REVIEW ARTICLE

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Total Knee Replacement Applications in Veterinary Surgery: A Review

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Abstract

Artificial joint prostheses are preferred as a good treatment alternative for joints that are difficult or impossible to treat. With the advancement of technological possibilities, the joints that need to be locked or amputated are saved by total joint prostheses. Although there is relatively more information about total hip joint replacements, there is not enough information and experience about total knee replacements. Active use of total knee replacement in veterinary surgery will improve the standard of living of many animals. The aim of this review is to provide information about total knee replacement, which is not yet widely used, and to consider it among treatment alternatives.

Keywords: Dog, total knee replacement, veterinary surgery, review.

INTRODUCTION

The knee joint is a weight-bearing joint that is subject to various forces and abrasions such as tension, compression, and torsion. It is very difficult to restore a traumatized joint (Zalavras et al. 2014; Yang et al. 2022). Knee osteoarthritis, which usually develops as a result of anterior cruciate ligament injuries, (Vasseur and Bery, 1992; Liebich et al. 2007; Thitiyanaporn et al. 2020) causes joint pain, decreased physical activity and lameness, especially in dogs (Sarıerler et al. 2013; Ramirez-Flores et al. 2017; Thitiyanaporn et al. 2020). In advanced cases, desired results cannot be obtained from medical treatment methods. Techniques such as arthrodesis and amputation do not provide permanent solutions. Total joint replacement (prosthesis) remains current as an effective and reliable technique in the treatment similar joint injuries and inflammations (Liebich et al. 2007; Allen, 2012; Zalavras et al. 2014; Thitiyanaporn et al. 2020; Memarian et al. 2022; Yang et al. 2022). Therefore, this technique prevents extremity loss (Liebich et al. 2007).

Total knee replacement (TKR) is a technique that is frequently preferred in humans and has successful results (Liebich et al. 2007). In this technique, metallon-plastic (ultra-high molecular weight polyethylene) condylar design implants with semi-constrained femorotibial joints are mostly used. In these implants, cemented fixation is preferred more than uncemented. Most of the total knee prostheses performed in dogs are derived from human total knee prosthesis models (Allen et al. 2009). Firstly, Ducheyne et al. (1977) developed a simple roller implant to examine the effect of dynamic loading on bone growth in cementless TKR. In the late 1980s, the development and optimization of cementless fixation techniques were emphasized and condular implant designs were introduced (Turner et al. 1989; Berzins et al. 1994; Summer et al. 1994; Liska et al. 2007; Allen et al. 2009). The first joint prostheses were made of stainless steel, but with the advancement of research and clinical applications, it has been understood that the corrosion resistance of these prostheses is weak and their strength is insufficient. Cobalt and titanium alloy prostheses with similar properties were produced in later times for the reasons stated. Since the surfaces of these prostheses are smooth, bone cement should be used to attach the bone to the joint prosthesis (Yang et al. 2022). In total knee prosthesis, the femoral condyles and the femoral trochlear groove are produced from a cobalt-chromium mixture, and the tibial surface is made of ultra-high molecular weight polyethylene mounted on a metal implant or ultra-high molecular weight polyethylene in the form of a monoblock only (Liebich et al. 2007). It is thought that there is a need for more comprehensive information about total knee replacement, which is thought to become one of the routine surgical procedures in the near future. The aim of this review is to give detailed information about total knee replacement.

ANATOMY OF THE KNEE JOINT

The knee joint is the largest synovial joint in the musculoskeletal system (Vérez-Fraguela et al. 2017). This joint consists of two different joints, the femorotibial between the femur and the tibia, and the femoropatellar between the femur and the patella (Dursun, 2008). Other parts that make up the knee joint are the bone and capsuloligamentous structures, the meniscus and the muscle-tendon system (Vérez-Fraguela et al. 2017). Bone structures of the knee joint are the condyles of the femur, the condyles of the proximal end of the tibia, and the patella. The condyles of the femur diverge distally and cranially. The condyles are separated cranially by the trochlea and caudally by the intercondylar fossa. The lateral and medial condyles at the proximal end of the tibia have a flat surface and correspond to the condyles of the femur. These condyles are separated by the intercondylar

