Introduction

Spinal arthroplasty offers an exciting alternative to fusion for the treatment of degenerative disc disease. Currently, the main indication for disc prosthesis in small animals is the treatment of disc-associated cervical spondylomyelopathy in dogs, also known as disc-associated wobbler syndrome (DAWS) (see Chapter 7). Another potential indication is the treatment of disc-associated lumbosacral stenosis (see Chapter 32). DAWS in dogs shares many similarities with cervical spondylotic myelopathy in people, and the Doberman breed has been proposed as a natural model to study the disease in humans [1].

The knowledge gained over the last 15 years in people with disc arthroplasty can be applied in veterinary medicine for the treatment of DAWS. However, this information should be interpreted cautiously by veterinarians because of biomechanical differences in dogs such as greater axial forces and greater amount of coupled motions in dogs compared to people [2, 3].

The goal of cervical arthroplasty is to preserve intervertebral mobility while providing distraction, stability, and neural decompression [4–6]. Cervical disc arthroplasty involves discectomy, spinal cord decompression, milling of the vertebral end plates, and placement of a device to maintain distraction and preserve intervertebral mobility at the treated space [4–11]. Maintenance of motion at a decompressed interspace may result in improved load transfer and reduced stress on the adjacent intervertebral discs and dorsal elements, although this has not yet been demonstrated conclusively in the canine spine.

Comparison of DAWS in people and in dogs

In people with cervical myelopathy and radiculopathy secondary to degenerative disc disease, anterior cervical discectomy and fusion (ACDF) is a reliable surgical treatment with a satisfactory outcome in 90–95% of patients [12]. However, there is a significant incidence of disc disease at adjacent sites causing recurrence of neurologic symptoms, termed domino effect [12–14]. Within 5 years of surgery, 92% of patients have radiographic
evidence degenerative disc disease at adjacent segments, and by 10 years, about 25% of people require a second surgery for the same problem at an adjacent space [12, 14]. The cause of this subsequent disc degeneration remains unknown. One suggested factor is an increase in intradiscal pressure at adjacent discs after fusion [15–18]. This increased pressure blocks the diffusion of nutrients from the end plate and is the most significant cause of disc degeneration [19].

Clinical studies using dynamic radiography show increased motion at adjacent segments above and below the level of cervical fusion, and this is also a factor associated with deterioration [20, 21]. After arthroplasty, the range of motion is increased or maintained in the surgically treated segment and mildly decreased at adjacent levels. However, this reduction is compensated by the movement of the artificial disc itself [22].

An interesting dilemma regarding domino lesions is whether such lesions are the natural progress of an underlying similar process at the adjacent vertebral motion units or if they are an accelerated degenerative process influenced by the biomechanical effect of fusion [21–23]. Motion preservation at the surgery site may reduce the rate of adjacent-level cervical disc disease [24–28].

Cervical disc prosthesis in people

The use of a cervical disc prosthesis in human patients was first reported by Ferstron in 1966 [29]. Over the last decade, clinical experience with many different types of artificial discs has been reported, including Cummins artificial cervical joint [30] (which evolved into Prestige [31], ProDisc-C [32], Bryan Cervical Disc [33], Discover [34, 35]), and several clinical trials are currently underway [28].

Classification of artificial discs

Currently, artificial discs are classified into three types: non-, uni-, and biarticulating. The implant may consist of a metal-on-metal design, metal-on-polymer (ultrahigh-molecular-weight polyethylene), and less commonly ceramic-on-polymer or a ceramic-on-ceramic design [36]. The disc is either modular (having replaceable components) or non-modular (without replaceable components, and some are used in conjunction with supplemental vertebral body screw fixation [36]. Certain designs promote biological bone ingrowth at the disc-end-plate interface. In terms of motion, artificial discs may be constrained, semiconstrained, or unconstrained [36]. Devices are considered constrained in certain planes if they restrict motion to less than that seen physiologically. Devices are considered semiconstrained in certain planes if they allow motion similar to that seen physiologically. Devices are considered nonconstrained in certain planes of motion if there is no mechanical stop to the motion and if they are reliant on the perispinal soft tissue and the inherent compression across the disc space to provide restraint to extremes of motion [37].

