REVIEW

Treatment of hip dysplasia

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Hip dysplasia is a common orthopaedic developmental disorder of dogs. This paper reviews the treatment options available for management of the condition in the skeletally immature and adult dog.

Journal of Small Animal Practice (2011) **52**, 182–189
DOI: 10.1111/j.1748-5827.2011.01049.x

Accepted: 2 February 2011

INTRODUCTION

Hip dysplasia (HD) is a common developmental disorder of the hip joint that is characterised by laxity of the joint and subsequent development of osteoarthritis. It may also develop as a result of altered joint morphology as the primary event. The onset and progression of HD depend upon the interaction of genetic susceptibility and environmental factors. It may develop in any breed of dog but is more prevalent in medium and larger breeds. Discomfort associated with hip laxity commonly appears in young dogs (typically four to eight months of age) (Fig 1), and with the development of joint capsule thickening, periarticular fibrosis and healing of microfractures of the dorsal acetabular rim (Riser 1973) there is usually clinical improvement associated with improved hip stability. Discomfort in the older dog is usually due to the development of osteoarthritis (Fig 2). Although hip laxity predisposes to the development of secondary osteoarthritis, the relationship between the development of osteoarthritis and hip laxity varies between breeds (Smith and others 1993, 2001). Based on breed radiographic distraction index (DI) distribution German shepherd dogs had five times the risk of developing osteoarthritis compared with the combined risk of golden and Labrador retrievers and Rottweilers (Smith and others 2001) with the same DI.

The clinical effects of HD are highly variable with many dogs being asymptomatic or having only mild clinical signs. A smaller number of dogs are more severely affected with significant deterioration in their quality of life. There is a large amount of information on the aetiopathogenesis, clinical assessment and radiographic evaluation of dogs with HD but the purpose of this article was to review treatment of this common disease.

MANAGEMENT OPTIONS

The aim of the treatment is to reduce or eliminate pain thereby improving or restoring limb function to normal. Disease progression may be influenced by conservative management or by specific surgical procedures in the young dog. Salvage surgical procedures can be performed where conservative management fails to result in adequate clinical improvement.

Factors that influence decision-making include age at presentation, severity of clinical signs, severity of radiographic changes (degree of joint subluxation and of osteoarthritis), patient behaviour and potential use, the presence of intercurrent medical or orthopaedic disease and financial constraints.

Conservative management of the young dog

The goal of conservative management of the young dog is to reduce or eliminate pain by a combination of exercise restriction, weight control, analgesics [normally non-steroidal anti-inflammatory drugs (NSAIDs)] and physical therapies. Several long-term studies have evaluated the results of conservative management. Barr and others (1987) reported that 76% of 50 dogs (mean age at presentation of eight months) with moderate to severe radiographic signs of HD followed up for a mean period of 4·5 years had no hindlimb gait abnormality or showed only slight or intermittent abnormalities when evaluated by their owners. From these 50 dogs, 19 were re-evaluated by a veterinary surgeon and 89% showed no gait abnormality or a slight pelvic swaying movement. In contrast to these results, Farrell and others (2007) reported that 42 to 66% of 74 dogs evaluated by their owners (median age at presentation is one year and median follow-up five years) were clinically affected depending on the criterion used for assessment and 40·5% required medication with NSAIDs (daily medication in the majority of cases). Of the dogs that were re-assessed by a veterinary surgeon (24 dogs), 92% were lame and there was a high incidence of pelvic limb muscle atrophy, restricted hip motion and pain on hip extension. However, 33% of these dogs had other pelvic limb abnormalities that were considered to be significant by the veterinary surgeon.

In a study comparing the outcome following conservative management, triple pelvic osteotomy (TPO) and excision arthroplasty, dogs managed conservatively showed more lameness, less gluteal muscling, more pain on hip extension and more restricted extension compared to the other groups (Plante and others 1997a). Although clinical signs were generally mild, owners' evaluation also showed that conservatively managed dogs were less active compared to those managed surgically. Unfortunately a major limitation to this study was small group sizes (total of 20 dogs).

