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Review Article

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Direct Anterior Approach Total Hip Arthroplasty for Managing Complicated DDH: Not Just Minimally Invasive in Nature

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Review

The aim of this article is to evaluate the article by Zai-yang Liu et al. titled "Direct Anterior Approach in Crowe Type III-IV Developmental Dysplasia of the Hip: Surgical Technique and 2 years Follow-up from Southwest China", published in the *Orthopaedic Surgery* in April 2020 and titled "Surgical technique and case series of total hip arthroplasty with the Heuter anterior approach for Crowe type IV dysplasia", published in *The Journal of Bone and Joint Surgery* in November 2020 , by Viamont-Guerra et al. [1,2]. Our team was the first in China to use a surgical approach and technology similar to that of Viamont-Guerra to treat developmental dysplasia of the hip (DDH), a serious hip disease. Since 2015, we have performed nearly 600 surgeries and have developed key techniques and standardized procedures for a Direct Anterior Approach (DAA) in line with the characteristics of Chinese people. During this period, we have published a series of clinical research papers on our findings [1,3-5]. We hope to present our unique viewpoint in this letter. To the best of our knowledge, this is the first paper to conclude that DAA helps to accurately obtain a functional pelvic position and adapt to the temporal and spatial changes of the lower lumbar spine-pelvic-hip complex in Total Hip Arthroplasty (THA).

We highly appreciate the outstanding achievements of the Viamont-Guerra team in this research field. They originally used DAA [also known as the Heuter Anterior Approach (HAA)] to effectively address severe acetabular defect, proximal femoral deformity, soft tissue imbalance, leg length discrepancy and other problems, with encouraging clinical results. In their article, 6 patients (8 hips) with Crowe type IV DDH who were treated with the HAA were observed. During a follow-up period of 2-6 years, the modified Harris Hip Score increased from 33 ± 7 points to 90 ± 7 points, the WOMAC score increased from 53 ± 14 points to 89 ± 6 points, and the postoperative leg length discrepancy was 3.2 ± 9.9 mm [2]. The authors emphasized that DAA surgery has been increasingly used in hip joint diseases. Compared with other approaches, DAA has the advantage of being minimally invasive, which is conducive to protecting nerve and muscle tissue, reducing pain, providing early functional improvement, shortening the hospitalization time, and reducing the rate of complications such as dislocation, and these advantages could be realized in patients with DDH.

We fully recognize the research results of Viamont-Guerra et al. regarding accelerated postoperative rehabilitation. However, we must acknowledge that in essence, the study was retrospective, uncontrolled, single-group observational studies (level IV, case series). More convincing controlled studies (prospective or retrospective; cohort studies; level I-III) are needed to confirm the value of the minimal invasiveness and accelerated recovery of DAA in complex DDH surgery. In a retrospective cohort study conducted at our institute (level III), 23 consecutive hips with

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Crowe III-IV DDH that underwent DAA were evaluated from 2016 through 2018 and were compared to 47 counterparts concurrently treated using the posterolateral approach (PLA). At the most recent follow-up (DAA 2.40 years; PLA 3.25 years), the mean increase in the Harris Hip Score in the DAA group was 48.2, compared with 30.3 for the PLA group ($p = 0.003$). The improvement in the WOMAC score was 15.89 higher in the DAA cohort than in the PLA cohort after adjusting for preoperative differences [$R2 = 0.532$, $p = 0.000$, 95% CI (10.037, 21.735)]. The DAA group had faster recovery of hip abductor strength at 1 month ($p = 0.03$) and of hip flexor strength at 3 months ($p = 0.007$) compared to the PLA group. Satisfactory improvement of limping was much higher in the DAA cohort (97.6%) than in the PLA cohort (90.0%, $p = 0.032$) [6].

Another limitation of their study published by Viamont-Guerra et al. is that the theoretical basis for using DAA for complex DDH was not described in detail. What is the benefit-risk ratio of this innovation that breaks from traditional treatment norms for both doctors and patients? In addition, a series of core technical questions were not answered in detail. For example, all of the operations were performed on the traction table, in contrast to the routinely used conventional operating table without a traction frame. The author did not clarify the particularities of intraoperative posture adjustment and management. How was the acetabular cup positioned at the actual acetabulum to achieve anatomical reconstruction? How to determine a suitable prosthesis to achieve initial stability? For patients with combined Subtrochanteric Osteotomy (STO) operations, which program of postoperative rehabilitation should take place to ensure the long-term survival of the prosthesis? These are the main reasons we write this letter to the editor, and we will discuss these issues systematically in the second half of this article.

