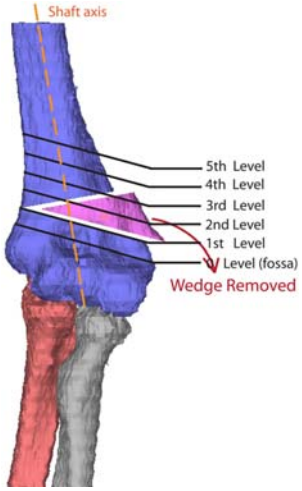

Fig. 3 A simulation of osteotomy was performed on CAD software as a virtual method of installing the medial hinge in various locations.

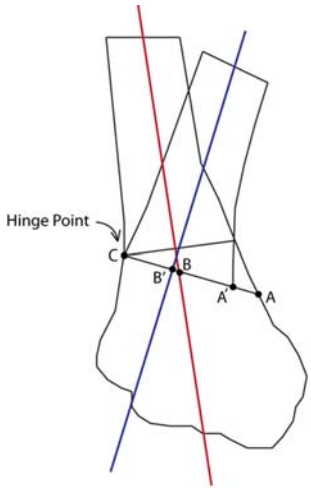

Fig. 5 The diagram shows the lateral condylar prominence index (LPI) after lateral wedge osteotomy: LPI = ((AB-BC) /AC)x100; distance AA' represents the step-off from the difference in the osteotomy surfaces.

Results

According to this study, which was based on three-dimensional models, it was found that the amount or degree of lateral condylar prominence is directly proportional to the level of medial hinge placement above the joint line. A difference in the degree (0, 5, 10 or 15 degrees) of the osteotomy surface cuts has no effect on the condylar prominence, but only on the step-off phenomenon (Table 1).

The step-off of the cut surfaces had a similar appearance with the normal humerus (Table 1 and Fig. 6). The lowest level of the medial hinge with osteotomy passing through the olecranon fossa resulted in lowest LPI. However, at the medial hinge tilting of the distal osteotomy surface at 10 to 15 degrees, it will reduce the step-off phenomenon. It was also found that the tilting plane of osteotomy will pass above the olecranon fossa and provide more area of bone opposition.

Discussion

Cubitus varus is a common complication resulting from the malunion of supracondylar fractures in children. Reported incidence varies from 4% to 58%[1,2]. This disorder is believed to result mostly from inadequate reduction or loss of reduction during the healing process[7,23-27]. Although various techniques of corrective osteotomy for cubitus varus deformity

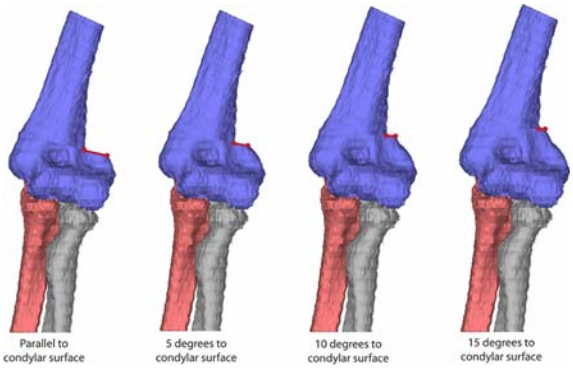

Fig. 6 Different degrees of tilting of the distal osteotomy cut surface at the same medial hinge level above the joint will affect only the step-off phenomenon, with a similar lateral condylar prominence index at each angle of cut.

