Thesis

Jannes Leonhard Joseph Koch
2024

Fig. 1.

UNIVERSITY OF VETERINARY MEDICINE

Department and Clinic of Surgery and Ophthalmology

Surgical Treatment Methods of Hip Joint Dysplasia in Dogs

(Review of literature)

Diploma work

Written by

Jannes Leonhard Joseph Koch

Supervisor:
Dr. Tibor Németh
PhD, Dipl. ECVS, CertSACS
professor, head of department, deputy rector for clinical affairs

Budapest 2024

Table of Content

Abbreviations and Acronyms

BFX	–	Bio Fixation
CFX	–	Cement Fixation
CFR-PEEK	–	Carbon Fiber Reinforced - Polyetheretherketon
DI	–	Distraction Index
DPO	–	Double Pelvic Osteotomy
FHNO	–	Femoral Head and Neck Ostectomy
FHNE	–	Femoral Head and Neck Excision
FHO	–	Femoral Head Ostectomy
HD	–	Hip Dysplasia
JPS	–	Juvenile Pubic Symphysiodesis
OA	–	Osteo Arthritis
PEEK	–	Polyetheretherketon
PHR	–	Partial Hip Replacement
PO	–	Pelvic Osteotomy
THA	–	Total Hip Arthroplasty
THR	–	Total Hip Replacement
TPO	–	Triple Pelvic Osteotomy
ZC	–	Zürich Cementless

List of Figures

Tables and Charts

Introduction

The following thesis is an analysis of the literature on the common, modern methods of surgical treatment of hip dysplasia (HD) in veterinary medicine. The various procedures are described and then compared, so that advantages and disadvantages as well as indications and contraindications become clear.
The topics covered include juvenile pubic symphysiodesis (JPS), triple and double pelvic osteotomy (TPO, DPO), femoral head and neck excision (FHNE), and total hip arthroplasty (THA), with a focus on the different prosthesis systems available.
I will then present the result in the form of a discussion with a conclusion.

Material

Etiology of hip joint dysplasia

Alongside cruciate ligament rupture, HD is one of the most common causes of hind lameness in dogs. In general, looseness in the young hip joint leads to a subluxation or luxation of the hip which in turn leads to a flat acetabulum, a flattening of the femoral head and finally to osteoarthritis.

Heritance

In principle, HD is to be regarded as a hereditary disease, as a genetic predisposition is a prerequisite for the phenotypic expression of the disease. Environmental influences may also play a certain role, but these alone are not sufficient to cause HD.
The question of the heritability of HD raises the question of the categorization of the disease according to Mendel's rules, whereby according to Linnmann a dominant inheritance with varying penetrance is most likely, as a solely recessive or dominant inheritance is not always possible since not all offspring of diseased parent animals develop HD, and animals from non-HD parents can also develop HD. When it comes to the question of which gene ultimately causes the development of HD, the literature assumes the involvement of several genes (polygenic), which have varying degrees of influence on the development of the disease, with

so-called major genes having a greater impact. When it comes to the question of when HD occurs, it is assumed that there is a threshold effect at which a number of certain genes must be exceeded for HD to be observed, as polygenic inheritance is assumed [9]

HD is therefore ultimately caused by the interaction of various genes with varying degrees of influence, as well as environmental influences such as feeding and activity of the animal, whereby environmental influences alone do not cause HD. Environmental influences and heredity complement each other, albeit with varying intensity, which means that the more HD-relevant genes are present, the less negative environmental influences play a role and vice versa. In general, however, it can be said that a genetic predisposition is always a prerequisite for the development of HD [10].

To represent the heritability of HD numerically, correlations are sought between parents and offspring as well as between full and half siblings and these are given as a percentage or decimal fraction which then represents the h2 value (heritability). These values can scale from 0 and 0.9, but usually range between 0.2 and 0.5. 0.5 would mean that 50% is based on genetic factors and 50% on non-genetic or environmental influences [10]. These calculations are mainly used in the breeding and prevention of HD.

Development of HD

HD develops at an early age, but there are different theories in the literature as to its exact origin. Linnmann compares the anatomical origins of HD based on various studies. The ossification of the acetabulum, development of the ligamentum capitis femoris, ossification of the femoral head, as well as different muscle groups or pelvic shape are compared as possible triggers of HD.

In the study by Köppel, 1991, considered by Linnmann, he describes the cause of primary acetabular or primary osseous dysplasia as aplasia, hypoplasia and/or persistence of the acetabular roof core of the acetabulum. Such a maldevelopment of the acetabular roof of the acetabulum always leads to HD, as in his study HD developed in every dog in which such a change in the acetabulum could be detected.

Köppel describes and defines primary soft tissue or primary ligamentous dysplasia as HD caused by premature degeneration of the ligamentum capitis femoris. According to Köppel, both dysplasia can occur together or independently of each other.

In other studies, compared by Linnmann, which investigate the cause in the ossification of the acetabular roof, some come to the same conclusion, but see the ossification of the acetabular roof as a secondary factor and not as the primary factor as described by Köppel, and instead see the instability of the femoral head as the primary factor.

The contrary assertion that the acetabular roof nucleus plays no role in the development of HD is supported by the fact that the dorsal ossification nucleus on the acetabulum is not one of the obligatory ossification nuclei and occurs only rarely and, if it does occur, could also be regarded as normal[10].

Linnmann considers delayed ossification of the femoral head to be a second possible starting point for HD and refers to a study carried out by Madsen in 1991 in which it was observed that all dogs aged 12 with undetectable ossification nuclei of both femoral heads always developed HD, while dogs of the same age with detectable ossification nuclei only developed HD in 33% of cases [10]. A lack of blood supply to the femoral head was thought to be the result of early synovitis, but more recent studies suggest that the timing of ossification is a hereditary factor and is also influenced by environmental factors such as body weight [10].

Another causal factor of HD could be underdeveloped pelvic muscles. In a 1967 study by Riser and Shirer, they determined a pelvic muscle index which showed the percentage of pelvic muscles in relation to total body weight [11]. They observed a correlation between the pelvic muscle index and the status of HD, in which it was found that with an increasing pelvic muscle index, the severity of HD decreases, and conversely, with a decreasing index, HD occurs more frequently [10].

The involvement of the pectineus muscle in HD was also discussed in a study by Bradens and Hardwick in 1968, which hypothesized that a spasm or shortening of the pectineus muscle would result in HD [12]. However, this was refuted by a later study in 1974 by Cardinet et al. who found that a pectineus myotomy, which had a positive effect on the development of HD in Braden and Hardwick's study, had neither a positive nor a negative effect on the development of HD [10].

The role of pelvic shape is also taken into consideration. In a study by Olsson and Kasström, 1972, they found a correlation between pelvic cavity and HD [13]. They found a narrower pelvic cavity in dogs with severe HD than in dogs with normal or less dysplastic hip joints [10].

This narrowing of the pelvic cavity is caused by increased internal inclination of the pelvic sides and leads to rotation of the acetabulum, which in turn provides less support for the femur due to the increased inclination of the acetabular roof. The consequence of a narrower joint cavity is that less joint loosening is required to increase the severity of HD [10].

Other pelvic dysplasia can also have an influence on the development of HD. The role of lumbosacral transitional vertebrae in pelvic and hip dysplasia is important if the transitional vertebra causes an asymmetrical connection to the sacrum [10]

Surgical Procedures

JPS (Juvenil pubic symphysiodesis)

JPS is one of the more modern surgical procedures for HD and is generally regarded as a preventative measure to prevent the development of HD in young dogs between 12-16 weeks of age.

The aim of the procedure is to prevent the growth of the symphysis pubis by cauterizing or inserting surgical staples. The resulting slower growth of the front half of the pelvis compared to the back half should allow the acetabulum to rotate better over the femoral head and thus lead to better coverage and stability of the hip joint [1, 10].

Indication of JPS

The indication and success of a JPS is related to various factors. In general, it can be said that the age of the dog and the degree of joint looseness probably have the greatest influence on a successful JPS. A dog should therefore be between 12-16 weeks old and have a distraction index (DI) of ≥ 7.0[10].

The age of the dog is crucial as there is still enough time after the procedure for the pelvis to grow and the acetabulum to remodel. As JPS is considered an operation to prevent HD, the time factor also plays a role, as the earlier the operation is carried out, the less likely it is that HD will develop or progress. Therefore, there is only an indication for JPS if there are signs or suspicion of the development of HD, but no clinical symptoms have yet manifested themselves [1, 14].

Other authors also agree that JPS only shows a significant improvement in mild to moderate HD development [10].

The breed of the dog also plays a role. Since giant breeds, for example, have a slower and longer growth phase than dwarf breeds and satisfactory results can still be expected after 20-22 weeks, the period for the possible JPS procedure can be extended to 12-22 weeks in giant breeds, although it must generally be said that an earlier procedure can be expected to produce a better result [10].

