Morphometric changes in the acetabulum after Dega osteotomy in patients with cerebral palsy

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We carried out a morphometric analysis of the acetabulum following Dega osteotomy in patients with cerebral palsy using three-dimensional CT. We assessed 17 acetabula in 12 patients with instability of the hip. A Dega osteotomy and varus derotation femoral osteotomy were performed in all 17 hips. Three-dimensional CT scans were taken before and approximately one year after operation. Acetabular cover was evaluated using anterosuperior, superolateral and posterosuperior acetabular indices, and the change in the acetabular volume was calculated. Inter- and intra-observer reliability was assessed using the intraclass correlation coefficient. After the osteotomy, the anterosuperior, superolateral and posterosuperior cover had improved significantly towards the value seen in a control group. The mean acetabular volume increased by 68%.

The Dega osteotomy is used to treat acetabular deficiency associated with severe instability of the hip in patients with cerebral palsy.^{1,2} The acetabular defects in cerebral palsy differ from those in developmental dysplasia of the hip (DDH) and posterior, anterior, superior and global wall defects have been reported.²⁻⁵ In a previous study,⁶ we carried out a morphometric analysis of the acetabulum in patients with cerebral palsy. Quantitative measurements of the acetabular shape showed a lack of anterosuperior, superolateral and posterosuperior cover and a decrease in volume.⁶ The Dega osteotomy has been modified to obtain posterior cover in patients with cerebral palsy,^{1,2} but the morphometric changes have not so far been clarified. In this study, we have examined the acetabular changes after a Dega osteotomy using three-dimensional (3D) CT, and its effect on acetabular cover.

Patients and Methods

A prospective study, approved by our institutional review board, of 12 patients with cerebral palsy was performed between April 2004 to July 2006. All patients (or their parents/guardian) gave informed consent. The inclusion criteria were patients with cerebral palsy in whom a Dega osteotomy was planned for the treatment of acetabular deficiency. These criteria were met in 17 patients and 12 (17 acetabula) agreed to participate in the study. The contralateral hips in ten patients with unilateral Perthes' disease whose data con-

cerning the acetabula had been archived previously on 3D CT were used as controls. All the patients in the study groups had spastic quadriplegia, three were classified by the gross motor function classification system (GMFCS)⁷ as level V, eight as level IV and one as level III.

The mean age at the time of Dega osteotomy was 8.1 years (5.4 to 11.9). The mean age at the time of the 3D CT evaluation in the control group was 8.8 years (5.9 to 13.2). Three-dimensional CT scans were taken a few days before surgery, and after removal of the blade plate used for the varus derotation-femoral osteotomy approximately one year later. The pelvic AP radiographs were evaluated at the same time.

The CT scans (Mx8000IDT; Philips Medical Korea, Seoul, Korea) were acquired at a thickness of 1 mm, from immediately above the anterosuperior iliac spine to just below the ischial tuberosity, to limit exposure. Multi-detector CT with an age- and weight-specific paediatric protocol was used.⁸ The 3D reconstruction, including multiplanar reformation and volume calculation, was carried out using Rapidia software (version 2.8; Infinitt, Seoul, Korea).

Three acetabular indices, anterosuperior, superolateral and posterosuperior, were measured. Details of these measurements are described in our previous study⁶ (Fig. 1). The acetabular volume was determined by integrating the acetabular area in the axial image and

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Fig. 1a

Fig. 1b

Illustration of a) the method of measuring the anterosuperior index. This is defined as the plane passing through the antero-inferior iliac spine and the posterior end of the ischial tuberosity on the true lateral image. The angle between the horizontal line connecting the triradiate cartilage and the line connecting the triradiate cartilage with the anterosuperior acetabular margin was measured. b) The superolateral index was measured as the plane passing through the centre of the acetabulum parallel to the line connecting the anterosuperior iliac spine and the symphysis. The posterosuperior index was measured as the plane passing through the line of the symphysis pubis and the postero-inferior iliac spine.⁶