First of all, we fully recognize that the traditional PLA has achieved good clinical results in the treatment of complex DDH [7] and is the surgical approach adopted by more than 95% of Chinese doctors. The PLA has the advantages of sufficient exposure, complete release, convenient osteotomy, and stable curative effect [7], but a series of problems (a high incidence of complications such as dislocation, leg length discrepancy, and nonunion of osteotomy; the destruction of the rear dynamic stability structure; slow gait recovery; poor patient satisfaction) have attracted increasing attention. In particular, it should be noted that with the PLA, THA is completed in the lateral position, and the contralateral hip flexion and knee flexion position leads to a backward pelvic tilt. It is not appropriate to implant an acetabular prosthesis in this nonfunctional position according to the standard abduction and anteversion angles. When patients return to the standing position and switch from standing to sitting, the position bias of the prosthesis and abnormal shear increases are likely to lead to surgical failure [9].

Scott Yang et al.[10] found that the overall results of PLA for Crowe type I and type II DDH were similar to those of THA in non-dysplastic patients. However, the risk of revision in patients with complex DDH (Crowe III-IV) 15 years after THA was 1.5 times higher than that in patients without DDH, and the risk of revision in patients with dislocation was 2.0 times higher than that in patients without DDH [10]. The reason was that the lower lumbar-pelvic-hip complex was gradually remodeled over time and with the recovery of joint function. The rotation of the pelvis on the coronal plane and the recovery of the tilt of the sagittal plane led to the deviation of the prosthesis from the safe area, resulting in an increase in the wear and dislocation rates of the prosthesis [12]. Therefore, we believe that PLA surgery should not be regarded as anatomical reconstruction and cannot accurately restore the biomechanics of the hip. Supine DAA is expected to obtain near-normal lumbar lordosis and a functional pelvic position and to provide accurate solutions for the imbalance of the lower lumbar-pelvic-hip complex in complex DDH.

Second, all of the cases in this study were treated without fluoroscopic assistance on the traction table. Although the radiation damage was reduced, the authors did not describe in detail the intraoperative posture adjustments or how to confirm the accuracy of the implant angle during prosthesis implantation. We know that intraoperative exposure is a major challenge in complex DDH, especially in cases of dysplastic acetabulum or combined defects, and the release of a proximal femur with proximal and posterior displacement is a bottleneck [13]. All of the DAA operations that we performed were performed on a standard traction table with the patient in the supine position. Arthroscopic 360° capsular release was performed in advance, and precise release of the adductor muscle, the origin of tensor fascia latae, and the distal iliac-tibial bundle was selectively completed. Then, the traction table was adjusted to over-extend the hip by 30°. The lower limb of the affected side was adjusted to be in extreme adduction and external rotation, to release the posteromedial capsule attached to the inner surface of the greater trochanter. When necessary, the piriformis and/or conjoint tendons were released to fully expose the proximal femur to the combined prosthesis implantation. During the implantation of the acetabular cup, we noted the overall status of the pelvis and determined the orientation using the functional position rather than the anatomical structure as a reference. We have published detailed reports on the key techniques and standardized procedures involved in the DAA process for complex DDH in *Arthroplasty Today*, *Orthopedic Surgery*, *Scientific Report* and other journals [1,3,6].

Third, the positioning of the acetabular rotation center in complex DDH has always been controversial. At present, there are two main methods: anatomical reconstruction and high-position reconstruction. Viamont-Guerra et al. chose the former. Fortunately, dislocation and prosthesis loosening did not occur in any cases, but complex DDH is associated with such problems as poor acetabular development tolerance, the disappearance of acetabular anteversion or even retroversion, forward movement of the acetabular rotation center, and acetabular bone defects. Therefore, anatomical reconstruction is in great challenge, and the risk of intraoperative fracture, postoperative dislocation and loosening is still high. A high acetabular center is the choice of some colleagues [14,15]. Montalti et al. [16] selected a high acetabular center in a cohort study of 84 cases with Crowe type III-IV DDH (average vertical and horizontal distances from the anatomical rotation center were 33 ± 8 mm and 30 ± 5 mm). After 15 years, only 2 cases had undergone revision due to aseptic loosening (1 cup and 1 stem). In a study by Galea et al. [17], 74 cases of non-dysplasia and Crowe type I hip joints and 49 cases of Crowe type II-IV dysplasia of the hip joint were treated with rotational center heights that were 21.2 mm and 28.4 mm higher than the Inter-Teardrop Line (ITL), respectively. After an average follow-up of 13.8 years, the average Harris Hip Score of the patients with Crowe type II-IV DDH was 89.9; there was no dislocation, and the center height of the hip joint was not related to the Harris Hip Score or the polyethylene wear rate. In contrast, Komiyama et al. [18], in a retrospective study of 910 patients (1079 hips) with DDH using a high-position reconstruction method, found that a high acetabular center was an independent risk factor for dislocation. The critical vertical distance between the rotation center and the ITL was 23.9 mm, and the dislocation risk increased at greater distances. Karaismailoglu et al. [19] also found that a high acetabular center reduced the range of motion of the hip joint and increased the load on the hip. In a control study of 40 patients with Crowe type II-IV DDH, the degree of hip extension in the high-position reconstruction group (-9.11° ± 8.92) was significantly lower than that in the anatomical reconstruction group (-1.87° ± 11.51), and the hip load was significantly higher than that in the anatomical reconstruction group.