Contraindication of JPS

To summarize, it can be said that an age of less than 12 and more than 24 weeks of life (some authors use 22 weeks as the upper age limit for giant breeds), a distraction index <0.4 and bilateral negative Ortolani signs are exclusion criteria for JPS [10].

If a JPS is performed despite contraindications, satisfactory results can no longer be expected. In this case, other procedures such as TPO are more suitable [10].

JPS surgical technique

The aim of JPS is to destroy the symphysis pubis, usually by electrocauterization, in order to achieve pubic symphysiodesis [10].

The operation is considered technically simple and is usually performed in an average operating time of 30 minutes.

To perform the JPS, a paraprecutaneous (ventral midline) incision is first made starting at the palpable cranial aspect of the pubis, which is then extended 3-5cm caudally and underlying soft tissue is sharply dissected. The abductor muscles can be lifted a few millimeters on both sides. The cartilage of the symphysis is usually recognizable as a line and stands out slightly darker from the surrounding bone. The symphysis is exposed, and a useful caudal landmark is a small palpable tubercle (bump) on the medial edge of the obturator foramen which marks the end of the pubic symphysis and the beginning of the ischial symphysis. The exposed symphysis is now destroyed using electrocautery from the cranial edge of the pubic symphysis to the caudal tubercle [1].

For example, a diode laser or radiofrequency electro-scalpel can be used for cauterization. In another surgical technique, the symphysis is resected using a spinal chisel forceps and then bridged using surgical staples. This method can be used individually or in conjunction with electrocauterization [10].

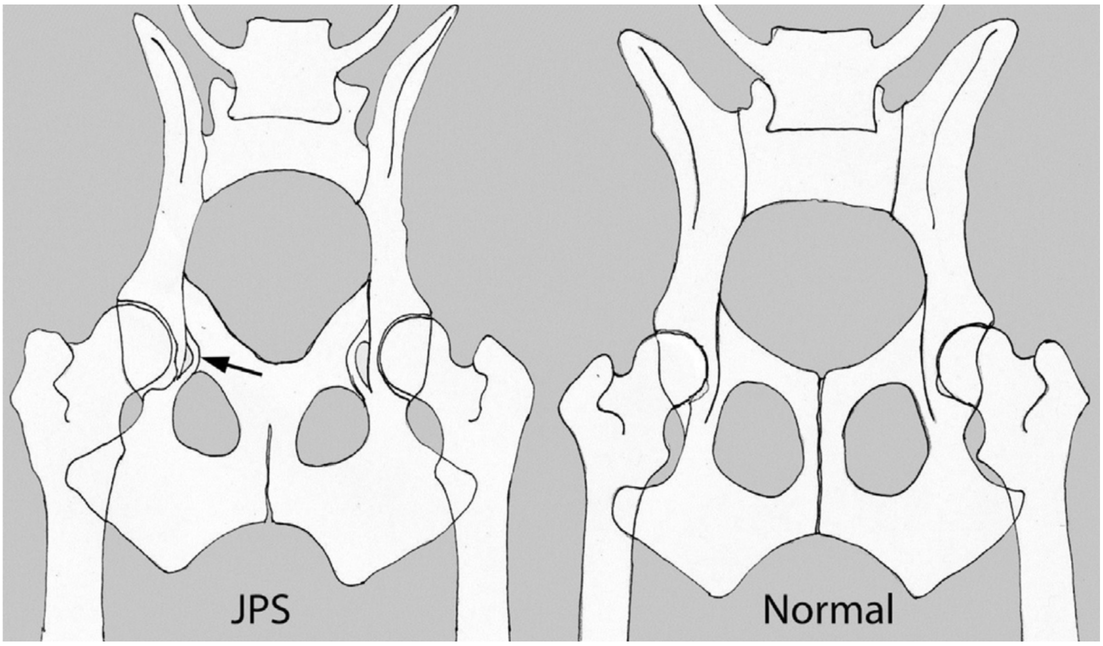

Fig. 2. Difference between JPS and a normal pelvis. Note the absence of the cranial pubic symphysis line, the thickened and irregular pubic rami, the reduced and relatively round foramen obturatoria. The arrow shows a pronounced medial projection of the acetabular fossa.

Complications JPS

JPS (Juvenile Pubic Symphysiodesis) is generally regarded as an operation with few complications. Possible postoperative complications include the formation of seromas, ulcerative skin lesions that can occur due to contact of electrocautery with the skin, and minor oedema formation. Soft, mucoid feces may also occur after the procedure. There is a risk of iatrogenic damage to abdominal organs such as the urethra or rectum. Because of the procedure, it is recommended not to breed with affected animals since the genetic background of the disease is still present. The patient can usually be discharged within 24 hours of the operation [1, 10].

Pelvic Osteotomy - TPO/DPO

Like JPS, pelvic osteotomies (TPO, DPO) are surgical methods for the prophylactic treatment of juvenile hip joint dysplasia and is aimed at axial rotation and lateralization of the acetabulum in order to create better coverage of the hip joint and thus reduce joint laxity, prevent coxarthrosis and create improved congruence by displacing the joint [10, 15].

Patient selection:

To justify a pelvic osteotomy and maximize the success of the procedure, certain parameters should be considered:

Age:

As TPO and DPO are generally regarded as prophylactic procedures for the treatment of HD, the age of the animal is one of the first points to be considered in view of the etiology of the disease. There is no consensus in the literature on the exact optimal time and when a pelvic osteotomy should still be performed and when a satisfactory result can no longer be expected. However, it can be observed that pelvic osteotomies were generally performed at an age of 5 - 14 months, with most patients being younger than one year old [16]. This not clearly defined age range is related to the fact that the age of the animals as such plays a rather subordinate role in the outcome of a PO. Although the young age of the animal can have a positive effect on the outcome of the operation, as the animal has the opportunity to adapt to the new anatomical conditions of the hip joint postoperatively as long as it is still growing, the primary focus is on the presence and degree of secondary osteoarthritis of the joint, as well as other degenerative changes that can be caused by HD, which are logically less likely to be present or pronounced at a young age than in an older animal [10, 16].

Status osteoarthritis:

As already mentioned, the condition of the hip plays a major role in relation to osteoarthritis and other degenerative joint changes caused by HD, as these can be a clear contraindication to PO.

There is no consensus in the literature on the exact degree of osteoarthritis and whether it should be present at all to create an indication for PO, partly because the determination and categorization of osteoarthritic changes is determined and interpreted in different ways.

However, it is certain that with a high degree of OA changes, a satisfactory result can no longer be expected, as PO can at best slow down the progression of OA, but cannot stop or reverse it and thus the resulting symptoms such as lameness would not persist [10, 16].

Laxity:

In HD, joint laxity is one of the main findings and is therefore also important for PO. The degree of laxity can be determined using various methods such as the Ortholani test and the degree of hip laxity can be quantified using distraction radiography such as the PennHIP method in the form of a distraction index (DI) [13].

Although the DI is a good aid for classifying laxity, the literature does not agree on the DI at which PO would be most useful.

An objection to performing a pelvic osteotomy in a dog with low hip laxity, recognizable by a low distraction index, would be that this dog is unlikely to develop clinical signs associated with osteoarthritis (OA). In contrast, an argument against treating a dog with marked hip laxity could be that pelvic osteotomy is unlikely to be sufficient to prevent subluxation of the femoral head in such cases, as has been clinically documented [13].

The optimal DI that a candidate should have for the PO therefore depends on the desired goals of the intervention.

Anatomy and constitution of the hip (acetabulum/femur):

The condition of the bony structures of the hip joint (femoral head, acetabulum) also plays an important role in the assessment of the dog when it comes to suitability for a PO.

Ideally, the bony structures should be in their normal shape and show no changes, such as flattening. In addition, the lateral section of the dorsal acetabulum should be intact and around a quarter of the femoral head should be covered by the acetabulum preoperatively. The condition of the teres ligament (femoral head ligament) and the articular cartilage should also be assessed [10, 13].

Summary:

In general, young dogs with hip joint laxity consistent with the early stages of hip dysplasia, but without radiographic evidence of secondary osteoarthritis, are usually considered candidates for pelvic osteotomy [12].

Thus, dogs with distinct subluxation (complete luxation), dogs without any joint coverage or dogs with substantial OA are unsuitable, as the TPO/DPO neither effectively counteracts excessive subluxation and can only cover the joint to a limited extent, nor prevents the progression of OA and does not treat the possible resulting pain [13].

TPO, DPO, 2.5 pelvic osteotomy (2.5 PO)

The first described DPO, in which the ilium and ischium are osteotomized, was first introduced into veterinary medicine in 1969 by Hones and James. In 1981, this was in turn extended by

Schrader, who provided for a third osteotomy on the pubic bone, thus allowing greater displacement of the acetabular segment [10].

In addition to Schrarder, other methods of TPO were established, of which Slocum's is probably the most frequently used in current veterinary literature.

Essentially, the methods differ from each other mainly in terms of their osteotomy interfaces and fixation of the acetabular segment [10].