Table 1. Results from the simulation study, including the lateral condylar prominence index (LPI) and the step-off phenomenon of the osteotomy surface at each location or level of medial hinge with different angles of distal osteotomy cut surface tilt

Osteotomy Level	Tilting Angle (Degree)	AB (mm)	BC (mm)	AC (mm)	LPI (%)	Step-off (mm)
0 Level	0	33.9	22.6	56.5	20.1	13.1
	5	33.9	22.6	56.5	20.1	11.2
	10	33.9	22.6	56.5	20.1	7.0
	15	33.9	22.6	56.5	20.1	4.1
1st Level	0	36.0	20.5	56.5	27.4	12.8
	5	36.0	20.5	56.5	27.4	7.6
	10	36.0	20.5	56.5	27.4	5.2
	15	36.0	20.5	56.5	27.4	2.9
2nd Level	0	38.1	18.4	56.5	34.8	8.8
	5	38.1	18.4	56.5	34.8	6.0
	10	38.1	18.4	56.5	34.8	4.5
	15	38.1	18.4	56.5	34.8	2.6
3rd Level	0	40.2	16.3	56.5	42.3	7.1
	5	40.2	16.3	56.5	42.3	5.6
	10	40.2	16.3	56.5	42.3	3.6
	15	40.2	16.3	56.5	42.3	2.3
4th Level	0	42.4	14.1	56.5	50.0	6.0
	5	42.4	14.1	56.5	50.0	4.6
	10	42.4	14.1	56.5	50.0	3.2
	15	42.4	14.1	56.5	50.0	2.4
5th Level	0	44.6	11.9	56.5	57.7	5.7
	5	44.6	11.9	56.5	57.7	4.4
	10	44.6	11.9	56.5	57.7	3.3
	15	44.6	11.9	56.5	57.7	2.4

have been described[4-14], the lateral closing-wedge osteotomy is the most commonly used procedure. However, the lateral closing-wedge osteotomy with medial hinge usually results in prominence of the lateral condyle of the humerus. This prominence was believed to result from the radial shift of the distal fragment of the humerus, relative to the proximal humeral shaft[4,13,16,18]. Wong et al reported on this problem with an incidence of 64% in a series consisting of 22 patients[18]. To minimize this complication, medial displacement of the distal fragment after osteotomy with firm fixation was recommended by some authors[14,25,27]. Some authors believe that lateral condylar prominence after corrective osteotomy may spontaneously correct if the osteotomy is performed early, before skeletal maturity[18,24]. From the results of the present study, the authors conclude that the level of the medial hinge above the joint line is a dominant factor regarding lateral condylar prominence. More specifically, the higher the level of placement of the medial hinge above the joint line, the higher the amount of lateral condylar prominence. Our findings also show that the degree of osteotomy surface cut (0, 5, 10 or 15 degrees) only affects the step-off phenomenon, but does not affect lateral condylar prominence. Lowering the level of the medial hinge closer to the joint just above the olecranon fossa with a 10 degree distal osteotomy cut is the best configuration in terms of minimizing lateral condylar prominence and the step-off of the cut surfaces and resulting in a similar appearance to a normal humerus.

Potential conflicts of interest

None.

