

Pelvic osteotomy techniques in the management of canine hip dysplasia – evolution of the treatment paradigm

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Summary

Canine Hip Dysplasia (CHD) is considered to be one of the most common orthopaedic diseases and it consists of coxofemoral joint incongruence leading to femoral head subluxation and osteoarthritic changes. The affected dogs tend to present progressive pain and mobility issues. The widely used CHD managing strategies, among others, include pelvic osteotomy techniques. In recent years, great efforts have been made to improve the surgical procedure and reduce the rate of complications, which seems to be a possibility due to the introduction of constructional changes in modern TPO/DPO plates.

Keywords: hip, dysplasia, pelvic, osteotomy

Causes and pathogenesis

Canine Hip Dysplasia (CHD) is considered to be one of the most common orthopaedic diseases in dogs (29). It was first described by Schnelle in 1935 and since then it has continued to pose challenges from both surgical and conservative treatment perspectives. Hip dysplasia is considered to be a polygenic and multifactorial developmental disease (19). Affected dogs are born with a healthy hip joint conformation, but the laxity of the supporting soft tissue leads to progressive femoral head subluxation and incongruity. As a result, osteoarthritis (OA) (Fig. 1) may develop (20, 36). Although CHD tends to affect mainly large and giant breed dogs (Labrador Retrievers, Newfoundlands, Rottweilers, St. Bernards and German Shepherds), smaller dogs like bulldogs, pugs and terrier breeds are also predisposed to it (11). Over the years, opinions regarding etiopathogenesis have been redefined and the relevant surgery techniques have evolved as well. This has led to more sublime patient qualification criteria for surgery and also to a lower rate of complication rates as a result (35). The genetic background has recently been widely investigated and the latest data strongly indicates the complex genetic nature of hip dysplasia in dogs, with multiple loci being associated with the trait, most of which are population-specific (41). There



Fig. 1. 3D MPR CT image

Explanations: Bilateral, massive osteoarthritic changes affecting the coxofemoral joints. Note the new bone formation in the region of DAR, femoral heads flattening and the vacuum phenomenon in both joint cavities

are also substantial signs that indicate the existence of partially distinct loci and genes or pathways in the development of incongruity, mild dysplasia, moderate-to-severe dysplasia and osteoarthritis of the canine hip

joints (22, 23, 41). The fundamental stabilizer of the coxofemoral joint consists of the ligament of the head of the femur, the joint capsule and the dorsal acetabular rim (DAR). Although hip laxity resulting in subluxation is a substantial cause of lameness in young dogs, the development of OA is a major cause of morbidity (21, 40). In response to joint capsule inflammation and microfractures of the DAR, periarticular fibrosis develops. As cartilage damage progresses, destructive enzymes like lysosomal enzymes, hyaluronidase, and proteinases from chondrocytes and synoviocytes are released causing further bone remodelling which results in the formation of osteophytes (31), this involves the shallowing and widening of the acetabulum which leads to the flattening of the femoral head (14).

Diagnosis and patient selection

The diagnostic protocol for CHD assessment always includes performing an orthopaedic test. The Barlow, Ortolani, and Bardens tests are early diagnostic orthopaedic tests for hip dysplasia, but the diagnostic value is different for each of them. In one study Vidoni demonstrated that the Ortolani test is more accurate than the Barlow and Bardens tests (40). While in another study, Puerto demonstrated that positive Ortolani test results are associated with an increasing distraction index where dogs are categorized as having mild, moderate and, in some cases, a severe positive Ortolani sign (24). However, the same study showed a correlation between the severity of the Ortolani sign and DI was weaker in dogs with radiographic signs of OA, which suggests that this test is less sensitive for older dogs with hip joint bone remodelling. The Ortolani sign provides a 92-100% sensitivity for identifying joint laxity in dogs older than 4 months of age which are destined to develop radiographic signs of CHD (5, 13). However, a study evaluating the Ortolani test in dogs between 6-10 weeks of age, demonstrated a low sensitivity for identifying dysplastic dogs (55%), and because of that, caution should be taken when categorizing a puppy as free of hip dysplasia using the Ortolani test alone. Ideally, this test should be used as a screening tool along with other tests.