The majority of TPO patients are predominantly young, active, large breed dogs under one year of age, with a less dense bone core structure than adult dogs, making them susceptible to implant-related, post-surgical complications[14]. Due to these non-negligible complications of the TPO, Haudiquet and Guillon introduced the DPO (Fig. 3), which was technically identical to the TPO and differed only in that no osteotomy of the ischium was performed, which, in addition to fewer complications such as screw loosening through the use of locking plates, should provide additional mechanical stability, better preservation of the pelvic width and geometry, as well as comfort for the animal [1, 13].

However, in addition to the advantages of the DPO, it also has disadvantages compared to the TPO. Thus, the existing integrity of the basin of a DPO compared to a TPO requires a greater degree of ventroversion to achieve the same effect as with a TPO [14]. In a DPO, the rotation of the ilium leads to plastic deformation of the pubic bone. Ilium torsion contributes only about 12% of the total ventroversion produced by the DPO technique. These forces are distributed along the ischial plate, creating tensile forces on the dorsal ischium and compressive forces on the ventral ischium. If the ischium cannot withstand this plastic deformation, a fracture can occur, which could impair the stability of the pelvis after a DPO [15].

To counteract this complication, the so-called 2.5 PO technique was described by Petazzoni and colleagues in 2012. The 2.5 PO technique uses an osteotomy of the dorsal cortex of the ischium to allow greater rotation of the acetabular segment. This osteotomy can also reduce the tensile forces on the ischium and reduce the risk of ischial fracture. However, this method has only been performed on cadavers, so there is no description of clinical results of the 2.5 PO [16].

Fig. 3. Illustration of a DPO procedure with DPO/TPO plate used on a canine pelvis.

Femoral Head and Neck Osteotomy

FHO is a simple and, compared to alternative surgical procedures, cost-effective operation for the treatment of HD in adult dogs.

The aim of femoral head and neck excision or femoral head ostectomy (FHO) is to resect the femoral head and neck, separate the bony connection of the hip joint and form a so-called pseudoarthrosis and thus eliminate joint pain [2, 9]. [10, 19].

Fig. 4. Radiographic image of a canine Hip after Femur Head and Neck Excision

Indications

Like THA, FHO is an established surgical method for treating end-stage HD. Due to the absence of implants, the surgical method is significantly easier and cheaper to perform than THA, which is why FHO is still very popular in small animal medicine. FHO can be successfully performed on dogs and cats.

An FHO is particularly indicated when conservative treatment options fail, or other surgical reconstructions of the hip joint are not possible. The main indications include chronic or recurrent dislocations of the hip joint and severe coxarthrosis, which is accompanied by progressive lameness and pain. FHO can also be considered for complex or highly fragmented fractures of the femoral head, neck, or acetabulum where primary treatment is not possible, as well as for aseptic femoral head necrosis (Perthes' disease). Furthermore, FHO can be used for revision of failed THA or other surgical procedures [10, 19].

As a rule, FHO is chosen as the last option when the coxofemoral joint cannot be preserved or restored and the clinical symptoms require immediate pain relief with FHO. Factors such as the patient's age, severity of clinical signs, breed, activity level and financial considerations play a major role in the decision. If the animal is still growing, other procedures such as JPS or DPO are usually favored as they can preserve joint function. There is also the possibility that the clinical symptoms that still exist during growth will improve in the adult state and therefore an FHO is not necessary [19].

Although FHO can generally be performed in all patients regardless of body weight, the expected outcome is more favorable in light patients than in heavy patients [19].

As the FHO is less expensive than a total endoprosthesis and shows good results in smaller dog breeds, it remains a common method in small animal medicine [19].

Complications

Complications that can occur when performing femoral head and neck resection (FHNO) are varied and depend on both the surgeon's technique and patient-specific factors. Common complications include muscle atrophy, proximal migration of the femur and fibrotic contracture, which can lead to restricted mobility [19, 20]. Other problems include persistent pain and lameness and reduced mobility of the hip joint, especially in large dogs [21, 22]. Improper execution, such as leaving remnants of the femoral neck, can lead to bony friction and impairment of the operated leg [20, 22]. The possibility of nerve damage, particularly to the sciatic nerve, and postoperative infections are additional risks that can occur during and after surgery [19, 22].

Total Hip Replacement (THR)

Total hip replacement (THR) or total hip arthroplasty (THA) is an established method for treating dysplastic hips or irreparable femur or acetabulum fractures when conservative treatment is no longer an option. Although the surgical procedure does not differ marginally in the surgical method, the different hip joint prosthesis systems have different approaches to solving the problems that arise, such as complications and wear of the implant.

In the following, I will compare the various hip joint endoprosthesis systems available on the market and discuss their advantages and disadvantages.

Indications/contraindications

Total hip replacement (THR) is indicated for dogs suffering from severe hip problems that do not respond to other treatments. These indications include canine hip dysplasia, fractures of the femoral head and neck, and chronic or irreducible dislocations of the hip joint. THR is also recommended when previous surgical procedures such as triple pelvic osteotomy (TPO), femoral head resection (FHO), dorsal acetabular rim arthroplasty or toggle pin stabilization have been unsuccessful. In addition, a revision of an already inserted hip prosthesis may be necessary if complications occur or an alternative system promises better results [5]. Contraindications to THR include the presence of infection, neoplasia, and severe neurological deficits, as these conditions can affect recovery and the success of the surgery. Concomitant medical problems, such as cruciate ligament damage, should be addressed before considering THR, as they can complicate the postoperative rehabilitation process and affect overall outcomes [5, 7].

Development and history

Initially, the first hip prostheses were limited to head or head-neck prostheses made of stainless steel or plastics such as acrylic or synthetic resin, which proved to be unsuitable in the long term, however, as these easily dislocated if the acetabulum was not deep enough[10].

The first total hip endoprosthesis was developed by Gorman. This stainless-steel prosthesis was attached to the acetabular segment using 3 screws, while the head was attached to the femur using a long metal pin. A system like Gorman's, made of stainless steel, was used by Creed and others in 1971. The problem with both systems was that the implants frequently became loose[10].

The first system with cement fixation was also developed in human medicine in the early 1970s, which then became established in veterinary medicine in the 1980s and is still used today[10]. The first established prosthesis system with cement fixation for dogs was the Richards Canine II system, which had an acetabular component made of polyethylene and a femoral Monoblock or fixed head component made of a cobalt-chrome alloy and which formed the basis for later prosthesis models [10, 23].

Two other systems were the TEP system developed by Periot in 1985, which used a retinted polyethylene cup to reduce dislocation of the hip, and a TEP system developed by Aesculap, which also worked like Periot's by means of a narrowed cup rim into which the head implant was pressed to prevent dislocation.

Unlike monobloc implants, the femoral components of modular prostheses consist of several units. One advantage of modular systems is that they can be better customised to the patient. Depending on the prosthesis system, different heads and stem necks can be selected so that a more precise adaptation to the patient's circumstances can take place [10].

One of the first modular systems was the Biomechanique prosthesis system, which was later replaced by its successor, the Porte prosthesis, which was similar in design to the Biomechanique. The stem of the Porte prosthesis is made of titanium, while the head and neck are made of a cobalt-chrome alloy. The acetabular component is made of polyethylene and is available in 4 different sizes. The heads of the Porte prosthesis are available in different drilling depths, which makes the prosthesis neck length customizable [10].

Another prosthesis system introduced in 1990 is the BioMedtrix Total Hip System developed in the USA, in the development of which Olmstead played an important role. Initially, the cemented version (CFX™) was favored, but later a cementless version (BFX™) was added. Today, the BFX™ system is used much more frequently than the CFX™, particularly in the ratio of 70:30 for cups and 60:40 for stems. In the UK, however, the CFX™ system remains one of the most widely used hip prosthesis systems [10, 24].

There are several reasons why cementless prostheses are used more frequently today than cement-retained prostheses. The main disadvantages of the polymethylmethacrylate (PMMA) cement, frequently used for cement-fixed prostheses, are the loss of volume due to shrinkage during hardening, the strong heat development (risk of tissue damage), the release of toxic monomers and possible allergic reactions. In addition, cement fractures can occur due to movement at the transition points because of varying stiffness, which favors prosthesis loosening and infections. Over time, the cement becomes brittle and mechanical stresses can lead to destruction of the cement [10].

Regarding these complications, there was great interest in the development of cementless prostheses as an alternative.

These new developed cementless Systems had to face new problems, mainly the primary and secondary fixation of the implant due to the absence of cement. Over the time there were different types of solutions in form of different prosthesis systems like the perforated hollow cylinder developed by Schawalder or the PCA (porous-coated anatomic) prothesis by D. DeYoung Richardsen or the later developed and still in use BFX System of Biomedtrix [10].

To date, the cemented and cementless methods of THR are in frequent use, without either system clearly standing out in terms of its advantages. Thus, the two systems coexist today and are mainly selected according to the surgeon's preference or particular indication. A combination of cemented and cementless systems, as well as the different manufacturers, is generally possible and is frequently used in revision procedures, for example.