Military working dogs, with a greater athletic requirement than pet dogs, that had mild or moderate radiographic signs of HD showed no difference in the total number of months worked

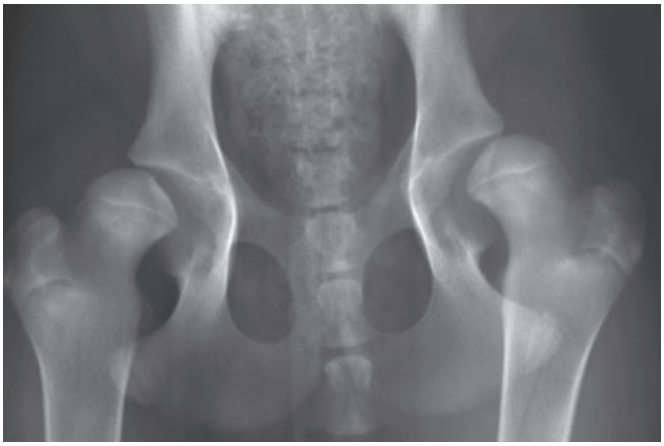

FIG 1. Ventrodorsal radiograph of the pelvis of a seven-month-old dog with HD

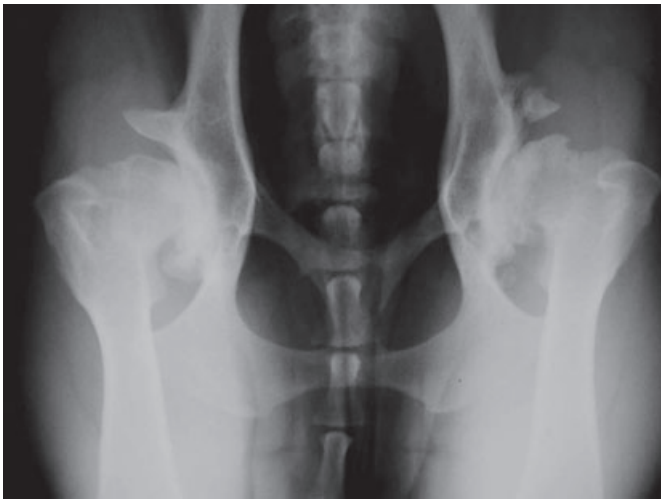

FIG 2. Ventrodorsal radiograph of the pelvis of an old dog with severe hip DJD secondary to HD

compared to dogs without HD (Banfield and others 1996) and the presence of HD was not associated with early retirement in guide dogs (Pfaffenberg and others 1976).

Physical therapies such as hydrotherapy are frequently used in the management of HD and personal experience shows that these can be valuable but there are no published reports on their efficacy.

The role of diet

Diet has been shown to have a significant effect on the development of HD in dogs predisposed to develop the disease and on the prevalence, severity and clinical signs of osteoarthritis. Young Labradors predisposed to develop HD fed a restricted diet (25% less food compared to the control group fed ad lib) from eight weeks to two years of age were found to have less hip joint laxity (evaluated radiographically) at any time point compared to litter mates fed ad lib (Kealy and others 1992). When these dogs were followed up for up to 14 years the restricted-fed dogs were found to have a significantly lower prevalence and later onset of hip osteoarthritis compared to controls (Kealy and others 2000, Smith and others 2006). Overweight adult dogs with clinical signs of hip osteoarthritis fed calorie-restricted diets have been shown to improve significantly at least in the short term (Impellizeri and others 2000, Mlacnik and others 2006). Excess bodyweight will increase stress on weight-bearing joints and this may contribute to degradation of articular cartilage. Obesity is also a known risk factor for the development of osteoarthritis of the hand in human beings suggesting that metabolic factors may also be important (Oliveria and others 1999).

The role of drugs

A wide range of drugs have been used in the management of HD and osteoarthritis in the skeletally immature and adult dog. A review of these drugs is beyond the scope of this article but their efficacy and safety have been reviewed elsewhere (Aragon and others 2007, Sanderson and others 2009, Innes and others 2010).