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prominence, which aligns with the intercondylar fossa of the femur. The intercondylar process consists of lateral and medial intercondylar tubercles. Among these tubercles are the cranial, central and caudal intercondylar areas for attachment of the meniscus and cruciate ligaments. Proximal to the tibia is an extensor groove to which the tuberositas tibia (attachment of the patellar ligament) and the long digital extensor muscle tendon are attached. Caudal to the tibia is the popliteal notch. The oval-shaped patella is located on the cranial side of the knee joint and articulates with the trochlea of the femur. The extension of the quadriceps femoris muscle forms the patellar ligament (Matthews and Goldstein, 1992; Hazıroğlu and Ekim, 2010). The central ligaments are cranial (anterior) cruriate ligament (anterior cruciate ligament) and caudal (posterior) cruriate ligament (posterior cruciate ligament). The peripheral ligaments are the patellar ligament, lateral patellar retinaculum, medial patellar retinaculum, medial collateral ligament, lateral collateral ligament, oblique popliteal ligament (Vérez-Fraguela et al. 2017).

KINEMATICS OF KNEE JOINT

The primary movement of the knee joint consists of flexion and extension, and this movement occurs in the sagittal plane. Due to the roller-shaped geometry of the collateral ligaments, cruciate ligaments, menisci, and femoral condyles, a monoplane movement does not occur. The secondary movement of this joint consists of the rotation of the tibia on the femur, and this occurs in the transverse plane (Kowaleski et al. 2012). The knee joint is the joint where dogs are most prone to orthopedic diseases. The treatment strategy is mostly focused on maintaining normal motion of the joint. Loss of extension or flexion of 10° or more is associated with clinical lameness. Therefore, range of motion (total flexion–extension capacity); It is a commonly used measurement for functional assessment of the knee joint in the treatment of cranial cruciate injury, total knee replacement, partial patellectomy, and multiple ligament injuries. When evaluating goniometric measurements of the knee joint in dogs, factors such as breed differences, body weights and muscle mass should be considered. Generally, goniometric measurements of the contralateral knee joint are often used as a reference value due to the assumption that the knee joint is symmetrical. However, this assumption may not be valid in cases of bilateral disease, greater mobilization of the contralateral limb for compensation, and other contralateral abnormalities. Extension and flexion degrees and normal range of motion vary according to races (Ates et al. 2011; Sabanci and Ocal, 2016). Data showing the extension and flexion degrees and normal range of motion of some breeds are shown in Table 1. Jaegger et al. (2002) reported that the extension and flexion angles of Labrador Retriever dogs were 162 and 42°, respectively. Thomas et al. (2006) reported that the extension and flexion angles and normal range of motion of German Shepherd dogs were 153, 33 and 120°, respectively. Ates et al. (2011) also reported that the normal range of motion in Kangal dogs was 118°.

Table 1. Data on extension, flexion and normal range of motion (expressed in degrees) of some races (Nicholson et al. 2007; Sabanci and Ocal, 2016).

	German Shepherd	Labrador Retriever	Golden Retriever	Belgian Malinois	Rottweiler	Boxer	Doberman pinscher	Greyhound
Extention	151	157	156	156	154	159	164	144
Flexion	34.0	37.6	34.1	29.3	34.1	39.1	29.8	50
Normal range of motion	117	119	122	127	120	120	134	94

KNEE PROSTHESIS TYPES

In total knee prosthesis produced for dogs, the femoral compartment is metallic and the tibial compartment is polymeric (Thitiyanaporn et al. 2020). These prostheses are commercially available in both cemented and cementless designs (Allen, 2012). Cementless fixation; It has advantages such as preserving the periprosthetic bone stock during surgery, eliminating bone cement, which is the source of particulate debris, shortening the operation time, and being more suitable for minimally invasive surgical approaches (Allen et al. 2012; Muir, 2018). Although this fixation has many advantages, it has a higher revision rate compared to cemented total knee replacement. In addition, data from human total knee replacement components indicate that there can be significant differences in both the size and distribution of bone apposition and/or ingrowth with cementless implants. For this reason, many surgeons prefer to use bone cement to provide initial stabilization and long-term fixation of total knee replacement components (Allen et al. 2009). Allen et al. (2012) investigated the efficacy of a bioactive coating (peri-apatite, a solution-deposited form of hydroxyapatite) in increasing the fixation of a cementless tibial component in canine total knee replacement. Although coated implants migrate more than cemented implants in the first 12 months after surgery, it has been reported that the difference is not clinically significant (Allen et al. 2012).

WHAT IS ULTRA-HIGH MOLECULAR WEIGHT POLYETHYLENE (UHMWPE)?