References

1. Hoyer A. Treatment of supracondylar fracture of the humerus by skeletal traction in an abduction splint. J Bone Joint Surg Am 1952; 24-A-3: 623-37.
2. Piggot J, Graham HK, McCoy GF. Supracondylar fractures of the humerus in children. Treatment by straight lateral traction. J Bone Joint Surg Br 1986; 68: 577-83.
3. King D, Secor C. Bow elbow (cubitus varus). J Bone Joint Surg Am 1951; 33-A: 572-6.
4. Bellemore MC, Barrett IR, Middleton RW, Scougall JS, Whiteway DW. Supracondylar osteotomy of the humerus for correction of cubitus varus. J Bone Joint Surg Br 1984; 66: 566-72.
5. Beslikas TA, Kirkos JM, Sayegh FE, Papavasiliou VA. Supracondylar humeral osteotomy in children with severe posttraumatic cubitus varus deformity. Acta Orthop Belg 1999; 65: 65-71.
6. Devnani AS. Lateral closing wedge supracondylar osteotomy of humerus for post-traumatic cubitus varus in children. Injury 1997; 28: 643-7.
7. French PR. Varus deformity of the elbow following supracondylar fractures of the humerus in children. Lancet 1959; 2: 439-41.
8. McCoy GF, Piggot J. Supracondylar osteotomy for cubitus varus. The value of the straight arm position. J Bone Joint Surg Br 1988; 70: 283-6.
9. Carlson CS Jr, Rosman MA. Cubitus varus: a new and simple technique for correction. J Pediatr Orthop 1982; 2: 199-201.
10. Graham B, Tredwell SJ, Beauchamp RD, Bell HM. Supracondylar osteotomy of the humerus for correction of cubitus varus. J Pediatr Orthop 1990; 10: 228-31.
11. Mahaisavariya B, Laupattarakasem W. Osteotomy for cubitus varus: a simple technique in 10 children. Acta Orthop Scand 1996; 67: 60-2.
12. Oppenheim WL, Clader TJ, Smith C, Bayer M. Supracondylar humeral osteotomy for traumatic childhood cubitus varus deformity. Clin Orthop Relat Res 1984; (188): 34-9.
13. Matsushita T, Nagano A. Arc osteotomy of the humerus to correct cubitus varus. Clin Orthop Relat Res 1997; (336): 111-5.
14. Laupattarakasem W, Mahaisavariya B, Kowsuwon W, Saengnipanthkul S. Pentalateral osteotomy for cubitus varus. Clinical experiences of a new technique. J Bone Joint Surg Br 1989; 71: 667-70.
15. Uchida Y, Ogata K, Sugioka Y. A new three-dimensional osteotomy for cubitus varus deformity after supracondylar fracture of the humerus in children. J Pediatr Orthop 1991; 11: 327-31.
16. Kanaujia RR, Ikuta Y, Muneshige H, Higaki T, Shimogaki K. Dome osteotomy for cubitus varus in children. Acta Orthop Scand 1988; 59: 314-7.
17. Tachdjian MR. Osteotomy of distal humerus for correction of cubitus varus. In: Smith AB, editor. Pediatric orthopedics. Philadelphia: WB Saunders; 1972: 1588-91.
18. Wong HK, Lee EH, Balasubramaniam P. The lateral condylar prominence. A complication of supracondylar osteotomy for cubitus varus. J Bone Joint Surg Br 1990; 72: 859-61.
19. Ippolito E, Moneta MR, D'Arrigo C. Post-traumatic cubitus varus. Long-term follow-up of corrective supracondylar humeral osteotomy in children. J Bone Joint Surg Am 1990; 72: 757-65.

20. Labelle H, Bunnell WP, Duhaime M, Poitras B. Cubitus varus deformity following supracondylar fractures of the humerus in children. J Pediatr Orthop 1982; 2: 539-46.
21. Griffin PP. Supracondylar fractures of the humerus. Treatment and complications. Pediatr Clin North Am 1975; 22: 477-86.
22. Tien YC, Chih HW, Lin GT, Lin SY. Dome corrective osteotomy for cubitus varus deformity. Clin Orthop Relat Res 2000; (380): 158-66.
23. Beals RK. The normal carrying angle of the elbow. A radiographic study of 422 patients. Clin Orthop Relat Res 1976; (119): 194-6.
24. Barrett IR, Bellemore MC, Kwon YM. Cosmetic results of supracondylar osteotomy for correction of cubitus varus. J Pediatr Orthop 1998; 18: 445-7.
25. Wilkins KE. Residuals of elbow trauma in children. Orthop Clin North Am 1990; 21: 291-314.
26. Yamamoto I, Ishii S, Usui M, Ogino T, Kaneda K. Cubitus varus deformity following supracondylar fracture of the humerus. A method for measuring rotational deformity. Clin Orthop Relat Res 1985; (201): 179-85.
27. Smith L. Deformity following supracondylar fractures of the humerus. J Bone Joint Surg Am 1960; 42-A: 235-52.

