Acetabular reaming and sartorius muscle pedicle iliac bone grafting in the treatment of developmental dysplasia of the hip in older children: a retrospective study of 15 patients with more than two years follow-up

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Abstract

Purpose Despite the early diagnosis and treatment of developmental dysplasia of the hip (DDH), some older children still need open reduction. It is usually difficult to get a satisfactory reduction particularly in patients with acetabular defect. The purpose of this study was to evaluate the short-term outcomes of acetabulum reaming and sartorius muscle pedicle iliac bone grafting in the treatment of older children with DDH and acetabular defect.

Methods The records of 15 patients with DDH (mean age 113.9 months (SD 29); 17 hips) who were treated with the reported technique between February 2015 and January 2017 were retrospectively reviewed. All patients acquired regular clinical and radiographic follow-ups, and alterations in the acetabular index, centre-edge angle and acetabular head index were measured. Joint function and radiographic results were evaluated with McKay and Severin modified criteria, respectively.

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Results A total of 15 patients were followed up for mean 32.4 months (SD 6.9). The percentages of excellent and good conditions were 94.1% (16/17) according to the Severin modified criteria and 88.2% (15/17) according to the McKay modified criteria. Avascular necrosis of the femoral head and redislocation only occurred in one hip. No cases of ankylosis or bone graft absorption occurred during the follow-up.

Conclusion Reaming the acetabulum and sartorius muscle pedicle iliac bone grafting for repairing the acetabular defect can recover the arcuate structure by increasing the volume of the acetabulum, which is beneficial for achieving a concentric reduction. The short-term outcome was satisfactory, while the long-term results need to be further observed.

Level of Evidence: IV – retrospective study

Introduction

Developmental dysplasia of the hip (DDH) is a group of bone and soft-tissue deformities of the hip. The preferred method of treatment for DDH is determined by the age of patient and severity of DDH.[1-4] Young patients (less than three years old) usually have satisfactory therapeutic effects, while the management of older individuals with DDH is a matter of great controversy.[5]

Acetabular defects, false acetabulum and proliferating cartilage tissue can usually be found in the acetabulum of older DDH patients and the shape of the acetabulum will be poor.[6,7] The outcomes may not always be satisfactory after a pelvic osteotomy, acetabuloplasty or capsular arthroplasty.[3,4,6,8-12]

The aim of this study is to analyze the short-term outcomes of a surgical technique that involves open reduction, proximal femoral shortening and derotational osteotomy, acetabular reaming and sartorius muscle pedicle iliac bone grafting in the treatment of older individuals with DDH, acetabular defects and proliferating cartilage tissues in the acetabulum.

Patients and methods

From 1st February 2015 to 31st January 2017, 15 patients (17 hips) received the surgical treatment technique introduced in this article. There were three hips of Tonnis classification grade II,[13,14] three hips of grade III and 11 hips of grade IV. Eight hips were of the right side, nine hips were of the left side and the mean age at the time of surgery was 113.9 months (SD 29). The inclusion criteria were as follows: 1) the patient's age was older than six years; 2) the lateral margin of the acetabulum showed slope and groove changes with or without a false acetabulum; 3) cartilage/bone tissue proliferating in the acetabulum (judged by the increased joint space of hip or proliferated tissue showed on CT/MRI of hip); 4) femoral head had an intact shape and cartilage. The exclusion criteria were as follows: 1) only an acetabular defect was presented; 2) flattening or gross deformity of the head contour; 3) severe damage to the hyaline cartilage of the femoral head.

Preoperatively, the radiographs , CT scans and 3D reconstructions of the hip were performed, MRI was performed if the condition of hip could not be assessed by radiograph or CT. We determined the location and shape of the acetabular defect and determined whether cartilage tissue prevented the femoral head from resetting in the acetabulum. The acetabular index (AI), centre-edge angle (CEA), acetabular head index (AHI) on the radiographs and femoral anteversion angle and neck shaft angle were measured on the CT image of the pelvis. Preoperative traction was not applied.