The implant model used in the production of knee prostheses consists of a polymer bed and a metal spherical component sliding on it. UHMWPE, a member of the polyethylene family, is preferred more as a bedding material in knee prostheses compared to other thermoplastics due to its high strength, abrasion and fatigue resistance. A cross-linked version of UHMWPE has been developed to prevent fatigue cracking, discoloration and friction that may develop in long-term use. Highly cross-linked UHMWPE has been successfully applied in knee prostheses (Kurtz, 2012; Güner ve Meran, 2020).

WHAT IS THE ROLE OF 3D MODELING IN TOTAL KNEE PROSTHESIS?

One of the most important factors that will increase the success in the prosthetic-based surgical approach of severe osteoarthritis (OA) cases in the knee joint is to produce case-specific implants (Liska and Doyle, 2009; Allen, 2012; Memarian et al. 2022). The first dedicated total knee replacement procedure was performed in 2005 to manage nonunion in the medial femoral condyle resulting from a gunshot wound in a dog. In this intervention, a tomography of the knee region was taken and a cemented total knee prosthesis was performed using the data obtained and 3D modeling (Liebich et al. 2007; Liska and Doyle, 2009).

INDICATIONS

In cases of lameness, joint pain and impaired joint structure, disability due to chronic pain occurs that does not respond to conservative treatment. When such a situation arises, joint replacement surgery becomes indicated. Indications for total knee replacement include advanced osteoarthritis (Liebich et al. 2007; Liska and Doyle, 2009; Sarıerler et al. 2013), joint fractures that cannot be repaired by surgery, non-union fractures that do not respond to treatment, and joint dislocations that cannot be corrected by surgery (Mckee and Arthurs, 2022).

CONTRAINDICATIONS

Contraindications for total knee replacement include joint diseases without pain and lameness, joint pain that can be treated conservatively, neurological problems, and septic arthritis (Mckee and Arthurs, 2022).

DETERMINATION OF IMPLANT SIZES

Specialized templates are used to determine implant sizes. By superimposing these templates on digital images, the most suitable size is determined. Caudocranial images are taken to determine the tibial component dimensions, mediolateral images are taken to determine the femoral component dimensions and measurements are made on these radiographs. When making measurements for the tibial component, the template is placed on the caudocranial images with reference to the tuberositas tibia, and care is taken not to exceed the medial and lateral cortex in order not to damage the collateral ligaments and fibula. For the femoral component, the template is placed directly on the cancellous bone in the mediolateral radiograph and centered on the femoral condyle in the caudocranial view (Liebich et al. 2007).

PREOPERATIVE EVALUATION

Preoperative complete blood count, blood biochemistry profile and urine analysis of cases suitable for total hip replacement should be evaluated. In addition, gait analyses, posture, limb measurements and radiographic evaluations should be performed (Liebich et al. 2007).

SURGICAL PROCEDURE

After providing asepsis-antisepsis of the skin, the area is prepared for the operation. The joint is reached with a craniolateral, medial or lateral parapatellar incision (Allen et al. 2009; Eskelinen et al. 2012; Liebich et al. 2007). After the incision, the lateral/medial retinaculum and fabellopatellar ligament are cut to luxate the patella medially/laterally (Allen et al. 2009; Liebich et al. 2007). The infrapatellar fat pad, meniscus, anterior and posterior cruciate ligaments in the knee joint are removed by dissection or electrocautery (Allen et al. 2009; Thitiyanaporn et al. 2020). The tendon of the musculus digitalis longus is separated from the extensor fossa on the femur, and the insertion of the popliteus tendon into the craniolateral aspect of the femur is partially or completely released to facilitate distal femoral osteotomy. Specially designed instruments and cutting blocks are used for tibial osteotomy and femur resection (distal, cranial, caudal and groove incision) (Allen et al. 2009). Prosthesis application can be started with tibial or femoral osteotomy (Allen et al. 2009; Liebich et al. 2007). The bone cutting template of the proximal tibia is fixed to the proximal tibia with Kirschner wire. It is protected with gauze in order not to damage the lateral and medial collateral ligaments of the knee joint. The proximal tibia is cut with an oscillating saw following the bone cutting pattern. An 8 mm hole is drilled in the middle of the cut proximal tibia area to accommodate the body of the tibial implant (Thitiyanaporn et al. 2020). The cut osteotomy surfaces are irrigated with saline and then dried (Allen et al. 2009). Bone cement is applied to the proximal tibia incision surface. The proximal tibial prosthesis is attached to the tibia. The femoral osteotomy guide is fixed to the distal femoral condyle with a Kirschner wire. The distal femoral condyle is cut with an oscillating saw using a template guide (Thitiyanaporn et al. 2020). In order to fix the prosthesis with bone cement, holes are made on the distal surface of the femur (approximately 3.2-8 mm) (Allen et al. 2009; Thitiyanaporn et al. 2020). Bone cement is applied to the surface of the femoral component. The distal femoral prosthesis is implanted by embedding on the bone cement surface (Thitiyanaporn et al. 2020). The joint capsule is sutured with nylon or polydiaxanone thread (Allen et al. 2009; Thitiyanaporn et al. 2020). Subcutaneous and skin are routinely sutured (Thitiyanaporn et al. 2020). Then, flexion, extension, abduction, adduction, internal rotation, external rotation movements and joint motion angles of the knee joint are checked. The patient's movements should be restricted in a way that only leash walks are allowed for six weeks postoperatively, and slippery surfaces should be avoided (Eskelinen et al. 2012).

