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Change in 2D and 3D femoral head coverage after curved periacetabular osteotomy

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Abstract

Femoral head coverage in patients with hip dysplasia (DDH) is often quantified using 2D parameters, including the lateral center edge angle (LCEA) and anterior center edge angle (ACEA). However, only moderate correlations have been observed between the 2D coverage and 3D coverage. The purposes of this study were to: 1) quantify the change in 3D head coverage after curved periacetabular osteotomy (CPO), and 2) analyze the relationship between 2D and 3D head coverage preoperatively and postoperatively. Forty-three hips of 39 female cases (age: 37±10 years) who underwent CPO were analyzed. 2D coverage was quantified using the LCEA and ACEA from CT images. 3D coverage was quantified in the anterior, superior, posterior, inferior head regions. 3D measurements were performed both pre- and post-operatively and were correlated to the measurements of 2D coverage to study interactions. Preoperative 3D percent coverage in each head region was 17.8±6.7%, 36.2±7.7%, 57.6±10.2%, and 15.3±6.4% for the anterior, superior, posterior, and inferior region, respectively. Postoperatively, 3D coverage in the anterior and superior regions increased to 23.4% and 53.7%, respectively while a significant decrease was found for the posterior and inferior regions (all $p<0.01$). When 3D and 2D coverage was correlated, significant positive correlation was found between the 3D superior coverage and the LCEA both preoperatively ($r=0.72$, $p<0.01$) and postoperatively ($r=0.67$, $p<0.01$). However, no correlation was found between the 3D anterior coverage and the ACEA, which became significant in the postoperative period ($r=0.69$, $p<0.01$). Results indicate that preoperative anterior coverage for patients with DDH should be evaluated three-dimensionally.

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1 Introduction

Curved periacetabular osteotomy (CPO) is a common surgery to treat developmental dysplasia of the hip (DDH). The procedure improves symptoms and reduces the risk of subsequent hip osteoarthritis [1]. Clinical outcomes are poor in patients who do not achieve adequate correction of the femoral head. Two-dimensional (2D) parameters of femoral head coverage, including the lateral center edge angle (LCEA) and anterior center edge angle (ACEA), are evaluated to inform initial diagnosis and to provide pre- and peri-operative planning information for CPO. Only moderate correlations have been observed between 2D measurements of femoral head coverage with three-dimensional (3D) coverage derived from anatomic reconstructions [2]. Thus, it remains uncertain if measurements of the LCEA and ACEA are reflective of 3D femoral head coverage and the change to-be-expected after CPO. The purposes of this study were to: 1) quantify the changes in 2D and 3D head coverage after CPO, and 2) analyze the relationship between 2D and 3D head coverage preoperatively and postoperatively.

2 Materials and methods

Forty-three hips of 39 female cases (age: 37±10 years, height: 158±4cm, weight: 54±8cm, BMI: 21.5±2.9) who underwent CPO between June 2009 and November 2017 were analyzed in this retrospective study. Two-dimensional coverage was quantified using the LCEA and ACEA, which were measured from the preoperative and postoperative CT images. Specifically, LCEA was measured on the coronal slice that included the head center and the ACEA was measured on the sagittal slice that included the head center. Two-dimensional coverage was also evaluated using the digitally reconstructed radiographs (DRR) generated from CT images. Both LCEA and ACEA were also measured using the DRR images (defined as DRR-LCEA, and DRR-ACEA herein). Measurements were performed using a software that allowed multiplanar reconstruction with an arbitrary oblique angle (3D-template; Kyocera, Kyoto, Japan).