สภาวะศอกด้านนอกโป่นหลังการผ่าตัดแก้ไขภาวะแขนคอก: การศึกษาโดยวิธีวิศวกรรมย้อนรอยโครงร่างสามมิติ

บรรจง มไหสวริยะ, กฤษณ์ไกรพ์ สิทธิเสรีประทีป, ณัฐพล จันทร์พาณิชย์, ณัฏฐภูมิ วัฒนาปฏิมากูล

ปัญหาการนูนของกระดูกต้นแขนส่วน lateral condyle มักเกิดขึ้นภายหลังการผ่าตัดแก้ไขภาวะแขนคอก โดยเชื่อว่าเป็นผลจากความยาวของผิวสัมผัสของรอยตัดที่แตกต่างกัน ผู้นิพนธ์ได้ทำการศึกษาปัญหา LP โดยอาศัยวิธีการจำลองเสมือนจริงด้วยโปรแกรมคอมพิวเตอร์ใช้วิธีการ reverse engineering สร้างรูปทรงกระดูกข้อศอก จากข้อมูลภาพถ่ายรังสีคอมพิวเตอร์ (CT) ของกระดูกผู้ป่วยหญิง 19 ปีที่มีแขนคอกที่ศอกซ้ายที่เข้ารับการผ่าตัดรักษาได้ทำการจำลองการตัดแต่งกระดูกในลักษณะการตัดเป็นลิ่ม โดยมีจุดหมุนอยู่ด้านในกำหนดให้จุดหมุนที่ศึกษามี 6 ระดับ โดยเริ่มต้นที่ระดับที่ตรงกับระดับ olecranon fossa และสูงขึ้นตามลำดับโดยมีระยะห่างช่วงละ 1 เซนติเมตร การตัดเป็นรูปลิ่มมีขนาดมุมของลิ่มเท่ากับผลรวมของมุมความผิดรูป (varus deformity) รวมกับค่ามุมหิ้ว (carrying angle) ของศอกข้างปกติในแต่ละระดับของจุดหมุนที่ใช้ตัดลิ่มกระดูก ทำการศึกษารูปแบบการตัดของแนวกระดูกตอนล่างของลิ่ม (distal osteotomy cut) 4 แบบ โดยแบบที่ 1 มีแนวตัดขนานกับระนาบของแนวช่องข้อศอก และแบบที่ 2-4 มีแนวตัดเอียงลงล่างทำมุม 5, 10 และ 15 องศา กับแนวช่องข้อศอกตามลำดับ ภายหลังการตัดลิ่มกระดูกออกนำภาพกระดูกสบเข้าหากันทำการวัดค่าดัชนีการนูนของกระดูกต้นแขนส่วน lateral condyle (LPI) และค่าความเหลื่อมกันของผิวสบในแต่ละกรณี จากการศึกษาพบว่าค่า LPI มีค่าต่ำสุดเมื่อจุดหมุนของลิ่มกระดูกที่ตัดอยู่ใกล้ระนาบของแนวช่องข้อศอกและมีค่าเพิ่มมากขึ้น เมื่อจุดหมุนของลิ่มตัดกระดูกห่างออกจากแนวช่องข้อศอกของข้อศอกและพบว่าการเกิดความเสื่อมของผิวสบจะมีค่ามากที่สุด เมื่อรอยตัดของลิ่มกระดูกตอนล่างขนานกับแนวหมุนข้อศอกและจะลดลงเมื่อตัดกระดูกเอียงลงล่างราว 10-15 องศา จากการศึกษานี้เชื่อว่าแนวการตัดกระดูกที่เหมาะสมควรมีจุดหมุนอยู่ใกล้แนวช่องข้อศอกและแนวการตัดกระดูกเอียงลงล่าง 10-15 องศา โดยอยู่ชิดขอบบนของ olecranon fossa จะให้รูปทรงใกล้เคียงปกติโดยมี LPI ต่ำที่สุดและมีระยะความเหลื่อมของผิวสบน้อยมาก