POSTOPERATIVE CARE

Caudocranial and mediolateral radiographs may be taken to confirm implant position. A Robert Jones bandage is applied to the involved extremity and rehabilitated. For postoperative pain management, morphine (10 mg IM) can be administered every 6-12 hours for at least 2 days. Carprofen (2-4 mg/kg, once a day, orally, 5 days) and cephalexin (22-30 mg/kg, twice a day, orally, 7-10 days) can be applied as a medical treatment combination (Allen et al. 2009).

COMPLICATIONS

Osteotomy performed on the tibial plateau may not completely cover the implant osteotomy area. Bone bleeding may occur in areas that remain open. These bleedings can be stopped with bone wax. As an intraoperative complication, the medial collateral ligament may be damaged during tibial osteotomy. Since the popliteus tendon may be damaged during distal femoral osteotomy, maximum care should be exercised during the intervention (Allen et al. 2009). One of the most common complications in total knee arthroplasty is polyethylene wear. However, periprosthetic joint infections are also considerably higher (Koh and Zeng, 2017).

PROSTHESIS-ASSOCIATED INFECTION

While the most common complication of total knee arthroplasty was polyethylene wear until fifteen years ago, periprosthetic joint infections have become more prominent in recent years (Koh and Zeng, 2017). Studies have reported that periprosthetic joint infections develop in 25%-38% of cases (Jie et al. 2019; Preobrazhensky et al. 2019). It has been reported that in order to reduce these rates to acceptable levels such as 1-2%, the factors causing the infection should be revealed and then effective treatment options such as perioperative antibiotics and intraoperative antibiotic cement use, intraoperative antibiotic calcium sulfate, sterilization of the operating room and elimination of local bacterial colonization should be applied (Petis et al. 2019). Among the isolated infectious agents, staphylococcus aureus (22%), coagulase negative staphylococci (22%), alpha and beta-hemolytic streptococci (9% and 5%, respectively), enterococci (7%), aerobic gram-negative bacilli (25%) and anaerobes (10%) have been reported (Brause, 2010). Pasteurella multocida infections are more common in total knee prosthesis performed after dog bites (Guion and Sculco, 1992; Heym et al. 2006; Heydemann et al. 2010).

REHABILITATION

All movements of the patient are restricted for 2 weeks postoperatively (Allen et al. 2009). Afterwards, a physiotherapy program including exercises accompanied by passive movements, low-level laser therapy and cryotherapy can be applied and this is continued for six months. After two weeks, active therapeutic exercises and underwater treadmill training therapy can be started. Underwater treadmill training is applied once a week for an average of three months, with varying frequency depending on the owner's ability to participate in therapy. Home exercises such as step-up, disabled, incline walking, pulling harness and squatting under the limbo stick can be launched approximately two months after the operation (Eskelinen et al. 2012).

CONCLUSION

In the light of developing scientific techniques today, it is underlined that prosthesis applications, which were used mostly in the hip joint in the past, can now be used in the knee joint as well. Adaptation of this technique to clinical practice is important in terms of regaining the mobility of the knee joint and preventing extremity losses. In this way, the living standard of animals, which were previously subject to limited treatment opportunities and whose welfare quality was adversely affected, will also increase. In the present review article, it is aimed to give more detailed information about total knee arthroplasty, which has become popular recently, based on the current literature.

Conflict of Interest

The authors declared that there is no conflict of interest.

Authorship contributions

Concept: Z.Y, K.K, Design: Z.Y, M.E.A, Data Collection or Processing: Z.Y., H.A, İ.A, Ö.M Literature Search: Z.Y, M.E.A, K.K Writing: Z.Y, K.K, İ.A, H.A, Ö.M, M.E.A

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