For the quantification of 3D coverage, surface models of the pelvis and femur were first generated from CT images using Amira (v.6.0.1, Visage Imaging, San Diego, CA, USA). From these surface models, the lunate surface and the head surface were selected using principal curvature in Postview (v.2.0, University of Utah, Salt Lake City, UT, USA). The 3D coverage of the femoral head was then quantified using the Coverage Tool in Postview [3,4]. Surface elements of the femoral head were considered ‘covered’ if they were intersected by the normal projection of any element of the lunate surface. To define regional coverage, the femoral head was divided around the neck axis in 90° increments to define anterior, superior, posterior, inferior using Matlab (v.7.10, The MathWorks, Natick, MA, USA). Coverage was then calculated in each quadrant and represented as a percent. Measurements were performed both pre- and post-operatively and were correlated to the measurements of 2D coverage to study interactions.

3 Results

In the preoperative analysis, 3D percent coverage in each head region was 17.8±6.7%, 36.2±7.7%, 57.6±10.2%, and 15.3±6.4% for the anterior, superior, posterior, and inferior region, respectively (Table 1). When 3D coverage was correlated to 2D parameters, significant positive correlation was found between the 3D superior coverage and the LCEA ($r=0.72$, $p<0.01$), between the 3D superior coverage and the DRR-LCEA ($r=0.72$, $p<0.01$), and between the 3D anterior coverage and the DRR-ACEA ($r=0.39$, $p<0.01$) (Table 2). No significant correlation was found between the 3D anterior coverage and the ACEA.

In the postoperative analysis, 3D anterior and superior coverage increased to 23.4% and 53.7%, respectively while a significant decrease was found for the posterior and inferior regions (all $p<0.01$) (Table1). When 3D regional coverage was correlated to 2D coverage, significant strong correlation was found between the 3D superior coverage and the LCEA ($r=0.67$, $p<0.01$), between the 3D superior coverage and the DRR-LCEA ($r=0.66$, $p<0.01$), between the 3D anterior coverage and the ACEA ($r=0.69$, $p<0.01$), and between the 3D anterior coverage and the ACEA ($r=0.67$, $p<0.01$) (Table 2).

4 Discussion

After CPO, 3D coverage in the anterior and superior regions increased 5.7% and 17.5% to reach a post-operative value of 23.4% and 53.7%, respectively. These results are strikingly similar to a previous study that analyzed asymptomatic, morphologically-screened control subjects, where 24.4% of the anterior and 53.1% of the superior region of the femoral head was covered [3]. Thus, CPO as performed in our sample effectively normalized anterior and superior coverage.

When regional 3D coverage was correlated to 2D measurements, there was a strong correlation between the LCEA, DRR-LCEA and the 3D superior coverage in both the pre- and postoperative analysis. On the other hand, there was no significant correlation between the preoperative ACEA and the 3D anterior coverage. This finding is important as previous studies have evaluated the anterior coverage using the ACEA measured from CT images for patients with DDH [5, 6]. As the head center may have little lateral coverage in patients with DDH, it seems that the measurement of ACEA on a head center slice in such patients is prone to large errors. On the other hand, a significant correlation was found between the DRR-ACEA and 3D anterior coverage in the preoperative analysis. However, the correlation was only moderate ($r=0.39$), indicating that DRR-ACEA is also not an ideal parameter to evaluate the anterior coverage. Thus, we recommend using 3D measurements to evaluate anterior coverage. There are some challenges to the 3D measurements as segmentation of the bone regions from CT images and the selection of the anatomical landmarks from the surface models may require time/effort. Future studies should overcome these challenges with the new developed computer technology, for example, statistical shape modelling and machine learning may be considered.

5 Conclusions

After CPO, 3D coverage in the anterior and superior regions increased while a decrease in the posterior and inferior regions were found. There was a strong correlation between the LCEA and the 3D superior coverage in both the preoperative and the postoperative period. However, no significant correlation was found between the ACEA and 3D anterior coverage in the preoperative analysis. Results indicate that preoperative ACEA should not be used to evaluate the anterior coverage for patients with DDH.