the slice thickness,⁶ a method which has been verified by Slomczykowski et al.⁹

In order to establish the inter- and intra-observer reliability of the CT measurements, they were undertaken by two orthopaedic surgeons (CYC, MSP) and a chief resident. The orthopaedic surgeons had 20 and five years' experience, respectively. After 30 minutes' instruction, the multiplanar reformation and measurement of indices were performed independently. The images were displayed on identical 19-inch computer monitors, with an identical setting for each examiner. Two examination sessions were carried out at an interval of three weeks. The patients' information was not given to the raters, and the order of the images was shuffled by a research assistant who did not participate in the reliability test.

Table I. Intra-observer reliability for the anterosuperior index (between first and second sessions, mean difference (range), mean of the absolute difference)

Rater	Experience (yrs)	Mean difference	ICC*	95% CI†
1	20	2.6 (0 to 9)	0.94	0.89 to 0.97
2	5	2.6 (0 to 10)	0.94	0.88 to 0.97
3	Chief resident	3.6 (0 to 9)	0.88	0.78 to 0.94

* ICC, intraclass correlation coefficient

† 95% CI, 95% confidence interval

Table II. Intra-observer reliability for the superolateral index (between first and second sessions, mean difference (range), mean of the absolute difference)

Rater	Mean difference	ICC*	95% CI†
1	2.8 (0 to 10)	0.96	0.91 to 0.98
2	3.0 (0 to 7)	0.96	0.92 to 0.98
3	3.4 (0 to 9)	0.91	0.82 to 0.95

* ICC, intraclass correlation coefficient

† 95% CI, 95% confidence interval

Table III. Intra-observer reliability for the posterosuperior index (between first and second sessions, mean difference (range), mean of the absolute difference)

Rater	Mean difference	ICC*	95% CI†
1	2.1 (0 to 6)	0.98	0.97 to 0.99
2	2.5 (0 to 7)	0.97	0.95 to 0.99
3	4.1 (0 to 10)	0.91	0.82 to 0.95

* ICC, intraclass correlation coefficient

† 95% CI, 95% confidence interval

The post-operative CT indices and acetabular volume were compared with the pre-operative data and the control group. The average CT indices of the first and second raters were used in the analysis. For the volume evaluation, measurement by the first rater was used for the comparison. The acetabular index and migration percentage on the plain radiographs were also measured.

Statistical analysis. This was performed using SPSS 11.0 (SPSS Inc., Chicago, Illinois). The comparisons between the pre- and post-operative data in the quantitative study were carried out using Wilcoxon's signed ranks test, and the intraclass correlation coefficient was used to assess the intra- and inter-observer reliability. A p-value < 0.05 was considered to be significant.

Operative technique. The patient was placed in the supine position. An anterior approach through a Bikini incision was used to expose the ilium above the acetabulum. Sartorius and rectus femoris were detached from their origin and an intramuscular psoas lengthening performed. Then, a varus derotation femoral osteotomy using a blade plate was performed through a lateral approach. In 14 hips, an open reduction was also required to achieve concentric

Table IV. Inter-observer reliability (mean of interclass correlation coefficient)

Session	Index*		
	AS*	SL	PS
1	0.85	0.92	0.91
2	0.92	0.93	0.89
Overall	0.88	0.93	0.90

*AS, anterosuperior; SL, superolateral; PS, posterosuperior

Table V. Comparison of the acetabular indices (mean, SD; °) and volume (ml) between pre- and post-operative acetabulum

	Index*			Volume
	AS	SL	PS	
Pre-operative	37 (8)	39 (7)	56 (6)	3.4 (2.0)
Post-operative	24 [†] (5)	18 [†] (5)	33 [†] (7)	5.6 [†] (3.4)
Control	20 (5)	17 (3)	39 (3)	14.2 (6.0)

* AS, anterosuperior; SL, superolateral; PS, posterosuperior

[†] significantly improved compared with pre-operative indices

reduction. After varus derotation femoral osteotomy and reduction, a bicortical cut was made just above the anterior inferior iliac spine, and a unicortical cut extending toward the sciatic notch using straight chisels to make the osteotomy. The osteotomy was opened, and iliac bone wedged into it to hold the position, more bone graft being inserted posteriorly to ensure posterosuperior cover. Post-operatively, bilateral short leg plasters with a connecting bar were applied for four to six weeks.