Surgical technique

The surgical technique was as follows (Figs 1 and 2). When patients were in a supine position on the operating table, a bikini type incision was made, and the skin, subcutaneous tissue and deep fascia were cut and dissected. The iliac crest and the origins of sartorius on the ilium between the sartorius and tensor fascia were exposed, and a certain length of the sartorius muscle was freed; the lateral femoral cutaneous nerve and blood supply of sartorius were protected. Then, subperiosteal stripping of the outer iliac crest plate to the greater sciatic notch was performed, preserving the inner iliac crest and avoiding damage to the cartilage of the iliac spine where the sartorius muscle was attached. The bone flap (a flap of bone, muscle insertion and alone with iliac crest apophyseal cartilage), which was approximately 4 cm × 2 cm × 2 cm in size, was removed along the anterior superior iliac spine from the attachment of the sartorius muscle for later use (Figs 2a and 2b). Next, the straight and reflected heads of the rectus femoris muscle were separated and temporarily cut. The tissues around the capsule were cleared and the iliopsoas tendon was detached. The defect of the ilium or pseudacetabulum above the acetabulum was exposed. The capsule was fully exposed and opened in a T-shaped manner, the remaining ligamentum teres was cut and removed and then the femoral head was dislocated from the acetabular fossa. The contracted transverse acetabular ligament was cut and released. The proliferating tissue in the acetabulum was probed and reamed using an acetabulum reamer (Figs 2c and 2d). The diameter of reamer comes in three sizes (17 mm, 20 mm and 23 mm). We usually start at 17 mm, and if the acetabulum was relatively large, we chose a larger size of reamer. We made the oval fossa of acetabulum as the ream centre and the acetabulum was reamed from the upward, inward and backward directions to restore the arcuate structure of the acetabulum and preserve as much normal 'horseshoe-like' cartilage as possible. Femoral shortening and derotational osteotomy was then performed if the surgeon judged the reduction
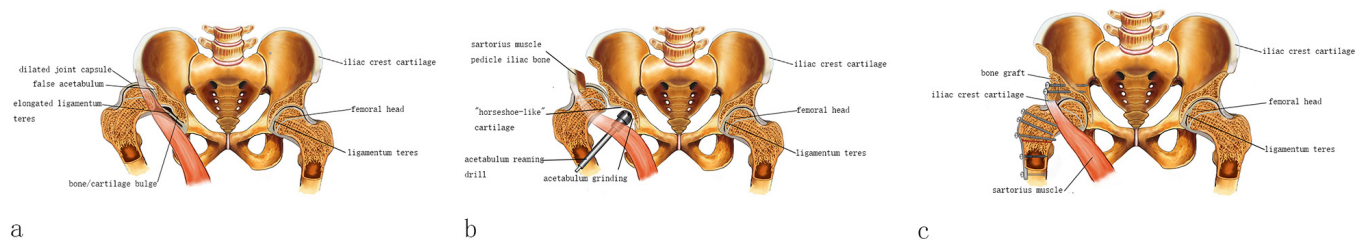