A reliable orthopaedic exam requires effective methods of result optimization such as DI measurements which may be better suited for the confirmation of a diagnosis (33). The change in the surgery solutions paradigm resulted in the application of goniometric study results as they are now considered critical for surgical management. Goniometric examinations consist of measurements of the reduction angle (RA) which is the degree of abduction of the femur, at which point the femoral head can be reduced to the acetabulum and subluxation angle (SA). Studies conducted by Vidoni and Tavola demonstrated that the Ortolani test and RA measurements appears to be superior over other manual methods of confirming joint laxity (22, 35). Many

imaging modalities such as radiography, computed tomography (CT), ultrasound, and magnetic resonance imaging (MRI) can be used in the assessment of canine patients with hip dysplasia. Several radiographic projections and methods have been proposed to evaluate and screen patients. The most commonly reported techniques include hip-extended radiography, Norberg angle (NA), distraction-stress radiographs, and the dorsal acetabular rim (DAR) view.

Combining different diagnostic methods gives the best results of forming a successful prognosis concerning the progress of OA. According to Todhunter, the most effective method is assessing the percentage value of dorsolateral subluxation dorsolateral subluxation score (DSL) while simultaneously assessing the Norberg angle (36). Conventional hip extended radiographs are still the most popular method for the evaluation of OA and are useful as a screening tool for joint laxity. However, other X-ray methods such as PennHip distraction radiography or the Vezzoni modified Badertscher distension device technique have been shown to improve the sensitivity of laxity detection, this allows for a more objective means of evaluation, and further aids in the prediction of future osteoarthritis development in younger animals (2, 4). The modern CHD management approach is unequivocal and surgical procedures also play a key role. Some authors have emphasized that the surgical approach seems to be more effective for young patients than a conservative treatment (39). Nevertheless, surgery candidate selection plays a major role. Several important characteristics must be considered for a dog to qualify for surgery. The presence of comorbidities affecting bone healing should always be considered in decision making. The dog must be of the appropriate age, a minimum of 5 months for double pelvic osteotomy (DPO) and 6 months for triple pelvic osteotomy (TPO) is necessary to obtain the proper mechanical strength of the bone tissue. A recent study concerning DPO strongly suggests that the older the dog is, the higher the complication rate which may be expected (7.8% for 5 mo., 8.6% for 6-7 mo. and 14.5% for > 7 mo.) (39). This may be correlated with excessive rigidity in the region of the ischial growth plate and pubic symphysis (39).

The main indications for osteotomy procedures are severe coxofemoral joint laxity with radiological changes suggesting high odds of CHD development, but without concurrent OA changes at the moment of presentation. Selected patients have to demonstrate intact lateral acetabular rim with a DAR value of not greater than 25 degrees and the difference between RA and SA ≥ 15 degrees and a DI of at least 1 (39). The NA value which is measured in VD radiographs should be considered as well. In a healthy hip joint NA should be equal to or greater than 105 degrees (39). Vezzoni, Santana and other authors strongly suggest including

femoral head coverage (FHC) for modern diagnostic protocols (39). Passive hip laxity (PHL) excludes dogs due to its low chance of preventing the femoral head from subluxating. PHL is considered to be the primary risk factor for CHD and is estimated using the distraction index (DI). Therefore, dogs with low FHC and a severely damaged dorsal acetabulum are poor candidates because adequate FHC after surgery is unlikely to be obtained. Furthermore, if osteoarthritic changes are present, the outcome of the surgery may be questionable.

Surgical management

Regarding the complex etiopathogenesis of CHD, numerous surgical techniques have been proposed and the recommended type of surgery should be selected depending on the severity of the disease and the dog's age. In 2000 Scot Swainson first reported Juvenile pubic symphysiodesis (JPS) as a suitable procedure in dogs (32). JPS is a minimally invasive surgery performed on puppies between 3 and 5 months of age. The aim of the procedure is the early closing of symphyseal cartilage with thermal injury. As a result, the shortened pubis puts limitations on ventromedial acetabular growth. As the more dorsally located ilium and ischium continue to grow, the acetabulum rotates ventrally, and this results in a better dorsal coverage of the femoral heads and a decreasing tendency for subluxation. It is possible to measure acetabular ventroflexion using many different methods. Two of the most reliable include the dorsal acetabular rim angle (DARA), which may be determined using plain radiographs or transverse CT and the acetabular angle (AA), which is determined using transverse CT (12) (Fig. 2).