The distribution of force and subsidence is possibly the most important biomechanical consideration for an artificial disc. The idea is to distribute the forces involved as uniformly as possible over a large area [37].

Intradiscal replacement of the nucleus pulposus represents an alternative to total disc replacement and spinal fusion procedures. The aim is to reconstruct the nucleus pulposus primarily while preserving the biomechanics of the annulus fibrosus and cartilaginous end plate. Nucleus pulposus implants are designed to provide stable motion, increase disc space width, relieve or lessen transmission of shear forces on the remaining annulus, and stabilize ligaments [38]. Nucleus pulposus replacement devices can be categorized into two groups: the intradiscal implants and in situ curable polymers. Intradiscal implants are biomechanically more similar to the native nucleus pulposus, whereas in situ curable polymers consist of compounds that harden after implantation. These implants are currently at different stages of preclinical and clinical investigations in veterinary medicine [39; F. Forterre, personal communication].

Cervical disc prosthesis in dogs

The first cervical prosthesis specifically for the canine cervical spine was designed and biomechanically tested in vivo in 2007 [7]. This prosthesis is made of a titanium alloy (Ti-6Al-4V-ELI) and consists of two end plates, with a range of movement of 30° between the plates (Figure 40.1). Titanium alloy was selected because it is resistant, is relatively inexpensive, has a good corrosion
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resistance compared to other materials, and is ideal for follow-up MRI studies in the event of postsurgical worsening and to evaluate domino lesions. This prosthesis is rotationally unconstrained, following the ball-and-socket principle, and does not require supplemental fixation. Unconstrained cervical prostheses designed for people usually allow about 11° of freedom [24]. The higher degree of freedom in this prosthesis was arbitrarily chosen considering that heterotopic ossification at the treated site observed in people significantly decreases the range of motion at the site of implantation over time. The outer surface of each end plate is convex to avoid prosthesis migration and has concentric grooves to allow bone ingrowth into the prosthesis. In the in vitro study, it was concluded that cervical spine specimens with the implanted prosthesis have biomechanical behaviors more similar to an intact spine compared to spinal specimens with ventral slot and PMMA fusion [7]. This was the prerequisite for the subsequent clinical investigation [8–10].

A pilot long-term clinical study using this prosthesis in two dogs affected by DAWS showed that

Figure 40.1 Adamo spinal disc®. US Patent # 8,496,707 B2. The prosthesis is made of a titanium alloy, and the concavity and convexity of the central aspects of the end-plate surfaces result in a ball-and-socket type of connection between the end plates. The external surface of each end plate is convex, resembling the concavity of the caudal end plate of the most caudal cervical vertebrae. The outer surface of each end plate has concentric grooves to allow bone ingrowth into the implant and is pretreated with a dual acid etch bath to promote bone ingrowth into the prosthesis (A). The convexity of the central aspect of the end-plate surface is made of polyether ether ketone (PEEK) (B). Two end-threaded stainless steel pins screwed into each piece of the implant and a barrel holder are used to hold together the two pieces of the implant during placement within the disc space (C and D). Six standard sizes of prosthesis are available, labeled S1, S2, and S3 and M1, M2, and M3. However, since each male piece of the prosthesis has to be assembled with a separate female piece, this makes a total of 12 different sizes when the disc is assembled in all possible combinations (E).
cervical arthroplasty was well tolerated with excellent outcome in both dogs. Mobility at the treated site was lost and distraction decreased over time in both dogs, without affecting the clinical outcome. Furthermore, the presence of the prosthesis did not affect the ability to reassess the area via MRI at a follow-up 18 months later, and domino lesions were not observed in either dogs [9].