Biomedtrix

BioMedtrix has been a leader in the field of joint replacement in veterinary medicine for 27 years. Over the years, various systems, and designs for total hip replacement (THR) implants, surgical instruments and training programs have been developed to meet the changing needs of

veterinary orthopedics and their patients. BioMedtrix manufactures implants and instruments for animals weighing from 2 to 80kg. The designs and materials of the implants have been continuously adapted to the progress of clinical research and the needs of surgeons. The company estimates that approximately 28,650 CFX, 8,900 BFX (biological fixation) and 700 micro and nano THR procedures have been performed since the market launch. This article provides an overview of BioMedtrix's currently available THR systems, the surgical procedure to place them, and the associated complications and outcomes[24].
In the following I will explain the different Biomedtrix systems and compare them with systems from other companies such as the ZC system from Kyon.

Structure:

The Biomedtrix THR systems consist of several modular components: a femoral implant (stem), an acetabular cup and a femoral head. The implants are available in different sizes to meet the anatomical requirements of dogs and cats of different sizes. There are two main techniques for anchoring the implants in the bone.
In cemented fixation (CFX), the implant is fixed into the bone with surgical cement. This technique provides immediate stability and is mainly used in older or less active animals where the bone quality may not be sufficient to support cementless fixation.
Cementless fixation (BFX) uses implants with a porous surface that enable biological fixation through bone ingrowth. This method is favored in young, active animals as it offers long-term stability through natural bone integration [25].
In addition, there are special systems for smaller animals such as the Micro and Nano THR system, which was developed for dogs and cats weighing less than 5 kg. These systems follow the same principles but are adapted to the specific anatomical requirements of small animals [26].

Cemented Fixation (CFX):

In 1990, Biomedtrix replaced the Canine Richards II system with its CFX system, which was the only commercially available THR system to date.
The Biomedtrix CFX system uses polymethyl methacrylate (PMMA) as cement to anchor the implant firmly in the bone.
The CFX system consisted of three modular components: an acetabular cup, a femoral stem, and a femoral head. The acetabular cups and stems were available in different sizes, but all fitted a uniform size of femoral head (17 mm diameter). The head was attached to the femoral

stem via a Morse taper. The 17 mm femoral heads were available in 10-, 13- and 16-mm sizes to optimize the length of the femoral neck and ensure adequate tautness of the joint during hip reduction. This modularity allowed for better customization of the implants to the individual patient[24].

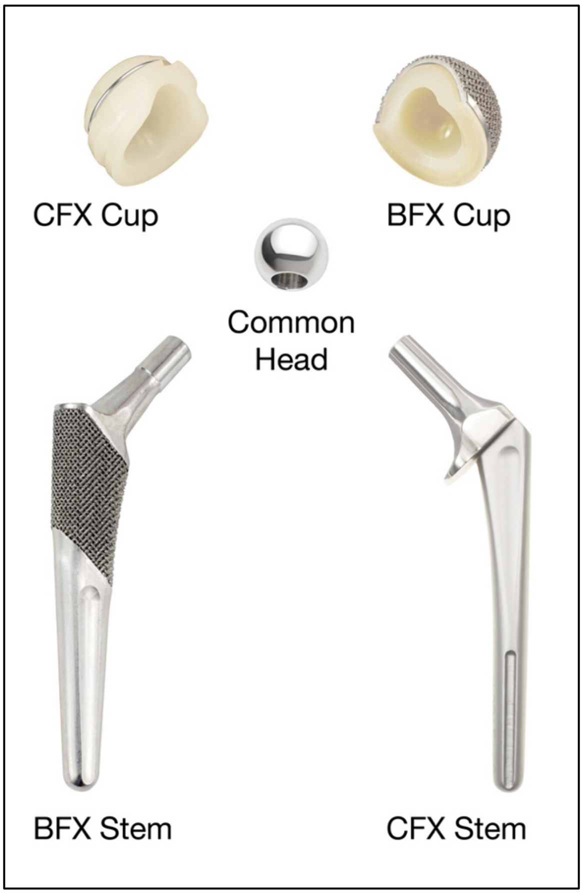

Fig. 5. Overview of the Biomedtrix Universal Total Hip Replacement System consisting out of Cementless BFX and Cemented CFX components.

Cementless Fixation (BFX):

To counteract possible complications of the CFX system such as aseptic implant loosening, the Biomedtrix BFX system was commercially introduced in 2004 on the basis of the PCA (porous-coated anatomic) Total Hip System from Howmedica [24].

This cementless system achieves its initial stability through the so-called press-fit procedure, in which the implant is pressed into the precisely prepared bone sockets with the help of acetabular reamers and femoral broachers. Later, permanent stability is achieved by osseointegration of the bone into the implant surface.

Although a cementless implant is initially less stable than a cemented implant, biological fixation offers the advantage that the connection between bone and implant is stabilized by living tissue. This can reduce the risk of infection and aseptic loosening [24].

Universal Total Hip Replacement System:

The Universal Hip System from Biomedtrix (Fig 5.) offers hybrid use of the CFX and BFX systems and is available in a variety of different sizes. This allows the surgeon to customize the implant more precisely to the patient's needs.

A standardized surgical approach and bone preparation method has been developed that is suitable for implant placement and is performed with the same instruments. Firstly, the bone bed is prepared precisely for the placement of a BFX implant with a press fit. If is changed to a CFX implant during the operation, only minor adjustments need to be made to the bone bed to insert the cemented acetabular cup, as the femoral canal is already prepared to fit the cemented stem. The system consists of three modular parts: an acetabular cup, a femoral stem and a femoral head. A standardized femoral head fits both a BFX and a CFX stem and can be combined with the respective acetabular cups of both systems within the same size category[24].

Micro and Nano THR:

These systems have been specially developed for smaller dogs and cats and are tailored to the specific anatomical conditions of animals weighing less than 5 kg. They also allow smaller patients to benefit from THR[26].

Complications Biomedtrix:

In a 2017 study by Henderson, there were significant differences in the frequency of complications when comparing the different implant systems from Biomedtrix, Henderson and Kyon. Thus, the study showed that a significantly higher complication rate occurred when using the BFX cup/stem prosthesis compared to the CFX cup/stem prosthesis, with the risk of complications being 4.48 times higher. The risk was also 2.85 times higher with the BFX prosthesis compared to hybrid prostheses. Of the complications with hybrid prostheses, most cases involved the combination of BFX cup and CFX stem. The complications observed included acetabular fractures, wound infections, cardiac arrest, and femoral fractures. One dislocation occurred with the CFX cup/BFX stem combination. No significant differences in complication rates were found for the other prosthesis types[8].

Kyon (Zurich Cementless)

The Zurich Cementless THR System is a cementless modular hip prosthesis and was developed by Tepic and Montavon at the University of Zurich in the 1990s. The THR prosthesis from Kyon was implanted for the first time in 1993 and has been available for clinical use since 1996. Over time, the system has undergone significant further development and is now available in its 6th generation[10].

Structure:

Unlike other cementless systems, which are fixed using press fit of the components, the Kyon system is fixed to the medial cortex of the femur using locking screws. This medial monocortical fixation of the femoral component transfers the joint force to the femur in such a way that it comes very close to the normal physiological loading of the femur [10]. A further advantage of this method is that the implant can grow with the bone and, unlike cement or press-fit fixed implants, can also be implanted in younger animals that are still growing.

The stems are made of a titanium alloy. Where the implant touches the bone, it has a porous surface coated with HA (hydroxyapatite) to facilitate early osseointegration[27].

Four different sizes (S, M, L, XL) of necks can be attached to the stem component, all of which are made of uncoated titanium alloys.

Kyon offers ceramic heads of different diameters (2-22mm) for its own as well as for Biomedtrix systems. Titanium heads are also available for cupless PHR (Partial Hip Replacement) systems[27].

Standard cups are available as inlay or PEEK double shell cups, as well as special cups (UHMPE double shell cup) and revision cups, which are fixed in the bone using a press-fit or, in the case of revision cups, using screws [10, 27]. The double shell cups have an outer shell coated with HA, which is perforated with holes to allow rapid ingrowth of the bone into the implant (bony ingrowth) and flexibility. The inside of the cup is made of CFR-PEEK (carbon fiber reinforced polyetheretherketone). There is a cavity in the center of the cup, the purpose of which is to minimize the contact point between the implant head and the cup (removal of contact point). The contact, which is now distributed over a larger area, is additionally supported by a CFR-PEEK ring, which is intended to improve the longevity of the implant [27].

Fig. 6. Zurich THR implant with acetabular CFR PEEK Cup.

Fig. 7. Zurich THR implanted System with femoral screws

6th Generation ZC THR

Kyon's Hip Replacement System has been continuously developed over the years and adapted to the growing demands of medicine. The current and highly developed THR system from Kyon is therefore the 6th generation system.