SURGICAL MANAGEMENT OF HD IN THE YOUNG DOG

Surgery in the young dog can be divided into procedures that aim to prevent or limit the development of HD and subsequent osteoarthritis and salvage procedures whose aim is to reduce or eliminate pain and thereby improve hindlimb function.

Surgical procedures that may prevent or limit development of the disease

Juvenile pubic symphysiodesis: Juvenile pubic symphysiodesis (JPS) is performed by applying electrocautery to the growth plate of the pubis resulting in thermal necrosis of germinal chondrocytes and premature closure of the growth plate (Mathews and others 1996). Uninterrupted growth in other areas of the pelvis results in the acetabulae rotating ventrolaterally over the femoral heads improving hip conformation and stability. The procedure has been performed in experimental guinea pigs and dogs, and studies have shown that the most significant corrections to hip joint conformation and stability are achieved by surgery at an early age (Mathews and others 1996, Swainson and others 2000, Dueland and others 2001, Patricelli and others 2002). Although the procedure results in significant decreases in pelvic inlet diameter, this has not caused any obvious complications (although dystocia is a possibility in bitches). Significantly less improvement in hip joint conformation has been reported in dogs subjected to surgery after 18 weeks of age compared to those operated on at 15 weeks of age or less (Manley and others 2007) but JPS performed at 18 to 22 weeks of age has been reported to be successful in giant breeds because of their more prolonged growth period (Bernarde 2010).

Several long-term studies have shown that JPS does not reduce passive hip laxity (evaluated by DI) or prevent the development or progression of osteoarthritis (Patricelli and others 2002, Manley and others 2007). When dogs have been categorised according to their susceptibility to develop HD using a range of criteria (DI, subjective clinical assessment of hip laxity and other radiographic

features), the procedure has been found to be most successful in dogs with mild or moderate susceptibility (Vezzoni and others 2008). Fewer dogs in these categories showed radiographic progression of HD compared to controls but dogs with the greatest susceptibility to develop HD showed no improvement compared to controls. Although these are encouraging results for dogs with mild to moderate susceptibility to develop HD, surgery must be performed at an early age, and in a proportion of dogs HD and osteoarthritis will still develop although usually with a lower severity compared to untreated dogs having a similar susceptibility (Vezzoni 2008). Dogs with the greatest susceptibility to develop HD (determined by DI and subjective assessment of laxity) are unlikely to benefit from JPS (Vezzoni and others 2008), and those with a very low susceptibility to develop HD (where DI is reported to be below 0·3) are not candidates for this procedure.

Advantage of JPS is that it is a simple and quick surgical procedure that requires no orthopaedic implants and results in bilateral acetabular rotation and could be combined with early neutering which should be considered mandatory given the alteration in phenotype. There is an early return to normal activity and complications of surgery are rare although iatrogenic injury to intrapelvic structures, especially the rectum and urethra, are possible.

Triple pelvic osteotomy: The concept of rotating the pelvis to improve coverage of the femoral head was established in human beings in the 1960s for treatment of congenital dislocation of the hip in children (Salter 1961). The use of TPO to treat dogs with HD was first reported in 1969 (Hohn and Janes 1969). The goal of TPO is to prevent subluxation of the femoral head by increasing dorsal acetabular coverage and is achieved by osteotomies of the ilium, ischium and pubis (Figs 3 and 4). The ilial osteotomy is stabilised with a bone plate that maintains the acetabular segment rotated to the desired angle (Slocum and Devine 1986). There is some controversy regarding the selection criteria for the procedure, particularly with regard to the severity of hip instability (assessed by clinical and radiographic assessment) and whether dogs with pre-existing osteoarthritis should be potential candidates. Preferred candidates for the procedure are those with pain on hip manipulation and lameness without excessive laxity assessed by manual subluxation and reduction of the hip (assessment under deep sedation or general anaesthesia) and radiographic evidence of mild to moderate hip subluxation with no or minimal radiographic evidence of osteoarthritis on a standard hip-extended ventrodorsal projection. Some authors have advocated the use of other radiographic techniques such as the dorsal acetabular rim view to provide information that may assist in case selection (Slocum and Slocum 1992). Arthroscopic evidence of cartilage degeneration has been reported in 80% of dogs with HD and no radiographic evidence of osteoarthritis but animals with the most severe cartilage lesions were more likely to show radiographic abnormalities (Holsworth and others 2005). However, the relationship between pre-existing cartilage lesions and long-term clinical success of TPO has not been determined although progression of osteoarthritis is likely.