A multicenter study evaluating the short and intermediate clinical and radiological results (average 15 months) using the same prosthesis in 12 dogs with single- and multilevel lesions has been reported [10]. In this study, the external surface of the prosthesis was treated with dual acid bath etch [40, 41] to promote bone-implant incorporation at the implant-vertebral end-plate interface, and dedicated surgical tools were created to facilitate implantation (Figure 40.2). To improve visual assessment, a high-powered headlamp, magnification loupes, and a Caspar cervical distractor were used as in the previous study (Figure 40.3). All 12 dogs had immediate postoperative recovery with good degree of distraction in the immediate postoperative radiographs (Figure 40.4). All dogs in this

![Figure 40.2](image-url)

**Figure 40.2** Dedicated surgical tools and other accessories. US Patent # 8,491,655 B2. Barrel holder. (A) After the two pieces of the implant are assembled, the two pins are inserted into the barrel holder. (B) The barrel holder has the double function of holding the prosthesis assembled with one extremity and to unscrew the end-threaded pins after the prosthesis is placed in the slot with the other extremity. Custom-made burrs. (C) Two dedicated custom-made burrs are used. The small burr head is used to enlarge the discectomy and to create enough space for the insertion of larger burr. The large head burr resembles the external convexity of the implant, and it is used for the final burring to create the specular concavity to accommodate the implant into the disc space. Twenty degree angle attachment. (D) A 20° angle attachment for the high-speed air drill is used to facilitate burring at an angle parallel to the disc space. Caspar cervical distractor. (E) This instrument is used to distract the two cervical vertebrae at the affected disc space. It allows better visualization of the dorsal aspect of the discectomy, facilitates the removal of the bulging disc, improves visualization of the dorsal longitudinal ligament, and facilitates the inspection of the vertebral canal for adequate spinal cord decompression. Sizing probe. (F) This instrument resembles at each extremity the shape of the S or M disc size, respectively it is used to probe the discectomy between burring (in place of the implant), and to assess the congruity of the discectomy to the implant. This instrument shortens the total surgery time by avoiding multiple times of checking of the discectomy with the actual implant, and it also facilitates proper selection of the size of the implant after the discectomy is completed.
Figure 40.3 Surgical technique. After routine surgical preparation, the ventral aspect of the affected vertebral bodies is accessed via a standard approach as for a ventral slot procedure. A discectomy is performed across the intervertebral space. The self-retaining Caspar distractor is placed and maintained distracted (A) to allow the final cleaning of the disc space and the subsequent burring with the two dedicated burrs (B). Burring is done following the direction of the intervertebral space, which is facilitated by the 20° angle attachment. Burring should be kept on the midline of the disc space and the widest part of the Burr should be centered at a depth of approximately 50% of the total disc space depth. Burring of the end plate of the cranial vertebra is minimal and limited to the removal of the final debris of the annulus fibrosus. The cranial end plate does not require excessive burring because it already has a natural concavity, which accommodates the convexity of the implant. Burring of the end plate of the caudal vertebra is limited in the central surface. Burring is also extended to the lateral edge of the discectomy as needed to allow the insertion of the sizing probe and later of the prosthesis. If the MRI study is suggestive of static spinal cord compression, the dorsal longitudinal ligament should be incised to visualize the spinal cord and explore the vertebral canal (C). In between burring, the sizing probe (which simulates the prosthesis) is used for pretesting how the actual prosthesis will be firmly seated in place (D). The prosthesis is inserted while maintaining the Caspar distractor in maximal distraction. Gentle pressure is applied to force the implant into the slot, and an audible click is usually heard when the convex area of the implant slips past the edge of the slot (E). To ensure that the implant is seated as much as possible on the midline, the barrel holder is rotated until the fissure of its proximal end is aligned with the long axis of the vertebrae. After implantation, the distraction is released, allowing the two vertebral end plates to collapse on the prosthesis (F). After assessing that the prosthesis is correctly seated in position, in order to ensure that the implant is firmly in position, the two pins still screwed in the prosthesis are grasped with a needle holder, and upward traction is applied in an attempt to dislocate the prosthesis from the slot (G). Once the surgeon is satisfied that the prosthesis is held snugly between the vertebrae, the two pins are unscrewed from the two prosthetic end plates (I), and the two Caspar distractor pins are removed from the vertebral bodies. Bone wax or gel foam is placed to stop the bleeding that might occur at the holes created by the two Caspar distractor pins. The longus colli, sternohyoideus, and sternocphalic muscles and subcutaneous and subcuticular tissues are then closed in a routine manner.
Figure 40.4  Postoperative radiographs. Immediate postoperative radiographs. German shepherd, 9 years old. Correct positioning of the implant on the lateral (A) and ventrodorsal projection (B) at the level of C5–C6. The implant used is M1, which provides adequate distraction. Two weeks post-op (same dog). The lateral (C) and ventrodorsal (D) views show that the implant is still well in place providing distraction at the treated site. The extension (E) and the flexion (F) views are performed to evaluate the degree of mobility at the treated site. The opening of the angle between the two implant end plates, as shown in the flexion view in this patient, indicates that mobility is maintained. At the reevaluation 6 months later, the radiographic findings were unchanged.
study, except one in which the technique was improperly performed, showed improvement in the neurological status during the observation period. In the majority of dogs, the distraction was moderately lost, and mobility at the treated sites decreased or became undetectable over time (Figure 40.5). A subsequent study using a redesigned thinner disc (2nd-generation disc) with the internal convex surface replaced with polyether ether ketone (PEEK) and an additional tool (sizing probe) to probe/test the disc space during burring before final disc implantation showed similar results but with the advantages that the surgery was facilitated by less burring and less implant manipulation and the implant accommodated easier along the natural angle of the disc space [11].