The sizes of the system are divided into the Mini, Standard & Giant and Tiger groups. The different implant sizes are subdivided into these groups. The Mini THR implants vary in stem sizes from 3mm (MINI XS) - 6mm (MINI XL) and are intended for patients from 2-15kg. The Standard & Giant group is available in stem sizes 8mm (Standard XS) - 9mm (Giant XXL), as well as with different numbers of screws (3-5). The Tiger group includes 11mm stem sizes with 4 screws and is intended for very heavy patients (Tiger size)[27].

Cups, heads, and necks are also available in different sizes and are compatible with the Biomedtrix systems. This means, for example, that revisions of BFX or
CFX implants can also be performed with KYON prostheses or Biomedtrix and Kyon components can be combined with each other. Special revision cups from KYON are also available which can be secured in the acetabulum with screws. [5, 10, 27, 28].

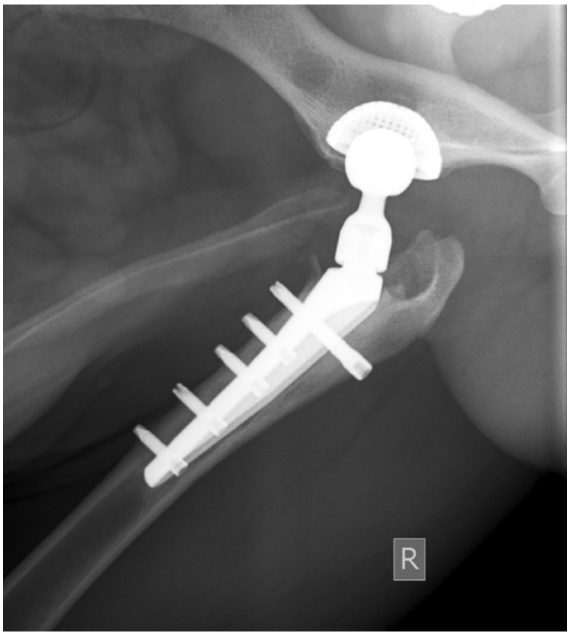

Fig. 8. Postoperative oblique femur radiographic image of a Zurich Cementless THR.

Cupless (PHR)

In a partial hip replacement (PHR), only the femoral part of the hip joint is replaced with an implant and therefore only part of the hip joint is replaced. In this case, the implant cup is omitted as the implant head is placed directly in the patient's acetabulum.

The main difference between the Kyon Cupless prosthesis and the Kyon THR prosthesis is its head, which is not made of ceramic but of a titanium alloy and is generally available in a larger diameter. This means that the cupless heads are available from 10mm - 32mm in diameter, while the THR ceramic heads range from 6mm - 22mm in diameter[27].

Dual Mobility Cup

Kyon's Dual Mobility Cup (DMC) was developed to reduce the risk of dislocation after total hip replacement (THR), especially in dogs with an increased risk of dislocation. The DMC combines two articulations: a smaller ball inside a larger shell. This design allows for increased freedom of movement and stability. Primary movement occurs within the inner ball, while the outer shell is activated during extreme hip movements to further minimize the likelihood of luxation [29].

The biomechanics of the DMC are based on increasing the "jump distance", i.e., the distance that the femoral head must travel before dislocation occurs. The additional movement between the two bearings also reduces wear on the joint surfaces. In veterinary practice, the DMC has proven to be particularly effective in large and giant dog breeds, which have a higher risk of dislocation after hip replacement surgery due to their anatomy[6].

Studies have shown that the DMC significantly reduces the dislocation rate in dogs, with success rates of up to 98% with no post-operative dislocations. This system is particularly suitable for dogs with chronic hip dislocations, irreparable femoral head fractures or severe hip dysplasia (Lanz, Forzisi and Vezzoni, 2021).

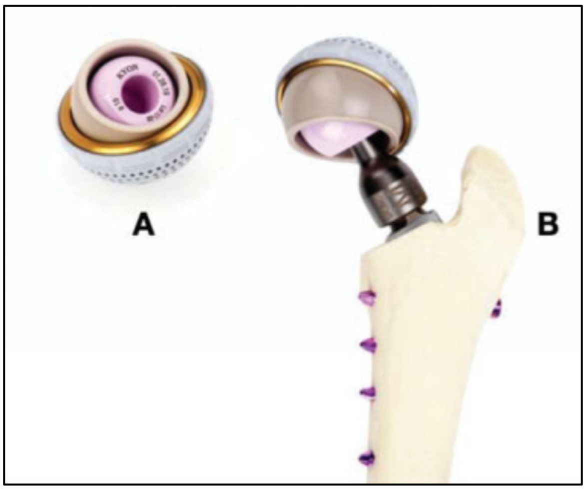

Fig. 9. (A) Dual Mobility Cup with head. (B) Zurich Cementless Stem and neck inserted into ceramic head followed by insertion into dual mobility cup

(Innoplant) THR systems

The Innoplant Total Hip Replacement System is a prosthesis system from Innoplant Medizintechnik GmbH in Hanover, Germany. Innoplant offers various cemented and cementless, as well as screw-in prosthesis systems, which can be combined with each other and offer great versatility.

Structure:

The design and materials are like other prosthesis systems available on the market. Thus, the femoral stem and acetabular cup shell are made of a titanium alloy and have a rough surface to facilitate bone ingrowth [7].

Innoplant offers classic systems, which are very similar to conventional systems, as well as a screw-in system. These are available as cementless (3Con Stem, HELICA TPS Stem) and cementable (CemtA Stem) stems. Cementless (Screw Cup SL) and cemented (CemtA Cup) cups are also available (Fig. 10).

A special feature of the INNOPLANT prosthesis is the cementless HELICA screw-in system, which differs significantly from conventional systems as the stem and cup are equipped with a self-separating thread with which the stem and cup are screwed into the bone. Unlike other systems, the femoral stem is anchored in the metaphysis and not in the diaphysis of the femur, which means that no reaming is necessary, and more bone structure can be retained. The outer cup of the screw-in system also has a thread with which it is screwed into the bone. Inside the cup is a high-density ultra-high-molecular-weight polyethylene liner in which the joint head is inserted.

The rod end is made of stainless steel and is coated with a titanium nitride layer to minimize wear [7].

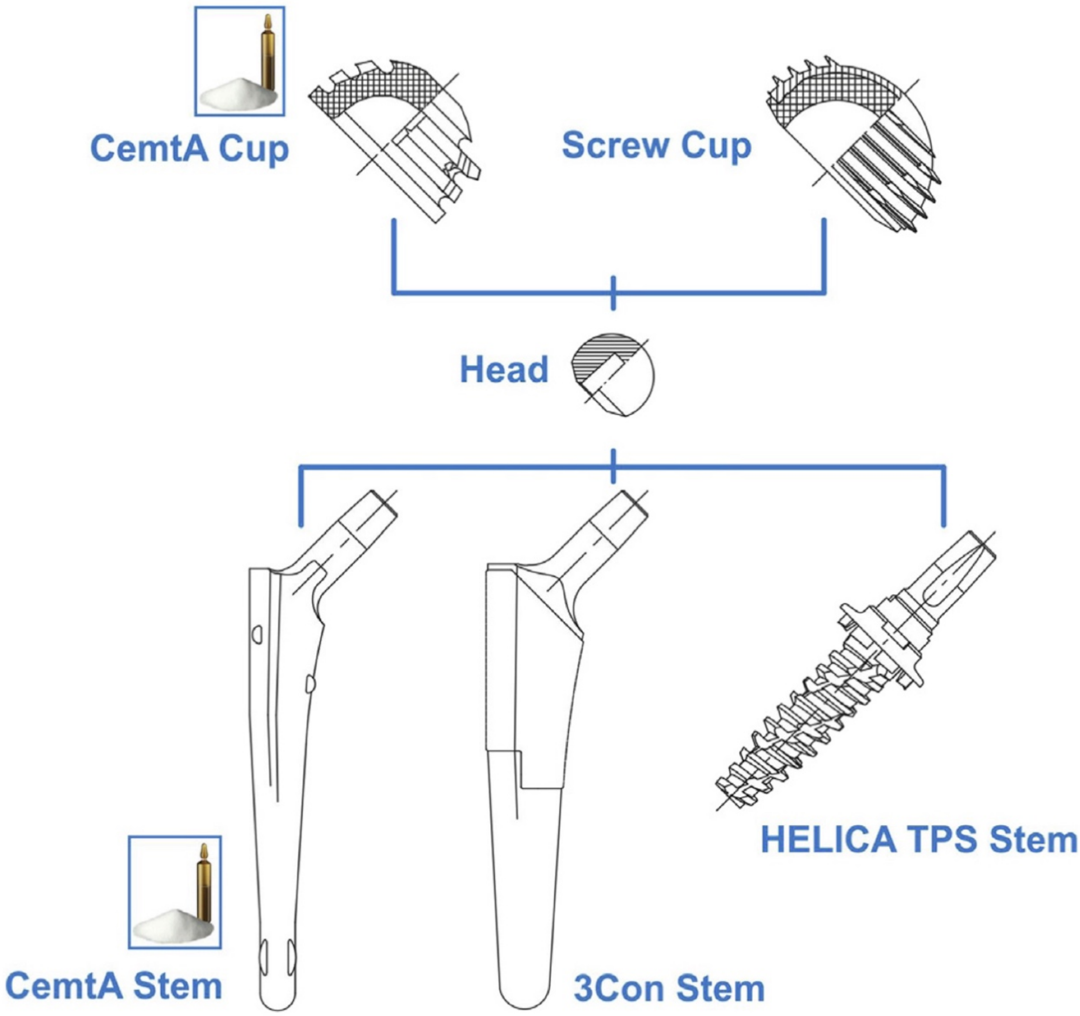

Fig. 10. Different Innoplant Cemented (left), Cementless (middle) and Helica screw in Stems (right) with Cemeted cup (left), head and screw in cementless Cup (right).