The goal of every CHD surgical procedure is to obtain the appropriate FHC which is suggested to be between 50% and 80%. Recent studies of other pelvic

osteotomies techniques, including the TPO procedure suggest that a 12.5 degree pelvic plate is adequate in order to obtain an appropriate degree of FHC. However, in this study DARA and AA were not measured (16). In studies that were used to evaluate changes in acetabular ventroversion after JPS in dogs, DARA was significantly reduced by 7.7 degrees 2 years after surgery and AA was significantly improved by 19 degrees after the same time period had elapsed (8). Due to the fact that AA represents the combined ventral angulation of both hips, half of the change in AA obtained using JPS should be comparable to the ventroversion measurement results obtained from the triple plate pelvic osteotomy (TPO) plate angle. In the author's opinion this may suggest that FHC is suboptimal compared to a 12.5 to 20 degree TPO plate acetabular rotation but further research is required. In dysplastic dogs, the pelvic inlet was 24% smaller after JPS 2.5 years after surgery as compared to those of the control group. This may increase the risk of dystocia developing in female dogs; however, no clinical example of this has been published to date (7). Currently 3 variations in pelvic osteotomy procedures have been described and are in clinical use: DPO, TPO and 2,5 DPO. TPO is the most thoroughly described of the surgical methods used for CHD treatment. The TPO technique was created by Slocum and has been described as a three-step pelvic osteotomy where the pubic, ischial and iliac bones are transected (31). The iliac cut should be fixed using a TPO bone plate, the ischiatic segments may or may not be connected with cerclage wire. When an osteotomy or minor ostectomy is performed, the pubic segments don't need to be fixed. A new, special type of bone plate has been designed for this procedure and patented.

Originally, bone plate stabilization was based on a lock made through contact between two surfaces

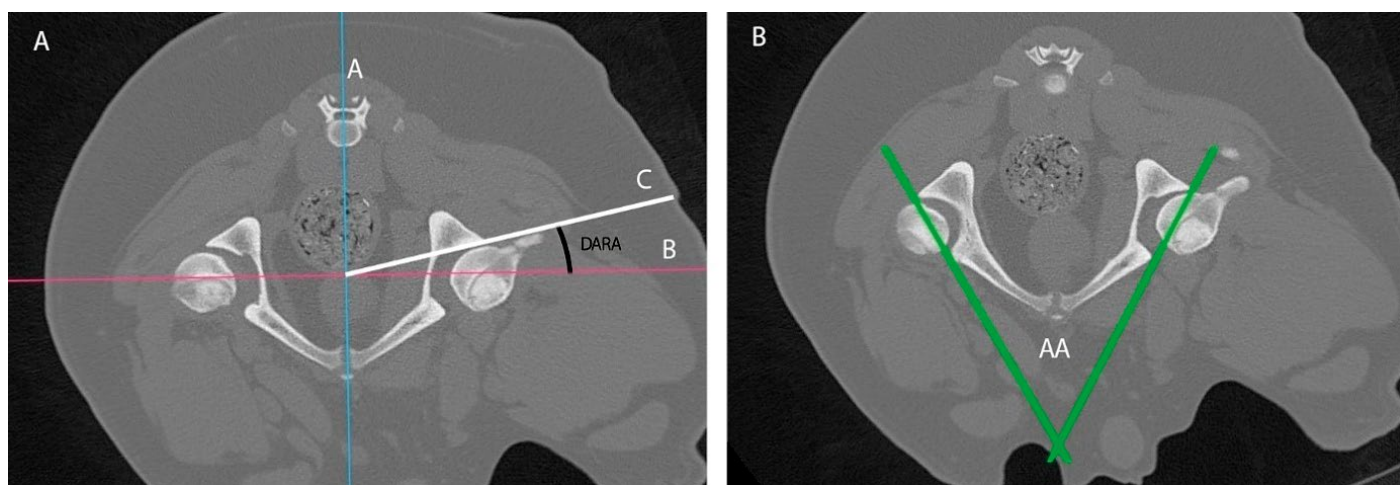


Fig. 2. Transverse pelvic CT images

Explanations: A line – the central pelvic height line, C line – the line superimposed on the plane of each dorsal acetabular subchondral articular surface, the B line is drawn at the point at which the DARA lines intersect. The determination of AA is performed on a transverse CT image taken at the midpoint of the acetabulum. Lines are drawn from the dorsal acetabular rim to the ventral acetabular rim of each hip and extended ventrally