Early reports of TPO suggested that the procedure halted or even reversed radiographic signs of osteoarthritis (Slocum and Devine 1987). More recently a number of studies have shown that TPO does not stop the development or progression of osteoarthritis particularly if case selection is inconsistent or lacking strict criteria (Johnson and others 1998, Rasmussen and others 1998). Age at the time of surgery influences development of osteoarthritis, with dogs on average seven months old at the time of surgery being 7 times less likely to develop osteoarthritis compared to dogs having surgery at 12 months of age (Rasmussen and others 1998) and this may relate to the ability of joint surfaces to remodel more effectively in the younger dog. Dogs with mild pre-existing osteoarthritis have not been shown to have a worse functional outcome compared to those with no osteoarthritis at the time of surgery (Rasmussen and others 1998).

Since TPO was first described there have been many reports on the technical aspects of the surgery and variations in technique. As per the early reports, the TPO rotated the acetabular segment up to 90° (Slocum and Devine 1987). Subsequent in vitro and in vivo analyses comparing different angles of acetabular rotation have shown that beyond 20° of rotation there is no

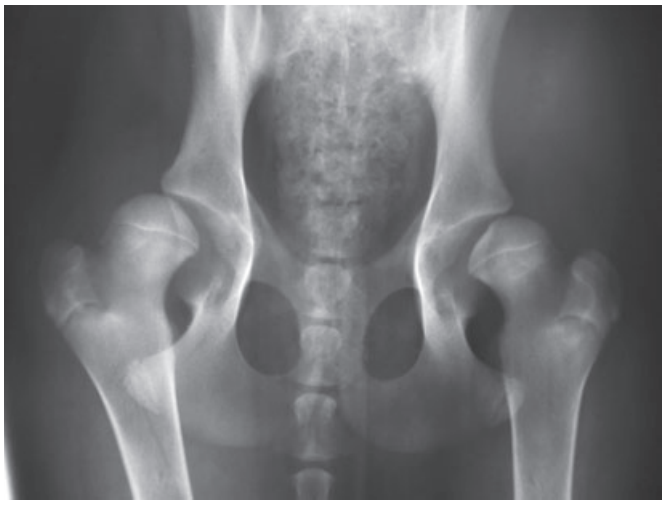

FIG 3. Ventrodorsal radiograph of the pelvis of a seven-month-old St Bernard with bilateral HD

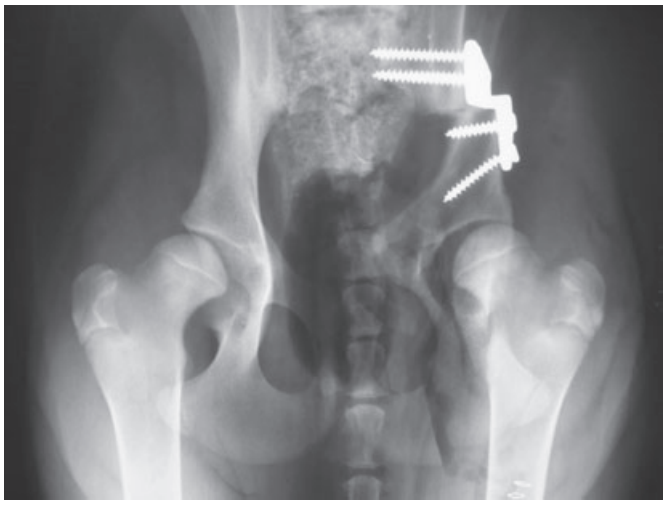

FIG 4. Ventrodorsal radiograph of the pelvis of the dog shown in Fig 3 following TPO

improvement in contact area between the femoral head and acetabulum or radiographic indicators of subluxation (Dejardin and others 1996, 1998, Tomlinson and Cook 2002). Additionally, rotation beyond 20° will significantly reduce pelvic inlet area, increasing the risk of constipation and may decrease the range of extension, flexion and abduction of the hip (Graehler and others 1994). Excess rotation could also result in femoral neck impingement on the acetabulum and medial subluxation of the hip (Slocum and Slocum 1992).