INNOPLANT Stems:

The 3Con Stem has a similar structure to conventional stems such as the BFX Stems from Biomedtrix. The 3Con Stem is made of a titanium alloy and has a lamellar porous surface (spherical ball-layers / lattice structure) on its upper half, which is intended to facilitate bone ingrowth. The lower half of the stem has a blasted surface [30].

As with BFX systems, the stems are fixed via press-fit and secondarily by bone ingrowth.

Available stem sizes range from #4 to #10.

The CemtA stem is the cement-fixed counterpart to the 3Con stem and is very similar to a conventional CFX system. It has small centering fins (self-centering) and, unlike the cementless stems, is not made of titanium but of a cobalt chrome alloy.

Available sizes of the stem range from #3 - #8

The HELICA TPS stem is part of Innoplant's screw-in system and, like other cementless systems, is made of a titanium alloy. As described above, the system differs in its design and function from the other systems frequently used in veterinary medicine.
By inserting the implant into the metaphysis and not into the epiphysis of the femur, as is usually the case, more bone can be preserved and a load like that of the normal physiological hip joint can be created.
The femoral component consists of 6 different stem sizes (8x31mm - 12-x39mm) which can be combined with 3 different sizes of flanges (18.5mm - 21.5mm) as well as a locking nut [7, 10, 30].

INNOPLANT Cups:

Innoplant offers different cups and cupless systems. The cementless Screw Cup SL is the counterpart to the HELICA TPS stem and works using the screw-in method. The cup itself is made of a titanium alloy, has a porous surface (trabecular like surface) with a self-separating thread and is available in 6 different sizes (22mm - 32mm). The inlay of the cup is made of high-density polyethylene.
In addition to the cementless cups, a cemented cup (CemtA Cup) is also available. This is made of UHMWPE and, like the CemtA stem, also has self-centering lamellae on its surface [30].
Both cups can be combined with all conventional implant systems.
Innoplant also offers a cupless system.

INNOPLANT Mini Hip:

For small and very small dogs and cats, Innoplant offers the Mini Hip System, which consists of a cementable cup and a cementless or cementable stem, as well as a head in different diameters and lengths.
A total of 5 different cup sizes (10mm - 17mm) are available, which are based on the CemtA cup design and are made of UHMWPE. There are also 5 different stems available, all made from a cobalt chrome alloy, of which 3 are cementable and 2 are cementless. The sizes of the stems range from #1 - #4. The heads are available in S, M and L versions and range from 6.5mm - 12mm. The 6.5mm head is supplied prefixed with the stem and, unlike the other heads, which are made of a titanium alloy, is made of a cobalt chromium alloy (CoCrMo) [30].

Hybrid usage Biomedtrix, Kyon, Innoplant

In view of the advantages and disadvantages of the different systems and regarding revision operations, a major advantage of Biomedtrix, Kyon and Innoplant systems is that they can be combined as a hybrid system.

Possible advantages of such a hybrid procedure could be the great adaptability to the patient's circumstances, as each system offers different approaches to solving the problems of THA and the demands on the implant, as well as the resulting lower complications and better outcomes.

A 2019 study therefore looked at the long-term outcomes of a hybrid system consisting of an Innoplant screw cup and a Kyon head and stem. A total of 16 THA were performed on 12 different dogs with this hybrid system and observed for 42 months afterwards, with complications occurring in 3 THA (19%) and thus no significant clinical advantage of this hybrid method over the normal method was demonstrated in this study [31].

Complications of THR

THR is generally regarded as a safe operation with few complications. Nevertheless, there are certain complications with the THR systems available on the market that should be considered. These include: Dislocation, femoral fracture, wound healing, aseptic loosening, acetabular fractures, sciatic paresis, femoral pain, femoral subsidence, protrusion acetabuli [8]. Complications are divided into 3 classes: Catastrophic, Major, and Minor.

One of the most common postoperative complications of THR is dislocation of the femoral head from the acetabulum. This occurs particularly in the first few weeks after the operation, when the surrounding muscles are not yet fully stabilized. Dislocations are either treated using closed reduction with an additional Ehmer sling or surgically with the same or longer stem neck of the implant [8, 26].

Aseptic loosening is a complication that is mainly observed with cementless implants such as the BSX (Biomedtrix) or the HELICA (Innoplant) system, usually sometime after the operation. This is usually treated by revision surgery and, if necessary, explantation[8].

Another possible complication is fractures of the femur, which can occur either intraoperatively or postoperatively. These fractures often occur at the point where the implant ends, as this is where the load forces are concentrated. According to Liska (2004), the incidence of femur fractures following THR was approximately 2.9%, with older dogs with osteopathy at higher risk [32]. In a study by Henderson 2017, fractures occurred more frequently with cementless systems. A total of nine femoral fractures were documented: five with the use of BFX components, one with CFX, one with a combination of BFX cup and CFX stem and two with the Kyon prosthesis. Of these, seven occurred postoperatively, while two fractures or fissures occurred during surgery. In the two intraoperative cases (CFX and BFX respectively), the fracture was successfully repaired using cerclage wire without removing the implant. A postoperative fracture occurred 17 days after the use of the Kyon prosthesis, which led to euthanasia of the affected animal.[8].

	Number of cases without complications	Number of cases with complications	Total number of cases	Complication rate %
BFX	29	10	39	25.6
CFX	130	10	140	7.1
Hybrid	66	8	74	10.8
Helica	28	6	34	17.6
Kyon	15	4	19	21.1
	268	38	306	12.4

Data recorded by surgeon or owner, January 2010–December 2012
In some cases, more than one type of complication occurred. However, statistical analysis was completed on the basis of whether the case had a complication, be that one or several

Table 1. Complication rates from a data collection of 306 THR cases with different Systems in period of two years.

Complications of Biomedtrix:

In a comparative study by Henderson 2017, various implant systems, including those from Biomedtrix and Kyon, were analyzed regarding their complication rate. It was found that the BFX cup/stem prosthesis had a significantly higher complication rate compared to the CFX prosthesis. Specifically, the risk of complications was 4.48 times higher with the BFX prosthesis than with the CFX prosthesis. The risk of complications with the BFX prosthesis was also 2.85 times higher than with hybrid prostheses, which consist of a combination of BFX cup and CFX stem. The most common complications included acetabular fractures, wound infections, and femoral fractures. One dislocation was recorded with the combination of CFX cup and BFX stem [8].

In comparison, the BFX system had a complication rate of 25.6%, the CFX system had a complication rate of 7.1% and the hybrid system had complications in 10.8% of cases[8].

Complications of KYON:

In Henderson's study, a complication rate of 21.1% was found for the KYON THR prosthesis. Postoperative complications occurred in 4 of the 19 dogs in which a Kyon prosthesis was implanted. Two dogs had femoral fractures, one had dislocations and another had wound complications[8].

In another study from 2021 in which the Kyon prosthesis was used to treat capital physeal fractures in dogs, intraoperative complications occurred in four of a total of 53 dogs (7.5%). Three of the four complications were trochanteric fractures while the other was a femoral fissure. Postoperatively, complications occurred in a total of 6 of the 53 dogs (11.3%), including 2 aseptic cup loosening, 1 stem loosening, 2 luxations, 1 fracture [33].

In a study by [31] which dealt with hybrid systems from Kyon and Innoplant, the major complications of cementless THA systems from Kyon generally ranged from 16-26%. In the study itself, the complication rate of the hybrid systems with Innoplant screw cup and Kyon Stem was 19%. In two other studies, coxofemoral luxation was described as the most frequently reported complication of the Kyon prosthesis; the Innoplant prosthesis did not show any luxations in this target area[31].

Complications Innoplant

In a study published in 2015, which looked at risk factors for femoral stem loosening in the HELICA implant from Innoplant, stem loosening of the implant was observed in 6 of the 16 dogs considered within one year of surgery, which implies a total complication rate of 37.5%. In one of the 6 observed complications, a positive bacterial culture was found, which ultimately resulted in an aseptic loosening rate of the HELICA femoral stems from Innoplant of 33.3% one year after surgery [34].