Results

The intra-observer reliability for the CT indices measured using the intraclass coefficient varied between 0.88 and 0.98 (Tables I to III). The inter-observer reliability also showed substantial agreement (Table IV).

All three CT indices were significantly improved compared with before operation (Wilcoxon signed rank test, $p < 0.001$, 0.001, 0.001, respectively; Table V, Figs. 2 and 3). The post-operative posterosuperior index was smaller than that of the control group. The mean acetabular volume increased from 3.4 ml (SD 2.0) to 5.6 ml (SD 3.4) (68%) (Wilcoxon signed rank test, $p < 0.001$, Table V).

Discussion

The Dega osteotomy was originally designed for DDH.^{10,11} It has been modified to correct superolateral and posterosuperior acetabular deficiency in patients with cerebral palsy.^{1,2} However, 3D morphological changes produced by the osteotomy have not been measured previously. There are several different techniques described in the literature,^{1,2,11} but there is a consensus that the osteotomy can alter the anterosuperior and posterosuperior aspects of the acetabulum.^{1,2} The hinge of the osteotomy can be the

Fig. 2a **Fig. 2b**

a) Pre- and b) post-operative left acetabulum in a male patient aged 9.8 years. The CT image shows a well-covered acetabulum after a Dega osteotomy. The arrows show the acetabular coverage in the anterosuperior, superolateral and posterosuperior directions, respectively.

triradiate cartilage or the incompletely fractured inner cortex of the ilium,¹¹ but neither alters the shape of the anterior and posterior wall of the acetabulum below the triradiate cartilage. As a result, the value of axial CT indices^{4,12} is limited in the assessment of the effect of a Dega osteotomy, because they reflect cover below the triradiate cartilage. Radiological indices, such as the migration percentage and acetabular index, are easy to understand. However, they only represent a coronal projection of a 3D structure, which can be affected by position in a patient with severe deformity, and abnormality in the AP plane cannot be easily detected. Three dimensional CT and multi-planar reformation provide a quantitative basis for morphological analysis of the effect of a Dega osteotomy on the acetabulum. In this study, the Dega osteotomy provided excellent anterosuperior, superolateral and posterosuperior cover in patients suffering from cerebral palsy with acetabular dysplasia.

Several studies have evaluated acetabular volume.^{6,9,13} We found that the volume was increased after Dega osteotomy. Previously, Ozgur et al¹³ used the coronal image obtained on MRI to calculate acetabular volume in DDH. However, their patients had a mean age of 29 months, compared with 8.1 years in our patients.

Fig. 3a

Fig. 3b

a) Pre- and b) post-operative anterosuperior index in the same patient as in figure 2.

The definition of acetabular volume is important. If it is defined as the volume of a sphere which makes the arc of the acetabular roof the circumference, the acetabular volume would decrease after Dega osteotomy, and most textbooks seem to advocate this definition.^{14,15} On the other hand, if the definition of acetabular volume is the depth of the acetabulum that contains the femoral head, then it will increase after a Dega osteotomy. We believe this definition to be preferable when assessing pelvic surgery for acetabular deficiency of acetabular volume.

There were limitations to this study. Patients with Perthes' disease were used as controls and it may be argued that the contralateral acetabulum in unilateral Perthes' disease is not 'normal'. However, we believe that the acetabula were close to those of a normal population. We obtained a 68% increase in acetabular volume, which was statistically significant. Although the percentage increase does not appear to progress spontaneously, there was a one-year interval between the pre- and post-operative CT scans. Therefore, it is possible that the volume increase was less than that shown in this study. Hence, we corrected for the effect of spontaneous growth on acetabular volume by making the assumption that the volume increase might correlate with the length cubed (volume = (length)³). When the pelvic width raised to the third power was used to standardise the acetabular volume of the same patient, the adjusted volume had increased by 48%, which is still statistically significant ($p < 0.001$). A further limitation was the bone age of the control group.