A recent study evaluating 50 disc spaces in 33 dogs treated with CDA for DAWS showed that on the

![Figure 40.5](image-url)  
**Figure 40.5** Two-level cervical disc replacement. Intraoperative photo (A) and immediate postoperative radiographs (B and C) of disc-associated wobbler syndrome (DAWS) at C3–C4 and C5–C6, with a suspected congenital vertebral fusion at C4–C5. Multiple cervical disc arthroplasty was recommended to avoid additional fusion at the affected spaces, which, in addition to the preexisting one, could have had predisposed the patient to a domino lesion at C6–C7. Nine-month postoperative radiographs with the neck in lateral (D), extension (E), flexion (F), and ventrolateral (G) positioning showed mild decrease of the original vertebral distraction, no heterotopic ossifications, and retention of mobility at both treated spaces. This dog had presented with a 4 month history of progressive ataxia/tetraparesis and regained full neurological function. MRI/T2 weighted of 6-year-old Doberman with a 2-year history of ataxia/tetraparesis treated with NSAID who presented acutely tetraplegic; the MRI showed multilevel DAWS lesions at C5–C6 and C6–C7 (H). The dog was treated with double cervical disc replacement and the immediate postoperative radiograph showed adequate disc placement at both treated sites (I). At 7-month follow-up, recheck radiographs showed decreased vertebral distraction and heterotopic ossification at both treated spaces (J). Mobility was not detectable at C6–C7 and significantly decreased at C5–C6. However, this did not affect the clinical outcome. The dog became ambulatory 2 weeks postsurgery and neurologically normal 4 months later. He continued to maintain his normal neurological status without any adjuvant anti-inflammatory or analgesic medication.
immediate postoperative radiographs, 15 sites were overdistracted, 34 sites were adequately distracted, and only 1 site was underdistracted. Overdistraction was mostly observed with the 1st-generation (thicker) implant, while the adequate distraction was mostly observed with the 2nd-generation (thinner) implant. On serial radiographic evaluation, the distraction was gradually decreased compared to the immediate postoperative radiographs and subsidence (defined as reduction of the width of the disc space equivalent to or less than the width of the preoperative radiographs) was seen in 7/19 sites (37%) at 6 months postsurgery and progressed to all the five sites evaluated at 2 years postsurgery. Subsidence, except for one dog, was seen only when the disc spaces were overdistracted, and it was more pronounced with the 1st-generation (thicker) and narrower implants and less pronounced with the 2nd-generation (thinner) and wider implants (Adamo, personal observation). Mobility was not detectable in 8/36 treated sites (22%) 2 weeks after surgery in 24 dogs examined and was lost or not detectable in 17/22 sites (77%) at 6 months after surgery in 14 dogs examined. No implant migration or implant infections were observed on serial radiographs or on MRI when available. In this study, the mean and median follow-up time was 16 and 12 months, respectively (range, 2 weeks to 42 months), and the outcome was considered good to excellent in 30 out of 33 dogs (91%). The three dogs with poor or unsatisfactory outcome were presented with over 2 months of nonambulatory tetraparesis and severe extensor rigidity in both thoracic limbs. Among these, one dog (12.4-year-old sheltie mix weighing 9 kg [19.5 lb]) was euthanized 2 weeks postsurgery because of a compressive fracture of C6 with ventral displacement of the implant, and another dog (13.5-year-old chow mix) was euthanized 8 months after surgery because of lack of significant improvement. Two dogs had recurrence of the neurological signs 18 months after surgery secondary to suspected osteophytes (noted on MRI) causing ventral spinal cord compression at the treated sites. Ventral osteophytes were seen at six treated sites, in four dogs on postoperative radiographs, causing bridging spondyloarthrosis and ankylosis at three disc spaces in two dogs. No neurologic domino lesion adjacent to treated sites was seen in any of the dogs during the observation period. Median postoperative hospitalization time was 1 day (range 0–5 days), and 5 dogs were discharged on the day of surgery. In this study, it was concluded that correct patient selection (dog’s weight not less than 20 kg [44 lb]), neurological status at presentation, size of the implant, end-plate preparation, and applied distraction during surgery were important factors that may influence the outcome (Adamo, personal observation).