Our choice of rotation center for Crowe type IV DDH is consistent with that of Viamont-Guerra. Clinical data from our center show that a high acetabular center was not only detrimental to patients' postoperative function and gait recovery, but also significantly increased the volumetric wear of the nonceramic interface. Osteolysis due to polyethylene particles and metal wear debris was more serious. The 15-year survival rate of the prosthesis was significantly lower than the results reported in the above literature. Our previous work also showed that with a preoperative design based on pre-operative CT and the Artificial Intelligence Assistance System (AI HIP), the height of the acetabular center did not show a linear increase in acetabular cup coverage. Specifically, for the Crowe type III DDH, the average coverage rate of the acetabular cup positioned at the anatomical center of rotation was approximately 57.5%, while a moderate upward shift of the rotation center (<10 mm) increased the mean coverage to 88.5%. In contrast, when the acetabular cup was positioned in false acetabulum, the average coverage was 91.2%. Therefore, a moving the center of rotation slightly upward (<10 mm) may be a better choice for Crowe III DDH because this position (1) ensures adequate acetabular coverage and initial stability; (2) maintains the lever-arm of the abductor muscle; (3) does not significantly aggravate interface wear; (4) reduces the use of structural bone graft and metal reinforcing blocks; and (5) promotes early weight-bearing and functional training of patients [20,21]. We describe this restrictive (<10 mm) rotation center reconstruction technique as "relative anatomical reconstruction".

Fourth, the concept of hip-spine relation should be emphasized in the total hip reconstruction of complex DDH. The hip-spine relation is a dynamic mechanism through which coordinated movements of the spine, pelvis and hip work together to maintain balance in the coronal and sagittal planes of the body. Lumbar lordosis (60° ± 10°) and pelvic anteversion (40° ± 10°) needed to increase acetabular coverage remain stable when the human body is standing, while spine straightening, pelvic retroversion (20° ± 9°), and hip flexion (132° ± 12°) occur when the human body is sitting [22,23]. Hip-spine decompensation is very prominent in patients with imbalances of the lower lumbar-pelvis-hip complex, such as those that occur in complex DDH; lumbar fusion; post-polio syndrome; and inflammatory arthritis, such as rheumatoid arthritis and ankylosing spondylitis. According to our observations, the hip-spinal relation undergoes specific temporal and spatial changes in patients with complex DDH. For example, most patients with unilateral complex DDH anatomically exhibit a coronal imbalance that manifests as a pelvic tilt toward the distal limb of the dislocated hip, with little change in the sagittal balance of the pelvis. After joint reduction and correction of limb length inequality after THA surgery, which results in the balancing of soft tissue tension, the pelvis is gradually unrotated in the coronal plane until it is restored to the neutral position, and spatial changes in the hip-spine linkage mechanism occur. Patients with bilateral complex DDH show severe sagittal instability, pelvic anteversion, increased lumbar lordosis (LL) angle (normal: male 61.4° ± 10.2, female 58.1° ± 10.8), decreased pelvic incidence (PI) (normal: male 53.2 ± 10.3, female 48.2 ± 7), decreased sacral slope (SS) angle (normal: male 41.9 ± 8.7, female 38.2° ± 7.8), decreased pelvic tilt (PT) angle (normal: male 11.9° ± 6.6, female 10.3° ± 4.8), and other changes [24]. Anteroposterior radiography of the pelvis showed a circular and enlarged pelvic inlet, and the obturator ratio (the ratio of the maximum sagittal diameter and the maximum transverse diameter of the obturator on pelvic X-ray) was less than 0.5 [25]. Approximately 6 months after ideal THA surgery, there is adaptive change in the lower lumbar-pelvis-hip complex with sagittal correction of the pelvic anteversion to near normal, showing a temporal change in the hip-spine linkage. In view of this phenomenon, we believe that the differences between the original pelvic orientation and the functional position should be fully considered in THA, especially in acetabular prosthesis implantation, to evaluate the degree of decompensation of the hip-spinal relation and to note to the angle changes caused by adaptive pelvic adjustment after acetabular prosthesis implantation. In our previous work, we effectively achieved this goal using artificial intelligence-assisted preoperative design and robotic (or computer navigation) assistance.

Conclusion

In summary, we believe that the advantages of DAA for treating complex DDH are not only minimal invasiveness and tissue sparing, but more importantly, the ability to personalize the position of and accurately implant the acetabular prosthesis with reference to the spaciotemporal effect of the hip-spine relation. The goal for the acetabular cup to achieve an ideal position after pelvic remodeling to the functional position and ensure the longevity of the artificial hip implant.

Declarations

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