The subjective clinical results of large numbers of dogs have been reported following TPO and have shown good or excellent results in most dogs with an improvement or resolution of lameness and improved function compared to that before surgery (Slocum and Devine 1986, Borostyankoi and others 2003). Objective assessment using force plate analysis has shown that it may take 5 to 10 weeks for vertical forces in the treated limb to reach pre-operative status and 28 weeks before they approach or reach the levels recorded in non-dysplastic dogs (McLaughlin and others 1991). However, one study failed to demonstrate any improvement in ground reaction forces following bilateral TPO compared to dysplastic dogs managed conservatively (Plante and others 1997b). Increased weightbearing in the non-operated limb could result in acceleration of remodelling and degenerative changes, suggesting that when surgery is to be performed bilaterally the interval between surgeries should be kept to a minimum (several weeks) or single session bilateral TPO may be applicable where both hip joints are considered to be suitable for the procedure (Borostyankoi and others 2003).

A number of complications have been reported following TPO including constipation due to pelvic canal narrowing, sciatic and pudendal nerve injury and dysuria associated with urethral compression from the pubic rami (Slocum and Slocum 1992, Papadopoulus and Degna 2006). Excessive rotation of the acetabular segment can result in bony impingement on the femoral neck resulting in an abnormal gait. Screw loosening is a common complication and can result in poorer limb function (Hosgood and Lewis 1993), loss of alignment between ilial segments and surgical failure. Most studies document a higher incidence of screw loosening in the cranial ilial segment compared to the caudal ilial segment (Hosgood and Lewis 1993, Remedios and Fries 1993, Doornink and others 2006) but this may be minimised by inserting screws to their maximal sacral depth (Whelan and others 2004). The application of an additional plate to the ventral aspect of the ilium may decrease screw loosening (Fitch and others 2002).

Recently a double pelvic osteotomy has been reported and the surgical technique is similar to TPO but only the ilium and pubis are osteotomised (Vezzoni and others 2010). The morbidity of this procedure has been reported to be lower than following TPO because of improved pelvic stability as a result of eliminating the ischial osteotomy (Vezzoni and others 2010).

Femoral neck lengthening (increasing the distance from the femoral head to the greater trochanter) has been advocated as an adjunctive procedure in breeds that have a high incidence of a shortened femoral neck to improve the mechanical function of the gluteal muscles (Slocum and Slocum 1992). The effectiveness of this procedure has not been established.

PALLIATIVE SURGICAL PROCEDURES

Denervation of the hip joint capsule

Denervation of the hip joint has been reported as a palliative treatment for pain related to HD. The procedure involves curettage of the craniodorsal rim of the hip joint with transection of microscopic nerves supplying the joint capsule possibly combined with elevation of the joint capsule ventrally. Reports of success appear to be very variable with 50 to 96% of dogs showing improvement (Kinzel and others 2002, Lister and others 2008) and gait analysis has confirmed improvement in ground reaction forces in a significant number of dogs (Lister and others 2008). The procedure has few potential complications and could be a valid treatment option although osteoarthritis is likely to progress.

Palliative surgical procedures described in the literature but rarely performed

A shelf arthroplasty was developed as a procedure that could be employed in dogs where the dysplastic changes were too severe to consider TPO or where financial constraints preclude total hip replacement (THR). The procedure involved placing a block and fibres of biocompatible osteoconductive polymer dorsal to the hip joint with the aim of improving hip stability and encouraging bony ingrowth, thereby creating a bony shelf or extension to the rim of the acetabulum (Jensen and Sertl 1992). Although some clinical success of this procedure has been reported (Jensen and Sertl 1992, Oakes and others 1996), the polymer has subsequently been found not to be osteoconductive and can elicit foreign body reactions (Trevor and others 1992) and the procedure is not routinely performed.