These studies showed that cervical disc arthroplasty is well tolerated and might be a valuable method to treat DAWs [9–11]. Furthermore, these studies showed that the cervical cast used in the previous study was not needed.

**Benefits of cervical disc arthroplasty**

Cervical arthroplasty in people is still an area of active research, debate, and controversy, and a 5-year follow-up has been recommended to assess the long-term functionality of the prosthesis and its influence at adjacent levels [42]. A technology overview from the *American Academy of Orthopaedic Surgeons* analyzed the results of multiple clinical studies and concluded that artificial disc arthroplasty is more beneficial in the short term compared to ACDF, although its long-term benefit over standard ACDF remains unclear [43]. The impact of cervical disc replacement on adjacent segment degeneration and the degree of heterotopic ossifications (HOs) of the treated segments remain a subject of intensive investigation. HO is a pathologic condition that leads to the development of bone within nonosseous soft tissues [44]. The bone that forms is believed to develop through stimulation by cellular mediators and altered neurovascular signaling [44]. Although the precise cause of HO remains unclear, it is certain that it increases with time, it may occur at the four corner of the disc space (most commonly anterosuperior or posterosuperior), and it has been reported with an incidence as high as 60.3% [45].

A prospective, randomized, multicenter study comparing cervical arthroplasty with ACDF with a minimum of 2-year follow-up concluded that cervical arthroplasty was associated with significantly greater overall success rate than ACDF. Furthermore, there were significantly fewer patients in the cervical arthroplasty group showing severe adjacent-level radiographic changes at the 2-year follow-up [46]. Another study with an average follow-up of 49.4 months evaluated
cervical disc replacement and its effects on adjacent segment discs and found satisfactory clinical and radiographic outcome. In this study, progression of adjacent segment degeneration was observed in 23% of patients, but this did not affect the clinical outcome [47]. A study of cervical arthroplasty with up to 2-year follow-up showed motion preservation at the treated site in 85% of patients, HOs in 4.5% of the treated levels, and radiological signs of adjacent-level degeneration in 9.1% patients. This study confirmed the efficacy and safety of the technique and concluded that the presence of HOs does not alter the clinical outcomes [48]. In another study, HOs was detected in 27.7% of treated segments but did not affect the clinical outcomes, and no specific risk factors for HOs were identified [49]. Fitting of the implants to end plates has been identified as a factor to reduce the development of HO [45, 49]. Finally, multilevel cervical disc replacement with contiguous and noncontiguous implants has been reported to be a safe and effective alternative to fusion. However, the impact of multilevel arthroplasty, especially on the adjacent segments, remains to be evaluated [50–52].