(bone-plate), and supported by the compressive forces exerted using bone screws. This technique rapidly gained popularity. It also quickly evolved through successive patent applications made by many authors. The first significant solution was offered by Robert L. Rooks (26). Some important features of the application were that one side of the plate had sharply angled surfaces to accommodate the rotated portions of the pelvic bones while the other side of the plate was seamlessly continuous and facilitated a more stable direct insertion of the bone screws to prevent an uneven pressure being applied to the bone screw holes (27). The proposed shape of the eight-hole plate increased the stability of the fixation of the plate and certainly represented progress. Unfortunately, the proposed solutions did not significantly improve the surgical complication statistics. The original paradigm established by Slocum was changed in the patent of Bruecker et al. (3) with the use of locking screws set in a multi-plane system. This significantly improved the statistics concerning early and mid-term postoperative complications, i.e. bone screw loosening and implant failure.

Further research focusing on the functionality of TPO/DPO plates and bone screws showed the need to integrate the so-called hybrid holes into the previously used patterns, experiments with the use of hybrid holes which are commonly known as „combi sockets”, allowed for the compression of fragments. The solution to these observations was a patent application (27). In this application, the authors presented a TPO/DPO plate with slots enforcing multi-plane screw guidance, it is equipped with one or two „combi” holes. This allowed for the selective compression of the two bone fragments as a result of the wedge tension generated during the fixation of the bone plate. This solution turned out to be very beneficial, because the screws may be locked (or not) on the board, depending on the operator's decision. At present, TPO/DPO plates produced in a recognized pattern have a standard length of the cranial and caudal (Fig. 3) aspect as well

as a standard number of holes and a standard distance between the holes (3). As a consequence of the various transformations and evolutionary changes, the currently used TPO plate consists of two ribbons that are not parallel to each other and are rotated on the long axis (β angle, Fig. 3.). Different cases of CHD require the use of plates with different β angles in order to provide the best possible cover to the femoral head. Studies and clinical observations show that this solution may be sufficient in a TPO osteotomy, because in this case the ischial bone plate is transected in the procedure, which relieves stress in the caudal aspect of the osteosynthesis of the iliac shaft.

Pelvic osteotomy implants are inserted with a specific amount of rotation, typically 20, 25, 30 and 40 degrees. The method used to select the amount of ventral acetabular rotation required has however not yet been clearly established to date. The plate angle used may be based on an attempt to achieve a final result of 5 degrees in excess of the subluxation angle. This strategy can result in the use of TPO plates angled at 30 degrees or more (13). Using plates with angles in excess of 20 degrees may cause excessive FHC (> 80%) in a number of cases (38). Excessive coverage has been associated with postsurgical complications that may include a decreased range of motion, gait abnormalities, abnormal abduction stance of the limb, hip pain, and lameness. The results of some studies suggest that increasing the plate angle over 20 degrees, doesn't correspond with any significant gain in hip joint contact area (6). In another study, 12.5 and 20 degree angled plates were compared and showed sufficient FHC in both variants, with a significantly decreasing occurrence of excessive FHC in the 12.5 degree group (16). Some authors, however, have used 60 degree angled plates as an alternative to total hip replacement (THR) and observed a subjective clinical improvement (10). In September 2006, at the 13th ESVOT Congress in Munich (Germany), P. H. Haudiquet and J. F. Guillon presented an *in vitro* study in which the performance of an osteotomy of the iliac and pubic bones, but omitting the ischium, resulted in a significant ventral acetabular flexion with a lateral rotation of the ilium and pubis, and a deformity of the ischium called a double pelvic osteotomy (DPO). The aim of the new technique was to simplify TPO and reduce the incidence of complications that had not been solved through previous modifications and innovations, i.e. the narrowing of the pelvic canal, excessive coverage of the femoral head by the acetabulum and the subsequent irritation of the femoral head, which resulted in the delayed healing of the iliac and ischial osteotomy sites. The results of the study were encouraging with regard to the degree of coverage of the femoral head by the acetabulum: DPO with a 25° hip rotation appeared to produce the same radiographic effect regarding cup coverage as the 20° rotation TPO technique. In addition, the new