Another paper from 2018 also described aseptic loosening as the most common complication of the Innoplant HELICA prosthesis. In this study, 55 THA were performed in 50 dogs with the HELICA prosthesis. Complications were observed in a total of 19 of the 55 implants used. Complications occurred in 9 of the 23 (39%) first-generation short femoral stems used. A total of 10 (32%) of the 31 second-generation femoral stems used experienced complications [35].

Results

To summarize, the different systems have many similarities and differences with which they fill different niches in problem solving and coping with complications.

Starting with the Biomedtrix prosthesis, which is the oldest and most established of the systems analyzed. It is characterized by low complication rates and compatibility compared to the other systems. This means that the Biomedtrix system can be used to carry out revisions of all other systems and vice versa, as the development of the other systems was modelled on Biomedtrix.

Biomedtrix also offers a cemented and cementless alternative as well as a combination of both, although this is also the case with the other systems.

Kyon is characterized by its advanced prostheses, which are fixed in the metaphysis by screw fixation and thus offer special primary strength without the use of cement. Ceramic heads made of hardened zirconium oxide and cups that have a wear-reducing geometry and whose inlay is reinforced with carbon fiber, among other things, testify to the high level of development of the Kyon prosthesis, which uses materials from human medicine, among other things.

Innoplant's HELICA prosthesis is also modelled on human medicine. The stem segment of the implant placed in the epiphysis is therefore unique in veterinary medicine, although there are similar implants in human medicine. The Cup of the Innoplant system is unique as well, as the whole unit is screwed into the bone for primary fit.

All compared cementless systems managed the primary fixation into the bone differently do to either press-fit, screw fixation or screw in of the whole implant. The secondary fixation for the cementless systems is in all the cases the in-grow of bone into the implant.

Cemented THR systems have the same important value for the veterinary surgery as the cementless. All in all, the cemented systems of Biomedtrix, Kyon and Innoplant work the same.

Discussion / Conclusions

This thesis deals with the comparative analysis of current literature on common surgical treatment methods for HD in dogs.

The treatment of canine hip dysplasia (HD) is a complex challenge that requires both preventive and corrective surgical interventions, depending on the age of the animal and the progression of the disease. The surgical methods examined in this thesis, such as juvenile pubic symphysiodesis, pelvic osteotomies such as TPO and DPO, as well as femoral head resection and, above all, total hip replacement (THR), illustrate the diverse approaches and methods for the surgical treatment of HD, with each method offering a different focus for the treatment of HD and resolution of emerging problems such as complications.

As a mainly preventive procedure in young, growing dogs, JPS offers a promising opportunity to prevent the later development of potential HD. However, to maximize the success of JPS, clear patient selection and a specific time window in the patient's growth are of particular importance. The literature does not specify a clear, standardized time for performing JPS. However, a satisfactory result is more likely in an adult patient in whom a JPS should be performed.

JPS is characterized by a simple, minimally invasive procedure, a low complication rate and manageable aftercare for the patient compared to other procedures.

TPO and DPO offer surgical options for improving hip joint coverage in dogs with juvenile HD before progressive arthritic changes occur. The aim of a pelvic osteotomy, as with JPS, is to create better coverage of the femoral head by axially rotating the acetabular segment. Because in PO the rotation is performed surgically and by inserting implants and not, as in JPS, by the growth of the dog, PO can also be performed at a later stage in adult dogs and thus offers an alternative to JPS in older dogs. The success of a PO is therefore only indirectly related to the age of the animal and more to the presence of an OA and the degree of luxation or joint looseness of the hip.

Opinions on the usefulness of PO for the treatment of HD are divided in the literature. Some sources reject PO in principle because, like JPS, it should be carried out as a preventive measure before HD with OA develops to maximize success, as it is only aimed at improving joint corpuscle and mechanics and does not prevent the progression of OA. Therefore, there is no indication for a DPO/TPO in a dog with already pronounced HD.

Another point of criticism would also be that not every dog with an initial joint looseness would necessarily have HD and therefore a TPO/DPO would be carried out without being able to prove a later clinical HD.

In advanced, pronounced HD with degenerative changes in the bony structures of the hip joint, JPS and PO are not an option, which is why FHNO or THA would be used in these cases.

FHNO is primarily used as an emergency alternative for immediate pain relief, especially in the event of failed conservative or surgical treatment attempts.
Pain caused by HD is primarily caused by the loss of cartilage and thus the direct contact between bone and bone. This contact can be immediately neutralized by an FHNO, and the pain thus eliminated. However, the joint function of the hip can only be maintained to a limited extent by forming a fibrous pseudo joint and by supporting the muscles.
To treat advanced HD and maintain the function of the joint in the best possible way, the THR is optio optima.
The various THR endoprosthesis systems, such as those from Biomedtrix, Kyon and Innoplant, each offer different solutions in terms of stability, wear and risk of complications and are constantly being adapted to the growing demands of modern surgery.
Hip joint prostheses can essentially be categorized as cemented or cementless. Cementless systems, such as the BFX prostheses, offer primary stability through press fit and secondary stability through bone ingrowth and are more stable in the long term, but have a higher initial complication rate compared to cemented prostheses, which have immediate primary stability due to the bone cement and are more likely to develop stability problems in the long term. It is not yet clear whether one of the two systems (cementless or cemented) will prevail, as neither has yet lost its status.
The choice of system depends heavily on the individual case, with factors such as the dog's body weight and age, the extent of the hip joint deformity and anatomy, as well as the owner's financial means, also playing a role. For example, one could say that cementless systems are more suitable for young dogs, as they can provide more long-term stability due to the ingrowth of the bone than cemented implants, which rely on the durability of the cement.
The constant further development of implants and surgical techniques suggests that complication rates will continue to fall, and the possibilities of implants will continue to increase, particularly in terms of stability and wear.

Summary

HD is a complex, multifactorial genetic disease characterized by maldevelopment of the hip joint leading to instability, subluxated or completely luxated hip joints and ultimately osteoarthritis. This thesis deals with the various common surgical treatment methods available in veterinary medicine.

Four main procedures are compared in this thesis. JPS can improve joint congruity and laxity and slow or prevent the progression of degenerative hip joint disease, taking into account a careful selection of patients, especially the age of the animal [1]. In contrast to other surgical treatment methods, this technically simple procedure is associated with few complications.

Pelvic osteotomies also offer an opportunity to improve the function of the hip joint by increasing the coverage of the femoral head by the acetabular segment. Careful selection of the patient is also crucial for this method to ensure the success of the procedure. TPO/DPO is controversial among surgeons, as the success of the method depends heavily on whether and how severe the patient's HD already is. The less degenerative change the patient shows, the greater the success of the procedure. An intervention in a patient with minimal or no clinical symptoms could be considered unnecessary. On the other hand, surgery is also unsuitable if the symptoms are too severe, as no reversal or healing of the degenerative changes and osteoarthritis can be expected [16]. In FHNO, the diseased joint is treated by removing the femoral head. It is a simple and financially favorable procedure for the treatment of painful changes in the coxofemoral joint. In FHNO, joint integrity cannot be restored and is particularly favored when nonsurgical management is not possible or other surgical procedures have failed [19].

In THR, the coxofemoral joint is replaced with artificial prosthetic components. The different prosthesis systems play a particularly important role in this procedure. Cemented and cementless systems from Biomedtrix, Kyon and Innoplant are therefore compared with each other. The prostheses share similarities in terms of design and material, and most components of the systems can also be combined with each other, which can be particularly advantageous in revision surgery. Nevertheless, the systems offer different approaches to the problems that arise, such as primary stability, wear, stress shielding and more, which can give some systems an advantage depending on the indication and patient situation [7, 10].

All in all, the choice of the optimal procedure and system depends on many factors and should, among other things, be based on thorough patient selection, consideration of the indication, the surgeon's experience, and the financial possibilities.