References

1. Naito M, Shiramizu K, Akiyoshi Y, Ezoe M, Nakamura Y. Curved periacetabular osteotomy for treatment of dysplastic hip. Clinical orthopaedics and related research (433): 129, 2005
2. Hansen BJ, Harris MD, Anderson LA, Peters CL, Weiss JA, Anderson AE. Correlation between radiographic measures of acetabular morphology with 3D femoral head coverage in patients with acetabular retroversion. Acta orthopaedica 83(3): 233, 2012

3. Uemura K, Atkins PR, Maas SA, Peters CL, Anderson AE. Three-dimensional femoral head coverage in the standing position represents that measured in vivo during gait. Clinical anatomy (New York, NY) 31(8): 1177, 2018
4. Uemura K, Atkins PR, Peters CL, Anderson AE. The effect of pelvic tilt on three-dimensional coverage of the femoral head: A computational simulation study using patient-specific anatomy. Anat Rec (Hoboken). 2019 Nov 22;10.1002/ar.24320. doi: 10.1002/ar.24320. (in press)
5. Tachibana T, Fujii M, Kitamura K, Nakamura T, Nakashima Y. Does Acetabular Coverage Vary Between the Supine and Standing Positions in Patients with Hip Dysplasia? Clinical orthopaedics and related research 477(11): 2455, 2019
6. Tani T, Takao M, Uemura K, Otake Y, Hamada H, Ando W, Sato Y, Sugano N. Posterior Pelvic Tilt From Supine to Standing in Patients With Symptomatic Developmental Dysplasia of the Hip. Journal of orthopaedic research : official publication of the Orthopaedic Research Society, 2019

Table 1. Change in 2D parameters and regional 3D coverage after CPO.

Dimension	Parameter	Preoperative	Postoperative	Change
2D	LCEA (°)	11.3 ± 8.5	34.1 ± 10.6	22.8 ± 11.1
	ACEA (°)	41.5 ± 11.0	58.0 ± 10.9	16.7 ± 13.7
	DRR-LCEA (°)	11.8 ± 7.5	35.2 ± 9.9	23.4 ± 10.0
	DRR-ACEA (°)	51.5 ± 8.0	59.1 ± 10.2	7.6 ± 10.8
3D	Anterior coverage (%)	17.8 ± 6.7	23.4 ± 8.4	5.7 ± 9.7
	Superior coverage (%)	36.2 ± 7.7	53.7 ± 10.9	17.5 ± 11.2
	Posterior coverage (%)	57.6 ± 10.2	44.6 ± 11.8	-13.0 ± 10.3
	Inferior coverage (%)	15.3 ± 6.4	7.6 ± 5.0	-7.7 ± 6.3

Table 2. Correlation between the 2D parameters and regional 3D coverage preoperatively and after CPO.

Parameter		Anterior	Superior	Posterior	Inferior
LCEA	Pre-op	r=0.19, p=0.14	r=0.72, p<0.01	r=-0.36, p=0.10	r=-0.44, p=0.06
	Post-op	r=-0.20, p=0.28	r=0.67, p<0.01	r=-0.45, p=0.05	r=-0.38, p=0.08
ACEA	Pre-op	r=0.20, p=0.14	r=0.24, p=0.06	r=-0.07, p=0.69	r<0.01, p=1
	Post-op	r=0.69, p<0.01	r=-0.58, p=0.02	r=-0.11, p=0.51	r=0.24, p=0.04
DRR-LCEA	Pre-op	r=0.18, p=0.17	r=0.72, p<0.01	r=-0.17, p=0.35	r=-0.34, p=0.11
	Post-op	r=-0.14, p=0.43	r=0.66, p<0.01	r=-0.37, p=0.09	r=-0.32, p=0.12
DRR-ACEA	Pre-op	r=0.39, p<0.01	r=-0.36, p=0.10	r=0.04, p=0.78	r=0.28, p=0.01
	Post-op	r=0.67, p<0.01	r=-0.52, p=0.03	r=-0.08, p=0.63	r=-0.31, p=0.13

Statistical significance is indicated in red letters.