In dogs, studies comparing long-term results of cervical disc arthroplasty with other surgical

![Figure 40.6](A) (B)

Figure 40.6 Three-level cervical disc replacement. Immediate postoperative radiographs of a 13-year-old dalmatian affected by disc-associated wobbler syndrome at C3–C4, C4–C5, and C5–C6. Correct positioning of the implant on the lateral (A) and ventrodorsal projection (B). The implant used is S1, which provides adequate distraction at all sites. Same dog 3 weeks postsurgery (C and D). Distraction and mobility are maintained at all treated sites. Immediate postoperative radiographs of a 14-year-old chow–lab mixed affected by disc-associated wobbler syndrome at C2–C3, C5–C6, and C6–C7. Correct positioning of the implant on the lateral (E) and ventrodorsal projection (F). The implants used in this patient are M1 at C5–C6 and C6–C7 and S1 at C2–C3, which provide adequate distraction at all sites.
techniques are still lacking. However, there are several benefits of this technique including minimal invasiveness, quick recovery, spinal cord decompression, distraction with immediate relief of radicular pain and vascular compression at the intervertebral foramina, treatment of multilevel lesions at adjacent or nonadjacent sites (Figure 40.6), and ability to reassess the spine with MRI in the event of complications and for long-term assessment of domino lesions. Furthermore, because cervical disc arthroplasty is well tolerated and the neurological status does not worsen in the immediate postoperative phase, dogs that are ambulatory prior to surgery can be potentially treated as outpatients.

The advantage of cervical disc arthroplasty over a ventral slot procedure is that the prosthetic disc acts as a spacer preventing early collapse of the intervertebral disc space as may occur with a ventral slot alone. Collapse of the disc space can compress the nerve roots and vasculature at the intervertebral foramina, causing cervical hyperesthesia and focal spinal cord ischemia, which in turn may cause an immediate worsening from the preoperative neurological status. Ventral slot alone may also be ineffective in completely decompressing the spinal cord [53–56]. Clinical effectiveness of the ventral slot procedures is typically evident over time, and any instability may be alleviated because these disc spaces may eventually fuse [57–59].

An advantage of cervical disc arthroplasty over other distraction and stabilization techniques is that the prosthetic disc is retained in the slot without the use of additional fixation [8]. This eliminates complications associated with impingement on neurovascular structures, plate fractures, screws pulling out, and delayed graft incorporation [10, 57, 58, 60, 61]. An additional advantage is that cervical disc arthroplasty may prevent domino lesions [10]. However, long-term follow-up studies in a large number of dogs are needed to investigate this potential benefit.

Prophylactic treatment of mildly affected adjacent disc spaces has been suggested to reduce the incidence of domino lesions [57, 58]. Because the cervical prosthesis is relatively easy to implant, is cost-effective (its cost may be equivalent to the cost of the pins and PMMA), and does not require special instrumentation for plating, it could also be used to other mildly affected disc spaces in conjunction with disc replacement at the affected space [10, 11]. This could be particularly indicated when at the suspected disc space there is a mild evidence of spinal cord signal hyperintensity on MRI T2-weighted images, which may be suggestive of “incipient lesions” (P.F. Adamo, personal communication).