Fig. 1 Diagrams illustrate sartorius muscle pedicle iliac bone grafting to repair acetabular defects and ream the acetabulum: **a)** acetabular defect/false acetabulum and proliferating cartilage tissues; **b)** sartorius muscle pedicle iliac bone and ream of the acetabulum; **c)** sartorius muscle pedicle iliac bone graft and repair of the acetabular defect. The acetabulum covered the femur head appropriately.
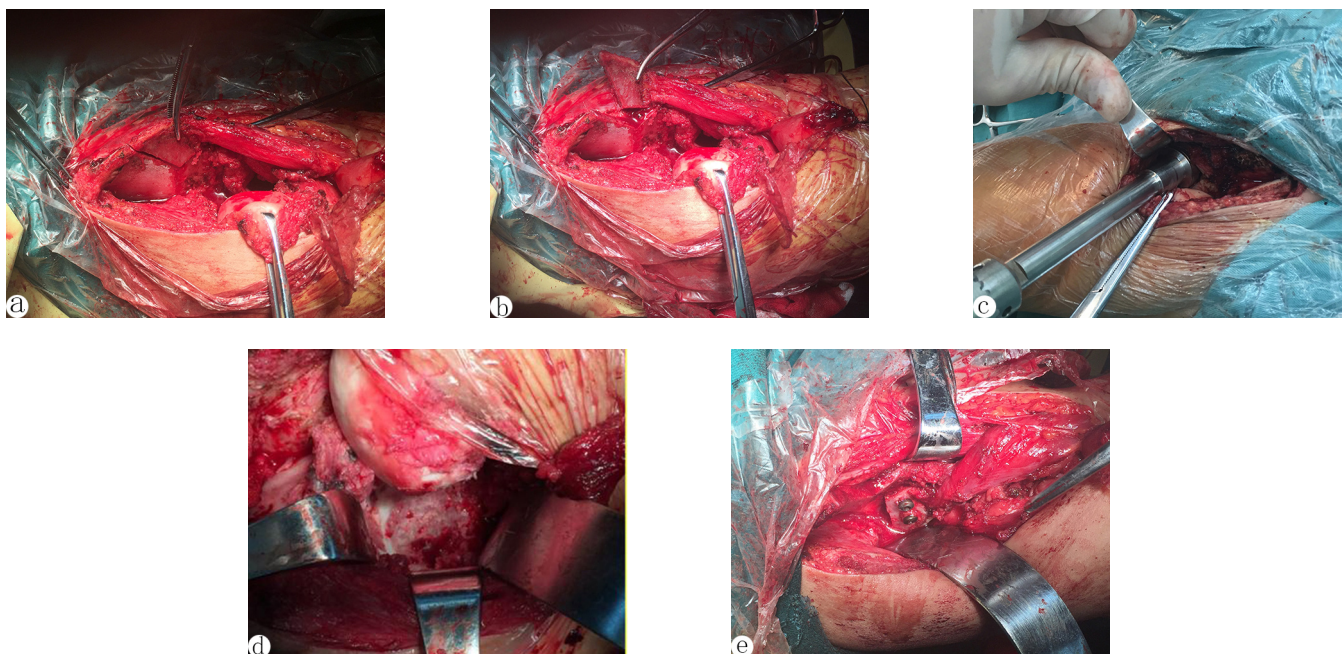
Fig. 2 Surgical technique: **a)** and **b)** obtaining the sartorius iliac crest flap; **c)** and **d)** acetabulum reaming; **e)** sartorius muscle pedicle iliac bone graft for repairing the acetabular defect.

to be under excessive tension and the hip joint could not maintain stability when the lower limbs were in a neutral position during the operation. The max shortening length was 2 cm in our cases. A straight or angled plate was used to fix the femoral osteotomy. For the next step, the femoral head was replaced, and the size and shape of the acetabulum were assessed to determine where and how to place the sartorius muscle iliac bone flap. The capsule was trimmed and repaired, and the capsule was sutured soon after the femoral head was reset. Then, the iliac crest flap was turned downwards, the outer plate of the bone flap attached to the wall of acetabular defect and the cartilage margin of the bony flap was on the same plane as the cartilage margin of the acetabulum. One Kirschner needle was used to fix the bone flap provisionally. When the bone flap was used to repair the acetabular defect and the repaired acetabulum was matched to the femoral head, two to three screws were used to attach the flap to the ilium above the acetabulum (Fig. 2e). Next, the stability of the joint was checked at 10° of adduction, 50° of abduction, 90° of flexion and 10° of posterior extension. Thus, the acetabular defect was repaired and the lateral of the acetabulum was reconstructed. The femur that had been shortened was then crushed to small bone blocks and piled above the sartorius muscle pedicle iliac bone around the iliac crest. Following this, the incision was cleaned and the straight head of the rectus femoris muscle was sutured and fixed *in situ*. When the incision was sutured layer by layer, a negative pressure drainage tube was placed on the muscular layer of the hip and thigh wound, respectively.