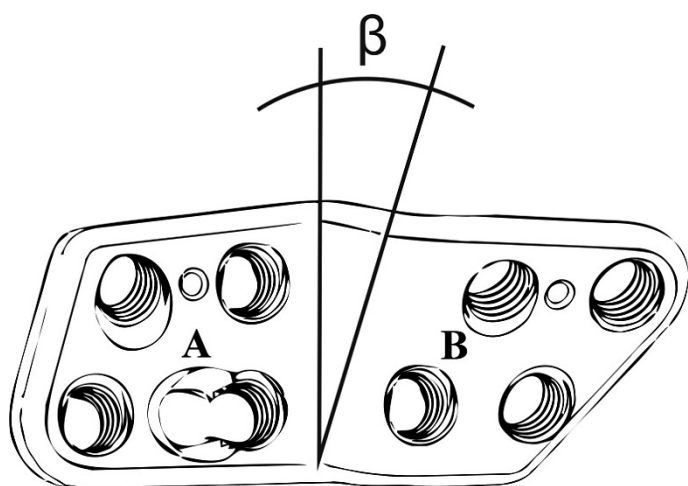


Fig. 3. Standard, locking screws DPO/TPO plate
 Explanations: A – cranial aspect, B – caudal aspect

technique eliminates the problem of the postoperative narrowing of the pelvic canal in 100% of cases. A recent study on the numerical model for the optimization of DPO implants has revealed that very pronounced acetabular ventroversion may lead to bone failure (44). The reason for this is the considerable stresses in the caudal aspect of the osteosynthesis of the iliac shaft (part B of the plate), which very often, in 70% of cases in fact, ends in the destruction of the entire osteosynthesis. The introduction of new solutions, such as the TPO/DPO multi-faceted plates (allow for the introduction of screws at different angles) and the development of new surgical techniques, i.e. Double Pelvic Osteotomy – DPO and 2.5 Pelvic Osteotomy – 2.5 PO, reduced the invasiveness of the procedure. The total rate at which complications develop as compared to the TPO technique is much lower because of the specific stability of the DPO (no need to cut the ischial plate). The potential advantages of a double pelvic osteotomy (DPO) also include the improved immediate postoperative comfort, and a much lower morbidity rate for unilateral or bilateral DPO as compared with TPO (13). Performing only 2 osteotomies may result in a more biomechanically stable construct that will better withstand the forces produced by young, active large breed dogs and result in less implant loosening and failure than TPO. However skipping the ischial transection changes the bone geometry in comparison to the TPO procedure which results in a need for the use of bone plates with a greater rotation angle. It has been shown that a 25° DPO plate allows one to obtain acetabular ventroflexion comparable to a 20° TPO plate (25). Although there may be benefits to leaving the ischium intact, there are also potential disadvantages to not performing an ischial osteotomy. Above all, achieving an acetabular ventroversion with DPO depends on plastic deformation including the flattening of the pubic symphysis (25). As a result, the intraoperative rotation of the acetabular segment during DPO is subjectively more challenging than with TPO and particularly with bilateral procedures (39). Although achieving the desired amount of rotation during DPO presents additional difficulties, these challenges may be outweighed by potential benefits especially those related to postsurgical complications. The 2.5 PO procedure is a modification of DPO in which the ischium is not fully transected. First, a 1.5 mm drill hole is made through the dorsal and ventral ischial cortices in a dorsoventral direction. The drill hole is at the lateral aspect of the obturator foramen, midway from the cranial to the caudal in the sagittal plane. Next, a dorsal cortical osteotomy is performed along this line using a reciprocating saw to a depth of 50% of the 1.5 mm drill hole, this was measured using a depth gauge in a ventral to dorsal direction. This technique allows for a larger acetabular ventroflexion angle (1.5 ± 0.6 degrees) (33).