Complications with cervical disc arthroplasty

In people, the most common complications include implant or end-plate subsidence (the penetration and collapse of the implant into the adjacent vertebral bone) [62, 63], splitting of the vertebral body during implantation [64], HOs and ankylosis at the treated site [65–67], adjacent disc degeneration including new formation or enlargement of osteophytes [65, 68], and device migration [69]. Less common complications include delayed hyperreactivity to metal ions and subsidence secondary to osteoporosis [62, 70].

In dogs, possible complications associated with this type of prosthesis may be similar to those reported in human patients. Among these, devices migrating out, infections, and subsidence would be the most serious. Although subsidence, HOs, and ankylosis have been observed, devices migrating out and infection have not been reported [9–11].

While canine disc arthroplasty may offer benefits over arthrodesis, it also requires that the surgeon acquire new operative techniques, and new complications might be introduced during this learning curve. Since the key to success in any surgical procedure is correct patient selection, treatment criteria also have to be determined in the future. Many patients may not be appropriate candidates for disc arthroplasty. Preoperative assessment should involve consideration of disc space width, although it is not clear at present whether there is a minimum width under which the device should not be used. Further, the effect of the artificial disc on angulation at the treated level and the overall spinal alignment may be important in long-term outcomes and rates of domino lesions. The angle of disc insertion is related to bone removal and end-plate preparation, and it is somewhat arbitrary, with no precise measure available to predict accurately the impact of the prosthesis on the vertebral alignment. However, the new generation of the thinner
implants requires minimal end-plate bone removal, which allows the implant to follow the angle of the natural disc space [11].

Subsidence

Subsidence is defined as sinking of a body with a higher elasticity modulus (e.g., graft, cage, spacer) in a body characterized by a lower elasticity modulus (e.g., vertebral body), resulting in three-dimensional changes of the spinal geometry. Magnitude of subsidence is directly proportional to the load pressure and to the difference between the elasticity modules but inversely proportional to the area of the graft–bed interface. Both biological and mechanical qualities of the graft–bed interface are important for the subsidence process. End-plate preservation and a dynamic modification of cervical plates may enable surgeons to control subsidence and reduce the number of complications [71].

Possible factors for the decrease of distraction and subsidence over time may be a combination of overdistraction and bone resorption around the prosthesis [8]. In most dogs, distraction of 2–3 mm is enough to restore a normal disc width of 4–6 mm, and overdistraction should be avoided [10, 11, 58]. New disc designs of thinner prostheses are under investigation (P.F. Adamo, personal communication). Prevention of vertebral space collapse may be difficult because muscle and tensile forces that control postures in the horizontally oriented quadruped vertebral column cause an inherent axial compression of the spine [2]. Furthermore, a mild degree of collapse may be desirable to allow accommodation of the implant over time within the intervertebral space, and to decrease the biomechanical stress of distraction on adjacent vertebral motion unit. Selecting a prosthesis with a larger surface area would exert less force per unit area on the vertebral end plate and be less likely to cause subsequent subsidence [10]. Finally, to avoid bone resorption around the implant, bone–implant incorporation should be promoted [11].

Bone–implant interface incorporation

Generally, implant-induced osteolysis is a manifestation of an adverse cellular response to the phagocytosis of particulate wear and corrosion debris. This mechanism is also known as “particle-induced osteolysis” or “implant-related debris osteolysis.” The effect of unintended debris resulting from wear and corrosion (e.g., micromotion between the interconnection mechanisms in spinal implants) remains a clinical concern [72].

Particulate debris should be expected any time an artificial disc implant is used. The generation of particulate debris can occur as a result of wear and corrosion. Titanium particulate debris has been shown to elicit a cytokine-mediated response with inflammatory infiltrates, increased intracellular tumor necrosis factor-α, increased osteoclastic activity and cellular apoptosis, and increased potential for aseptic osteolysis [72, 73]. Causes of implant failure in people have included failure of osseointegration, midsubstance elastomeric tears, and osteolysis, which may also result in heterotopic new bone equivalent to a fusion or pseudoarthrosis [74].