The hip joint was fixed at 45° abduction and 10° internal rotation in the adjustable abduction brace.

Postoperative management and follow-up

Passive hip flexion exercises were performed with the protection of the lower extremity abduction brace from the first postoperative day; the angle of buckling was increased by at least 10° each day, and almost 90° of hip flexion was reached before discharge from the hospital. After being discharged from the hospital, the patients were instructed to continue the functional hip exercises with the protection of the brace every day, and the rehabilitation training was assisted by the Continues Passive Motion Machine (CPM) machine (Continues Passive Motion Machine, Jingdian Medical Tools Factory, Zhejiang, China) eight weeks after operation.The angle of movement was increased by 5° each day. We usually removed the brace ten to 12 weeks after surgery if the radiograph showed bone healing of fracture and the patient could start partial weight-bearing exercise. The fixing screw and steel plate were removed ten to 12 months after the operation.

Another pelvic radiograph examination was performed on the day of surgery and two days, four weeks, eight weeks, 12 weeks and six months after surgery. Then, follow-up examinations were conducted at least once a year. AI, CEA and AHI were measured on each radiograph of the pelvis to determine the visual changes in the affected hip after the operation. Additionally, flexion, extension, abduction, internal and external rotation of the hip were observed and photographed. Functional and radiological

Table 1 The McKay criteria[13]

Grade	Description
Excellent	Stable, painless hip, no limp, negative Trendelenburg sign and a full range of movement
Good	Stable, painless hip, slight limp, negative Trendelenburg sign and a slight decrease in range of movement
Fair	Stable, painless hip, limp, positive Trendelenburg sign and limitation of movement
Poor	Unstable or painful hip, or both; positive Trendelenburg sign

Table 2 Follow-up data of cases

Case	Sex	Age (mths)	Follow-up(mths)	Side	Tonnis grade	ST-L (cm)	Preoperative AI (°)	Final-FU AI (°)	Final FU CEA (°)	Final FU AHI	Complications	Severin grade	McKay grade
1	M	86	35	R	IV	1.5	39.7	19.7	40.5	1.05		I	II
2	M	78	44	R	IV	1	33.1	7.3	43.6	1.04		I	I
3	M	138	26	R	IV	1.5	41.4	14.2	41.6	0.96	RD	I	III
4	M	153	29	L	IV	1	40.5	8.9	70.3	1.2		II	II
5	M	139	29	L	II	1.5	22.2	9.4	43.6	0.92		I	I
6	F	127	41	L	IV	0	39.6	11.7	46.3	1.07		II	I
7	F	134	35	L	IV	2	48.3	9.3	48.7	1.18		II	II
8	F	90	31	L	III	1	49.4	15.6	39	0.88		II	III
9	F	84	26	R	IV	0.5	35.6	14.5	47.4	0.97		II	I
10	F	123	25	L	IV	1.5	47.7	10.5	40.2	0.96		II	II
11	F	168	25	R	II	1	25.6	9.9	44.3	1.02		I	I
12	F	85	24	R	IV	1	44.7	22	37.5	0.88	AVN	III	II
13	F	130	29	L	III	1	28.6	20.5	37.8	0.98		I	I
14*	F	77	36	L	II	0.5	24.2	7.8	44	1.03		I	I
15*	F	82	31	R	IV	0.5	17.5	8.6	53.9	1.17		I	II
16**	F	125	39	L	III	2	24.6	10.7	48.4	0.98		I	I
17**	F	118	46	R	IV	1.5	25.3	16.6	48.7	1.28		I	I

*hip 14 and hip 15 belong to the same patient, a female with bilateral developmental dysplasia of the hip (DDH)
**hip 16 and hip 17 belong to the same patient, a female with bilateral DDH
ST-L, shortening length; AI, acetabular index; FU, follow-up; CEA, centre-edge angle; AHI, acetabular head index; RD, redislocation; AVN, avascular necrosis

outcomes were assessed by the McKay[15] (Table 1) and Severin[16] modified criteria, respectively.