An intertrochanteric femoral osteotomy was developed to improve the contact area of the femoral head with the acetabulum by varisation, normoversion and medialisation of the femoral head and neck (Prieur 1987). This was achieved by removing a medially based wedge from the proximal femur just distal to the greater trochanter and stabilising the osteotomy with a double hook plate, having made the above corrections (Prieur 1987). Although good or excellent results have been reported in up to 90% of skeletally immature and adult dogs (Walker and Prieur 1987, Evers and others 1997), the procedure does not prevent the progression of osteoarthritis (Braden and others 1990) and is rarely performed.

A number of other palliative procedures have been reported including pectineus myotomy or myectomy (Vaughan and others 1975) and dorsal rim acetabuloplasty (Slocum and Devine Slocum 1998) but these procedures do not alter the progression of osteoarthritis and are rarely performed.

SALVAGE PROCEDURES

Excision arthroplasty

Femoral head and neck excision results in a pseudoarthrosis with remodelling of the acetabulum and proximal femur that continues

for years after surgery. There is a general agreement in the literature that bodyweight influences outcome, with small dogs performing better after surgery than large dogs (Duff and Campbell 1977, Gendreau and Cawley 1977, Montgomery and others 1987). However, some authors report only fair or poor outcomes in dogs with relatively low average weights of 12 to 17 kg (Gendreau and Cawley 1977). Better results for dogs of this size or heavier with HD were reported by Berzon and others (1980) but outcome measures were less stringent and postoperative assessment was undertaken only by owners. Unfortunately most of the dogs that presented with clinical problems with HD at any age are over 20 kg, where outcome following excision arthroplasty is more variable compared to lighter dogs. Plante (1997a,b) reported that bilateral excision arthroplasty was a more effective treatment for HD compared to conservative management but the results were not as good when compared to dogs subjected to TPO.

Variations in surgical technique have been reported including the use of muscle slings (Tarvin and Lippincot 1987) but none have been shown to affect long-term outcome (Montgomery and others 1987, Lewis and others 1988) although better limb use was demonstrated in a small number of dogs up to three weeks following surgery compared to those without a muscle sling (Prostredny and others 1991).

Common long-term problems include persistent lameness, discomfort after excessive exercise, stiffness in cold weather and difficulty jumping and climbing stairs. Common findings on re-examination include restricted extension and pain on extension of the hip, limb shortening and muscle atrophy which are more prevalent in larger breeds (Duff and Campbell 1977). Patellar instability (in the operated and non-operated limb) appears to be commoner in small breeds of dog but is rarely of clinical significance (Duff and Campbell 1977).

Good results can be obtained from excision arthroplasty but success is likely to depend on factors such as individual temperament, bodyweight and conformation, severity of muscle atrophy at the time of surgery and postoperative physical activity. Better results may be obtained in younger patients with good muscle mass. Physiotherapy and hydrotherapy may be very valuable following surgery but their efficacy remains to be confirmed by appropriate studies.

Total hip replacement

Total hip replacement (THR) is generally considered to be the salvage procedure that most effectively provides pain relief and results in the best performance in dogs with HD and osteoarthritis. It can be performed from 9 to 10 months of age (when longitudinal bone growth has ceased), and with advances in implant design there is virtually no lower limit to the size of dog that can have the procedure. The procedure can be performed bilaterally although unilateral THR results in acceptable function in 80% of dogs with bilateral HD (Olmstead and others 1983). A number of cemented (Fig 5) and cementless systems are commercially available but it is unclear whether there are advantages or disadvantages to their use in different clinical situations in HD. It may be that biological fixation in a younger patient with a more active lifestyle and longevity is advantageous. However, older patients