The presence of nonresorbable, osteoconductive hydroxyapatite (HA) particles could help maintain a denser and more functional peri-implant bone structure [75]. HA largely consists of calcium and phosphorous. This composition allows HA to function as a coating that promotes osseointegration between bone and various orthopedic implants. HA coating is wear-resistant and promotes osseointegration between bone and implant. The presence of HA seems to promote the maturation of collagen fibers surrounding the titanium implants and to support osteoconduction. Moreover, in an in vivo study, new formation of bone was faster in all samples where implants were inserted together with HA [76–79].

Coating with a modular bone growth factor “modular bone morphogenetic peptide (mBMP)” in orthopedic implants has also been recently investigated. The results of this study demonstrated that mBMP coated onto an HA–titanium implant stimulates new bone formation and may be useful to improve implant fixation in total joint arthroplasty applications [80].

However, excessive stimulation of bone formation at the intervertebral disc space with mBMP or other growth factors may be potentially deleterious, because it may induce excessive bone growth into the vertebral canal and subsequent compression of the spinal cord.

Improved bone–implant osseointegration may prevent subsidence, osteophytes, HOs, and
ankylosis and therefore may reduce loss of mobility. To promote bone–implant incorporation, the artificial disc presented in this book section has been upgraded with an external HA coating (third-generation disc) (Figure 40.7), and to decrease subsidence, additional wider and taller disc sizes have been made available. A clinical study using this third-generation disc implant is currently under investigation (Adamo, personal communication).

Decrease or loss of mobility over time

Decrease or loss of mobility over time could be secondary to the HO and ankylosis at the treated sites [10–12] and/or to fibrotic tissue ingrowth between the two articular faces of the implant. However, it has been postulated that the gradual decrease or loss of mobility at the treated sites (when it occurs) allows the rest of the vertebral column to slowly and gradually accommodate to the new dynamic until a final dynamic stabilization occurs [10]. It is also possible that although some degree of mobility at the treated spaces persists, it is not detectable with the current method of investigation [10]. This could explain the excellent clinical outcome in dogs treated with cervical disc arthroplasty [10, 11]. New technical strategies to retain implant mobility at the treated disc spaces over time are currently under investigation [68]. Finally, packing the ventral edges of each vertebra facing the external surface of the implant with bone wax may prevent bone and fibrotic tissue ingrowth between the two articular faces of the implant, as well as ventral bridging spondylarthrosis and ankylosis, which in turn may help in maintaining mobility at the treated site(s) (Adamo, personal communication).

![Figure 40.7](image)

Figure 40.7 Third-generation Adamo spinal disc coated with hydroxyapatite (HA). The external surface of the implant is coated with HA to improve bone–implant osseointegration. Assembled disc (A); the micropores of the HA coating are visible in the external surface of the magnified picture of one shell of the disc (B). To allow adequate surface of contact between the implant and the vertebral end plates in larger-size dogs, additional wider and taller disc sizes labeled WT1 and WT2 are added to the original S1, M1, and M2 disc sizes (C).
Clinical concerns

An additional concern in humans is the longevity of the clinical outcomes. The average age of the patients considered appropriate candidates for disc arthroplasty is significantly younger than that of patients typically undergoing total appendicular joint replacement. This means that the longevity of the implants must be extended for decades compared with those of total hip or total knee replacements [71]. This problem might be less important in veterinary medicine because DAWS patients at presentation are usually at least 6 years old and have a shorter lifespan compared to people.

Conclusion

By preserving the motion segment, arthroplasty attempts to prevent adjacent segment degeneration while treating the underlying disease. Overall the results of the preliminary studies using cervical disc replacement in dogs affected by DAWS are encouraging. The minimal morbidity and the potential benefit of avoiding domino lesions, together with the other many advantages, may change the pet owner’s perception of DAWS patients often having a guarded to a poor prognosis and may therefore increase their willingness to pursue this surgical treatment compared to other extant options.

Note

1. Adamo spinal disc®. Applied Veterinary Technology LLC, San Mateo, CA, 94403

References

Will There be a Role for Disc Prostheses in Small Animals?