Results

In all, 15 patients received complete follow-up (Table 2), and the average follow-up time was 32.4 months (24 to 46). The mean amount of blood lost was 320.6 ml (sd 225.3; 20 to 700) and the mean length of hospital stay was 10.1 days (sd 2; 8 to 15). Prior to surgery, the mean AI was 34.6° (sd 10.2°). At the final follow-up, the mean AI, CEA and AHI were 12.8° (sd 4.7°), 45.6° (sd 7.8°) and 103.4 (sd 11.5), respectively. There were ten hips (58.8%) of Severin grade I, six hips (35.3%) of grade II and one hip (5.9%) of grade III. We considered hips with grades I and II as satisfactory and those with grades III and IV as unsatisfactory. Hence, we obtained 94.1% satisfactory results. According to the McKay modified criteria, there were nine hips (52.9%) in excellent condition, six hips (35.3%) in good condition and two hips (11.8%) in fair condition. Therefore, we grouped hips with good and excellent evaluation as satisfactory and those with poor and fair evaluation as unsatisfactory. Thus, we obtained 88.2% favourable results. There was one hip with avascular necrosis (AVN) and one hip with redislocation. No hip ankylosis or pain occurred during the follow-up. Typical cases are shown in Figures 3 and 4.

Statistical analysis

Data were analyzed using the Statistical Packages for Social Sciences 19.0 software (SPSS Inc., Chicago, IL, USA). Descriptive statistics (means, frequencies, sd) were used to describe the characteristics of the follow-up data.

Discussion

Acetabular defects and cartilaginous tissue bulges in the acetabulum are usually found in older children with DDH[17] and acetabular defects are mainly located at the outer, superior region of the acetabular margin. Previous studies have shown that acetabular defects and abnormal hyperplasia tissues in the acetabulum blocked the reduction of the femoral head and lead to postoperative redislocation.[18] The outcomes of DDH in older children were not usually satisfactory.[19-21] In our study, after a mean follow-up time of 32.4 months, the satisfactory rates were 94.1% and 88.2%, according to Severin's radiograph standards and McKay functional standards, respectively. The results were similar to the recently reported surgical treatment outcomes of DDH in older children.[22,23] There was no pain or ankylosis in the joint during the follow-up period.

The sartorius ilium flap grafting has been previously used for the treatment of osteonecrosis of the femoral head and femoral neck fractures, and it has also been used
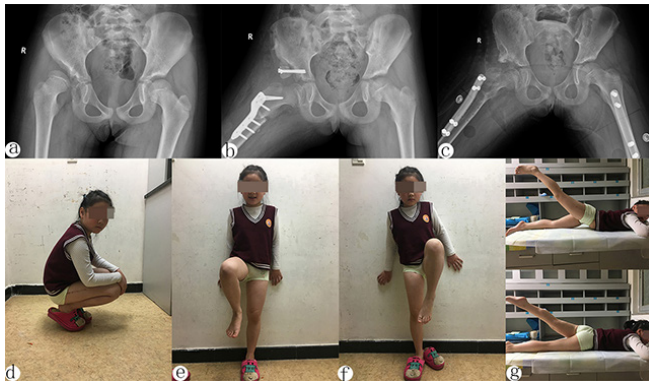
Fig. 3 Female patient diagnosed with developmental dysplasia of the right hip. Surgery was performed at the age of seven years: **a)** preoperative radiograph; **b)** six weeks after surgery; c) 13 months after surgery; **d)**, **e)**, **f)** and **g)** functional imaging 13 months after surgery.