FIG 5. Ventrodorsal radiograph of the pelvis of an adult dog following cemented total hip replacement

with more questionable bone quality or where there are anatomic features that are not ideally suited to a press-fit fixation may be better suited to cemented implants. Recommendations relating to the optimum hip system for patients of different ages with different activity requirements remain to be established in the veterinary literature. The results of cementless THR in young patients (4·5 to 8·5 months old) have been reported and the complication rate is higher than in adults using the same implant system but recovery from surgery is quicker (Vezzoni 2008). There are also concerns regarding the survival and longevity of the implants, particularly polyethylene wear of the acetabular component. A problem that is encountered in some dogs with HD requiring surgery is inadequate dorsal acetabular bone stock where there is insufficient bony coverage for the acetabular component. This can be addressed by augmenting the dorsal acetabular rim with a corticocancellous graft made from the excised femoral head (Pooya and others 2003).

Good or excellent long-term function (no or mild intermittent lameness) is reported in 91 to 98% dogs following THR (Olmstead and others 1983, De Young and others 1992, Massat and Vasseur 1994, Marcellin-Little and others 1999). Good or excellent outcome has been reported in 83% of smaller dogs

FIG 6. Jack Russell Terrier (5 kg) with dysplasia of its left hip

FIG 7. Ventrodorsal radiograph of the pelvis of the dog shown in Fig 6 showing left cemented total hip replacement

(average weight 19 kg) using a cemented miniature prosthesis system (Warnock and others 2003). A cemented micro-system is available for dogs (and cats) under 12 kg in weight and an excellent outcome has been reported in 91% of patients (median bodyweight 6·4 kg, Liska 2010) (Figs 6 and 7).

Many complications have been reported following cemented and cementless THR including luxation, infection, aseptic loosening, femoral fracture, cement granuloma and subsidence (femoral component in cementless systems) (Olmstead and others 1983, Marcellin-Little and others 1999, Guerrero and Montavon 2009). The success rate for treating complications varies significantly depending on the nature of the complication.

CONCLUSION

Dogs with HD and osteoarthritis have a wide range of treatment options potentially available to them. The management of the skeletally immature dog with HD is controversial. Very few studies have investigated the long-term results of conservative management and one of these studies showed that a significantly higher proportion of dogs remained clinically affected compared to previous studies (Barr and others 1987, Farrell and others 2007). However, it is clear that many dogs perform well as family pets and working dogs and do not require treatment as they grow older.

In contrast, there are large numbers of reports of surgical treatment of HD in young dogs. A review of this literature has shown that some studies potentially have statistical errors or inadequate study design (Kapatkin and others 2002). Early surgical intervention in the appropriately selected patient can lessen the severity of HD and although osteoarthritis may still result, its severity may be less than if the patient had not been treated. Although as a generalisation the radiographic severity of osteoarthritis does not correlate well with its clinical effects, some authors have shown that dogs with the most severe osteoarthritis are more likely to suffer more severe clinical signs (Banfield and others 1996). It may also be the case that dogs with milder disease as a consequence of intervention function better in the long term but this needs to be established by an evidence-based approach using a wide range of veterinary and owner outcome measures. The latter can provide valuable information although it may not correlate with a veterinary assessment (Innes and Barr 1998). Demonstrating a positive patient-orientated outcome may be more important than demonstrating disease-orientated outcome (Kapatkin and others 2002). For example, it is more useful to know whether immature dogs subject to disease-modifying surgery are less dependent on medication later in life, function better and do not require further surgery than to know what extent there is improvement in femoral head coverage or development of osteoarthritis. As our understanding of breed-specific variation in susceptibility to develop osteoarthritis improves, this information may be used to assist in case selection for procedures whose aim is to modify disease progression. Rather than adopting a universal approach to patients, information such as breed susceptibility to develop osteoarthritis and the potential function of the patient (pet *versus* working) could be used to tailor treatment. It is clear that there is a need for more well-designed long-term evaluation of some treatment options with appropriate controls before firm conclusions can be drawn on the optimum management for many patients.

Conflict of interest

The author of this article has no financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper.

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