References

1. Linn KA (2017) Juvenile Pubic Symphysiodesis. Vet Clin North Am Small Anim Pract 47:851–863. https://doi.org/10.1016/j.cvsm.2017.03.004
2. AO Foundation (2024) llustrating a DPO procedure with a veterinary DPO/TPO plate on a canine
3. Mount Pleasant Veterinary Group (2024) Xray Image of a canine Hip after Femoral Head Ostectomy (Fho)
4. Biomedtrix (2024) Biomedtrix Universal Hip System with Cemented (CFX)/Cementless (BFX) components
5. Hummel D (2017) Zurich Cementless Total Hip Replacement. Vet Clin North Am Small Anim Pract 47:917–934. https://doi.org/10.1016/j.cvsm.2017.02.004
6. Lanz OI, Forzisi I, Vezzoni A (2021) Zurich Cementless Dual Mobility Cup for Canine Total Hip Prosthesis: Implant Characteristics and Surgical Outcome in 105 Cases. Vet Comp Orthop Traumatol 34:294–302. https://doi.org/10.1055/s-0041-1725015
7. Harper TAM (2017) INNOPLANT Total Hip Replacement System. Vet Clin North Am Small Anim Pract 47:935–944. https://doi.org/10.1016/j.cvsm.2017.03.003
8. Henderson ER, Wills A, Torrington AM, Moores AP, Thomson D, Arthurs G, Brown G, Denny HR, Scott HW, MacQueen I, Dunne J, Onyett J, Walker JD, Prior J, Owen MR, Burton N, Whitelock R, Girling S, Morrison S, Gilbert S, Langley-Hobbs SJ, Gemmill TJ, Störk CK, Bright S, Comerford E, Pettitt R, Macdonald N, Innes JF (2017) Evaluation of variables influencing success and complication rates in canine total hip replacement: results from the British Veterinary Orthopaedic Association Canine Hip Registry (collation of data: 2010–2012). Vet Rec 181:18–18. https://doi.org/10.1136/vr.104036
9. Walter Schleger, Irene Stur (1986) Hundezüchtung in Theorie und Praxis : Ein genetischer Leitfaden für erfolgreiche Rassehundezucht. Jugend und Volk
10. Linnmann SM (2012) Die Hüftgelenksdysplasie des Hundes, 2., völlig neubearb. und erw. Aufl. Veterinärspiegel Verlag, Berlin
11. W H Riser, J F Shirer (1967) Correlation between canine hip dysplasia and pelvic muscle mass: a study of 95 dogs
12. J. W. Bradens, H. Hardwick (1968) New observations on the diagnosis and cause of hip dysplasia. Vet Med Small Anim Clin
13. H Kasström, S E Olsson, P F Suter (1972) Panosteitis in the dog. A radiographic, scintimetric and trifluorochrome investigation. Acta Radiol Suppl
14. Simon C. Roe, BVSc, PhD, DACVS (2007) The Rationale for Surgery in Hip Dysplasia. World Small Anim Vet Assoc World Congr Proc 2007
15. Johnston SA, Tobias KM (2018) Veterinary surgery: small animal, Second edition. Elsevier, St. Louis, Missouri
16. Guevara F, Franklin SP (2017) Triple Pelvic Osteotomy and Double Pelvic Osteotomy. Vet Clin North Am Small Anim Pract 47:865–884. https://doi.org/10.1016/j.cvsm.2017.02.005
17. Punke JP, Fox DB, Tomlinson JL, Davis JW, Mann FA (2011) Acetabular Ventroversion with Double Pelvic Osteotomy Versus Triple Pelvic Osteotomy: A Cadaveric Study in Dogs. Vet Surg 40:555–562. https://doi.org/10.1111/j.1532-950X.2011.00802.x
18. M. Petazzoni , R. Tamburro , T. Nicetto , M. P. Kowaleski Evaluation of the dorsal acetabular coverage obtained by a modified triple pelvic osteotomy (2.5 pelvic osteotomy).

Schattauer 2012. https://doi.org/10.3415/VCOT-11-08-0109
19. Harper TAM (2017) Femoral Head and Neck Excision. Vet Clin North Am Small Anim Pract 47:885–897. https://doi.org/10.1016/j.cvsm.2017.03.002
20. Lippincott CL (1992) Femoral Head and Neck Excision in the Management of Canine Hip Dysplasia. Vet Clin North Am Small Anim Pract 22:721–737. https://doi.org/10.1016/S0195-5616(92)50064-X
21. Kenneth A. Johnson (2010) Outcome of femoral head ostectomy in dogs and cats. Vet Comp Orthop Traumatol
22. Johnson K (2015) Femoral head and neck excision: The (most) unkindest cut of all? Vet Comp Orthop Traumatol 28:V–V. https://doi.org/10.3415/VCOT-15-08-0147
23. Anna Dettling (2016) Hüftgelenksendoprothetik Komplikationsanalyse bei Hund und Mensch im Vergleich
24. Schiller TD (2017) BioMedtrix Total Hip Replacement Systems. Vet Clin North Am Small Anim Pract 47:899–916. https://doi.org/10.1016/j.cvsm.2017.03.005
25. Montgomery ML, Kim SE, Dyce J, Pozzi A (2015) The effect of dorsal rim loss on the initial stability of the BioMedtrix cementless acetabular cup. BMC Vet Res 11:68. https://doi.org/10.1186/s12917-015-0383-z
26. Liska W, Israel S (2018) Morbidity and Mortality Following Total Hip Replacement in Dogs. Vet Comp Orthop Traumatol 31:218–221. https://doi.org/10.1055/s-0038-1632365
27. KYON (2024) KYON Product Catalog 2023. In: movora.com. https://movora.com/wp-content/uploads/2023/05/Movora_KYON_ProductCatalog_2023.pdf?__hstc=141846637.a246f58f4060f3333f6a47a88b6a828c.1726951632155.1726951632155.1727005595229.2&__hssc=141846637.1.1727005595229&__hsfp=1507836341&_gl=1*u0mb5n*_ga*MTAwODgyNTc5MS4xNzI2OTUxNjI5*_ga_SY8YEYBSR8*MTcyNzAwNTU5My4zLjEuMTcyNzAwNTU5My42MC4wLjA.#page=4. Accessed 21 Sep 2024
28. Vezzoni L, Bazzo S, Vezzoni A (2017) Revision of a BFX total hip replacement stem using a Kyon stem and a head adaptor in two dogs. Vet Comp Orthop Traumatol 30:81–87. https://doi.org/10.3415/VCOT-16-05-0070
29. Batailler C, Fary C, Verdier R, Aslanian T, Caton J, Lustig S (2017) The evolution of outcomes and indications for the dual-mobility cup: a systematic review. Int Orthop 41:645–659. https://doi.org/10.1007/s00264-016-3377-y
30. (2024) Innoplant veterinary implants. In: Wwwinnoplant-Vetde. https://www.innoplant-vet.de/. Accessed 3 Oct 2024
31. Bayer K, Matiasovic M, Steger H, Böttcher P (2019) Complications and Long-Term Outcome in 16 Canine Cementless Hybrid Hip Arthroplasties. Vet Comp Orthop Traumatol 32:073–078. https://doi.org/10.1055/s-0038-1676072
32. Liska WD (2004) Femur Fractures Associated with Canine Total Hip Replacement. Vet Surg 33:164–172. https://doi.org/10.1111/j.1532-950X.2004.04024.x
33. Alvarez-Sanchez A, Amsellem P, Vezzoni L, Vezzoni A (2021) Zürich cementless total hip arthroplasty as a treatment option for capital physeal fractures in dogs: Outcome in 53 cases. Vet Surg 50:1054–1064. https://doi.org/10.1111/vsu.13605
34. Agnello KA, Brown C, Aoki K, Franklin S, Hayashi K (2015) Risk factors for loosening of cementless threaded femoral implants in canine total hip arthroplasty. Vet Comp Orthop Traumatol 28:48–53. https://doi.org/10.3415/VCOT-14-02-0027
35. Denny HR, Linnell M, Maddox TW, Comerford EJ (2018) Canine total hip replacement using a cementless threaded cup and stem: a review of 55 cases. J Small Anim Pract 59:350–356. https://doi.org/10.1111/jsap.12827

Thesis progress report for veterinary students

Name of student: Jannes Koch

Neptun code of the student: IXJQJE

Name and title of the supervisor: Prof. Tibor Németh, Head of Department

Department: Surgery

Thesis title: Treatment and therapy of hip dysplasia in dogs

Thesis progress report I. – 10th semester

	Timing			Topic / Remarks of the supervisor	Signature of the supervisor
	year	month	day		
1.	2024.	03.	11.	Review of literature	[signature]
2.	2024	04.	08.	"	[signature]
3.	2024	05.	13.	"	[signature]
4.					
5.					

Thesis progress grade achieved at the end of the first semester: grade (5)

ÁLLATORVOSTUDOMÁNYI EGYETEM Sebészeti és Szemészeti Tanszék és Klinika Tanszékvezető 1787 BUDAPEST

Thesis progress report II. – 11th semester

	Timing			Topic / Remarks of the supervisor	Signature of the supervisor
	year	month	day		
1.	2024	09.	09.	Advices on thesis writing	[signature]
2.	2024	10.	07.	– " –	[signature]
3.	2024	11.	04.	– " –	[signature]
4.					

ÁLLATORVOSTUDOMÁNYI EGYETEM Tanszékvezető 1787 BUDAPEST

5.					

Thesis progress grade achieved at the end of the 11th semester: ....grade V.........

The thesis meets the requirements of the Study and Examination Rules of the University and the Guide to Thesis Writing.

I accept the thesis and found suitable to defence,

....
signature of the supervisor

Signature of the student:...

Signature of the secretary of the department: ....

Date of handing the thesis in. 20.11.2024 ....