Complications

The overall complication rate was 17.5% to 20.7% with the following problems being defined: implant failure, distal hip fracture (3.5-6%), partial dislocation of the plate (9.4%) and incomplete fracture of the ischial bone plates (7.5%). Similar data from own observations were provided by B. Peroni; implant failure with screw loosening (6%), fracture of the ischial bone plate (3-9%), fracture of the distal iliac bone (3%); distal hip fracture due to the non-functionality of the locking screws (3%) (38). The postoperative complications described above usually occur within the first month after the procedure and mainly concern the breaking of the screws in the distal portion of the osteotomy. The literature emphasizes that the degree of rotation of the ilium in the distal aspect, relative to the osteotomy site, is dependent on the shape of the ischial bone plate and the possibility of cartilage bending/flexibility of the pubic symphysis in growing dogs. It also emphasizes that this flexibility has a direct impact on the stability of the fixation of the plate with a distal fragment of the osteotomy. In cases of failure, the consequences for the patient are severe. The need for another operation and preparation for surgery is particularly difficult for the animal and requires a period of rehabilitation and recovery. Moreover, the loss of stabilization may leave the patient in a worse condition than before the operation. This result strongly suggests the need for further investigation in this field in order to establish the most optimal algorithm for choosing the plate angle. There is no statistically significant difference in complication odds between patients undergoing unilateral and bilateral surgery (37).

The previously reported complication rate for TPO ranges from 35% to 70% (4, 15, 28). The most common include screw loosening and implant failure. Additional complications include a decreased range in joint motion caused by the effect of FHC on the dorsal acetabulum, pelvic canal narrowing, pain, infection, ilio-psoas impingement, iatrogenic sciatic nerve injury, the progression of degenerative joint disease, dysuria caused by urethral impingement, constipation due to pelvic inlet narrowing, the delayed healing of the iliac and ischial osteotomies and pain, especially after bilateral surgery (39). The complication rate related to plate angle is higher for 30 degree plates than for 25 degree plates (9.4 vs. 6.1%). Higher traction forces act on the caudal part of the plate: in cases where further rotation of the ilium is required, this is probably the cause (35). One of the “game changers” in the techniques used to perform pelvic osteotomies was the implementation of locking screw systems for traditional pelvic plates. Recent studies have shown a tremendous decrease in screw related complication to 0.5% (34). Locking technology reduces the need for precise plate contouring because the locking screws do not rely on friction

between the plate and the underlying bone and this may significantly reduce the incidence of screw loosening. Locking implants creates a monolithic construct that eliminates motion between the components: the plate, the screws, and the bone. Monolithic constructs are 4 times stronger than load-sharing beam constructs (9). Despite the tremendous progress that has been made in the field of implants technology, screw loosening remains the most frequent complication (37% of all). Solution reducing traction forces has been proposed and was patented in 2012 (28). The further development of plate systems would involve the implementation of combi holes which may be used as a standard dynamic compression or a locking hole depending on the surgeon's intention. This solution was patented in 2012 (43).

Conclusion

The DPO procedure is considered to be preferable to TPO because it eliminates the need for ischiatic transection, thereby reducing the rate of complications and discomfort and increasing pelvic stability (38). It is nevertheless a more demanding procedure compared to TPO, requiring a more difficult intraoperative torsion of the caudal iliac segment in order to achieve the required acetabular ventroversion. The most recent study with DPO assessed the long-term health outcome of young dogs with hip dysplasia that either underwent DPO or were not treated, showing that DPO significantly reduced the progression of radiographically visible degenerative changes; however, these results weren't correlated with the clinical outcome (17). The current literature suggests that both TPO and DPO procedures can improve function in young dogs with dysplastic hips (17, 39). However, despite the improved function of the coxofemoral joint, OA changes may still develop. Data for a long-term follow-up have been reduced to a maximum of 2 years duration; however, the evidence seems more convincing with regard to the benefits as opposed to the drawbacks. The greatest degree of investment and improvement will probably be continued with regards to the matter of making improvements in implants that could potentially provide a reduction in the complications associated with the procedure. Therefore, there is a need to implement a new TPO/DPO locking plate and an updated system to fix it in place, which can be securely stabilized to the hip bone shaft during osteotomy. The aforementioned plate should present the possibility of anatomical adjustment to the bone surface, create the possibility of inducing a selective compression of the osteotomy gap, and allow for a multi-plane setting of the locking screws and ensure the high resistance of osteosynthesis to both the twisting and shearing forces, which are particularly significant in the DPO and 2.5PO techniques.

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