After surgery, the volume of the acetabulum increased but was less than that seen in the control group. Because skeletal maturity was delayed in the patients with cerebral palsy compared to the control group, this should be standardised with regard to bone age in a future study.

We had previously shown by a morphometric analysis of the acetabular dysplasia in patients with cerebral palsy that hip dislocation was associated with a global defect. This further study has shown that posterosuperior and anterosuperior cover are improved following a Dega osteotomy, which can be used to treat global acetabular deficiency.

Supplementary Material

e Tables showing the demographic details, CT indices and acetabular volume of the patients are available with the electronic version of this article on our website at www.jbjs.org.uk

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References

1. Jozwiak M, Marciniak W, Piontek T, Pietrzak S. Dega's transiliac osteotomy in the treatment of spastic hip subluxation and dislocation in cerebral palsy. *J Pediatr Orthop B* 2000;9:257-64.
2. Robb JE, Brunner R. A Dega-type osteotomy after closure of the triradiate cartilage in non-walking patients with severe cerebral palsy. *J Bone Joint Surg [Br]* 2006;88-B:933-7.
3. Buckley SL, Sponseller PD, Magid D. The acetabulum in congenital and neuromuscular hip instability. *J Pediatr Orthop* 1991;11:498-501.
4. Gugenheim JJ, Gerson LP, Sadler C, Tullos HS. Pathologic morphology of the acetabulum in paralytic and congenital hip instability. *J Pediatr Orthop* 1982;2:397-400.
5. Kim HT, Wenger DR. Location of acetabular deficiency and associated hip dislocation in neuromuscular hip dysplasia: three-dimensional computed tomographic analysis. *J Pediatr Orthop* 1997;17:143-51.
6. Chung CY, Park MS, Choi IH, et al. Morphometric analysis of acetabular dysplasia in cerebral palsy. *J Bone Joint Surg [Br]* 2006;88-B:243-7.
7. Palisano R, Rosenbaum P, Walter S, et al. Development and reliability of a system to classify gross motor function in children with cerebral palsy. *Dev Med Child Neurol* 1997;39:214-23.
8. Morgan HT. Dose reduction for CT pediatric imaging. *Pediatr Radiol* 2002;32:724-8.
9. Slomczykowski M, Mackenzie WG, Stern G, Keeler KA, Glutting J. Acetabular volume. *J Pediatr Orthop* 1998;18:657-61.
10. Dega W. Transiliac osteotomy in the treatment of congenital hip dysplasia. *Chir Narzadow Ruchu Ortop Pol* 1974;39:601-13.
11. Grudziak JS, Ward WT. Dega osteotomy for the treatment of congenital dysplasia of the hip. *J Bone Joint Surg [Am]* 2001;83-A:845-54.
12. Weiner LS, Kelley MA, Ulin RI, Wallach D. Development of the acetabulum and hip: computed tomography analysis of the axial plane. *J Pediatr Orthop* 1993;13:421-5.
13. Ozgur AF, Aksoy MC, Kandemir U, et al. Does Dega osteotomy increase acetabular volume in developmental dysplasia of the hip? *J Pediatr Orthop B* 2006;15:83-6.
14. Weinstein S. Developmental hip dysplasia and dislocation. In: Morrissy RT, Weinstein SL, eds. *Lovell and Winter's pediatric orthopaedics*. Sixth ed. Philadelphia: Lippincott Williams & Wilkins, 2006:987-1037.
15. Herring J. Developmental dysplasia of the hip. In: Herring J, ed. *Tachdjian's pediatric orthopaedics*. Philadelphia: WB Saunders Company, 2002:513-654.