Fig. 4 Female patient diagnosed with bilateral developmental dysplasia of the hip. Surgery of the right hip was performed at nine years, nine months old, and surgery of the left hip was performed at ten years, four months old: **a)** preoperative radiograph; **b)**, **c)**, **d)** and **e)** radiographs during a follow-up; **f)** radiograph after removing the internal fixation; **g)**, **h**) and **i)** functional imaging.

to repair acetabulum defects in a total artificial hip joint replacement.[24] In 2012, one of the authors of this paper reported the use of the sartorius muscle pedicle iliac bone grafting technique for repairing acetabular defects in DDH patients.[7] An appropriately sized portion of sartorius muscle pedicle iliac bone was obtained intraoperatively, was placed at the location of the acetabular defect, which increased the volume of acetabulum effectively, and the grafted ilium healed quickly and ilium flap was not easily absorbed. The branch of the deep femoral artery located at the apex of the blood supply branch of the sartorius muscle pedicle iliac bone is the most important blood supplier of the sartorius muscle.[25] Special attention should be paid to protect these blood vessels when freeing the iliac crest flap. During surgery, the blood supply of the bone flap can be confirmed by observing the amount of bleeding at the cutting end of the bone flap. When implanting the bone flap, placement of the outer plate of the flap against the iliac crest at the acetabular defect was required. The cartilaginous surface of the superior border of the iliac crest should face outwards and downwards and the cartilaginous surface of the bone flap should be at the same level as the cartilaginous surface of the acetabulum. Thus, a formation of a 'ladder' sign between the bone flap and acetabulum can be avoided.

Tools such as a curette or bone chisel are usually used to deal with proliferating tissue in the acetabulum; these tissues may cause the inner wall of the acetabulum to be rough, and it is difficult to restore the arcuate and smooth structure of the acetabulum with these tools. When the femoral head does not align with the acetabulum, the hyaline cartilage on the surface of the femoral head is easily damaged by movement over time, which may lead to pain and limited movement of the joint. Reaming the acetabulum to treat DDH has been reported for decades,- such as Colonna's[26] and Zahradnicek's[27] type of technique.

However, these procedures were associated with relatively high rates of necrosis, joint stiffness and subsequent revision procedures,[11,28] although in 2012 Ganz et al[11] reported 84 average Harris hip scores with 7.5 years follow-up using the one-stage procedure of surgical hip dislocation and capsular arthroplasty. There have been few reports with this technique in recent years. The author of the current study was inspired by the technique introduced by Zahradnicek,[27] in which the acetabular reamer was used to ream the acetabulum and restore the arcuate structure of the acetabulum. The technique employed to deal with the acetabulum in our research is similar to that of Zahradnicek's surgery but includes some modifications. The purpose of reaming was to restore the arcuate and smooth structure of the acetabulum, so reaming was only confined to the cartilaginous tissue protruding in the acetabulum; the acetabular horseshoe-shaped cartilage was preserved. The volume of acetabulum was enlarged mainly by repairing the acetabulum defect with sartorius muscle pedicle iliac bone graft rather than by reaming the acetabulum. Excessive reaming was not needed to deepen the acetabulum to accommodate the femoral head, which preserved as much of the normal cartilage as possible. To strengthen the reconstructed acetabulum, femoral fragments and artificial bone were planted at the lateral of the acetabulum, which grew in a favourable manner after surgery, and the lateral of the enlarged acetabulum was integrated and firm.

After the operation, the affected lower extremity was maintained at 45° abduction and 10° internal rotation position with the adjustable abduction brace. Passive flexion and stretching exercises of hip joint were carried out on the first day after surgery, and each day thereafter, the flexion exercises were increased by 10° and the stretching range of movement was increased. The range of hip movement reached 90° nine days after surgery.

Early implementation of passive functional exercises with gentle and slow movements effectively prevented adhesion and stiffness of the hip joint and maintained blood circulation in the bone flap. Thus, the success of the bone flap and the fusion of the bone flap to the ilium were guaranteed, allowing the enlarged acetabulum which has a strong bone shape and matches the femoral head.

AVN and redislocation are common complications of open reduction; there was one hip with AVN and one hip with redislocation in our study. The incidence of AVN was similar to that in reports of older children by other researchers.[5,23] The incidence of redislocation was higher than that in the latest report of large case-control research;[29] however, considering the age of the patients in this study, the incidence of redislocation is acceptable.

The advantages of this technique are as follows: 1) the bone flap is smooth along the bony edge of the true acetabulum and fixed onto the ilium by two to three screws, which increases the acetabular coverage of the femoral head and prevents the ladder sign. As the iliac flap of sartorius muscle is an autologous vascularized bone flap, the bone flap healed quickly and performed well after bone grafting, and the increased acetabular containment was not easily lost; 2) we only reamed the protruded tissue in the acetabulum; most of the acetabular horseshoe-shaped cartilage was preserved and there was no damage to the 'Y'-shaped cartilage of the acetabulum, which may not disturb the normal development of the acetabulum. Proper reaming of cartilage hyperplasia tissue in the acetabulum using a reamer restored the arcuate structure of the acetabulum and distributed the forces on the femoral head; 3) the vast majority of the acetabulum cartilage was preserved and the joint interface was still 'cartilage to cartilage'. Early implementation of postoperative functional exercises effectively prevented postoperative joint adhesion and reduced the risk of joint rigidity. The difficulties with the surgery are the following: 1) younger patients have a thinner iliac crest, and the bone flap for acetabular defects repairing is not sufficient. Thus, additional autologous or artificial bone grafting above the flap must be added, and whether the grafted bone can grow to form a firm acetabular apex is uncertain; 2) the size of the sartorius muscle iliac bone flap currently depends on the experience of the surgeon, and there is no specific quantitative standard for the degree of reaming of the acetabulum; therefore, this technique requires a relatively high amount of surgical experience.

This study also has the following limitations: 1) the study lacks a control group; 2) the cases were limited, and the follow-up time was relatively short; 3) whether the newly enlarged acetabulum has formed cartilage and whether the cartilage of the original acetabulum can heal with the acetabulum needs to be further proven; 4) the resulting development of the capsule between the increased bony tissue over the acetabulum and the femoral head has not been clearly studied. Previous studies[11,30,31] reported that the capsule between the increased bony tissue over the acetabulum and the femoral head may be transformed into atypical fibrous cartilage. However, pathology and animal experiments are needed to prove the specific mechanism.

Conclusion

Acetabular reaming and sartorius muscle pedicle iliac bone grafting are useful in treating older children with DDH accompanied by acetabular defects and cartilage hyperplasia tissue in the acetabulum and provide an alternative surgical technique for older children. Further observations and studies are worthy to determine the long-term efficacy.

COMPLIANCE WITH ETHICAL STANDARDS

ETHICAL STATEMENT
Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Institutional review board approval was waived as it was not necessary in this type of study.
Informed Consent: Informed consent was not necessary for this work.

ICMJE CONFLICT OF INTEREST STATEMENT
None declared.

AUTHOR CONTRIBUTIONS
ZF: Design of the work, Analysis of data for the work, Revising the manuscript critically for important intellectual content.
LC: Design of the work, Analysis of data for the work, Final approval of the version to be published.
LHang: Design of the work, Analysis of data for the work, Revising the manuscript critically for important intellectual content.
LM: Revising the manuscript critically for important intellectual content.
WJ: Collecting data.
HZ: Collecting data.
LHaoyu: Revising the manuscript critically for important intellectual content.

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