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Limb prosthetics in animals

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Mobility is essential for maintaining a healthy and active life in animals. Given their relatively long lifespan and substantial body weight, prolonged discomfort and immobility can have serious consequences for their overall well-being and quality of life. Limb loss, most commonly resulting from trauma (65%) and neoplasia (35%), is a major cause of permanent disability and impaired mobility in animals.

In recent years, restoration of mobility and improvement of quality of life have become important concerns for animal owners. This has led to the increasing use of exoprostheses and endoprostheses in veterinary practice. Although orthotics and prosthetics are well-established fields in human medicine, their application in veterinary medicine remains relatively underexplored. In India, veterinary orthotics and prosthetics are still in an emerging phase, with considerable scope for research, innovation, and clinical application.

Exoprostheses are relatively easy to fabricate and affordable; however, they have certain limitations, including stump pain, soft-tissue irritation and damage, skin necrosis, and infection arising from the stump-socket interface. An alternative approach that eliminates the need for a stump-socket interface is osseointegrated prosthetic limb attachment, in which the artificial limb is directly anchored to the residual bone. Osseointegration is commonly achieved using titanium-based implants, which establish a strong and stable interface with bone, thereby providing effective load transmission and improved limb function.

One of the most recent advances in endoprosthetic limb rehabilitation is the Intraosseous Transcutaneous Amputation Prosthesis (ITAP), which combines direct skeletal attachment with a transcutaneous interface and has the potential to overcome several limitations associated with conventional socket-based prostheses. With increasing advances in biomaterials, implant design, and regenerative technologies, veterinary orthotics and prosthetics are emerging as promising fields of clinical research. In India, veterinarians and researchers are increasingly exploring innovative approaches in orthotics and prosthetics, with the potential to position the country as a global hub for affordable and innovative solutions for animal mobility and rehabilitation.

Keywords: Animal rehabilitation, Endoprosthesis, Exoprosthesis, Limb prosthetics, Orthotics

Prosthesis is an artificial device designed to replace a missing body part, which may have been lost due to trauma, disease, or congenital abnormalities. Ambroise Paré is widely regarded as the father of modern prosthetics. He introduced the concept of amputation to the medical community and, in 1536, developed an artificial arm and elbow, followed by the design of other prosthetic limbs. The use of prostheses, however, dates back much further in history. One of the earliest references is found in the Rigveda, which describes the warrior queen Vishpala, who reportedly lost a leg in battle and was fitted with iron prosthesis around 3500 BC. Among the earliest archaeological evidence of a prosthetic limb is a device unearthed at Pompeii, dating to approximately 300 BC. It was constructed from thin bronze plates fitted over a wooden core and secured to the residual limb using a leather sleeve (Seymour, 2002).

Prosthetic devices are particularly recommended for animals of high genetic, economic, or sentimental value. In animals, limb amputation is most commonly necessitated by trauma (approximately 65%), with crushing injuries and neoplasia accounting for the remaining cases (35%). Although amputation can be life-saving and prolong survival, it may adversely affect postoperative function and quality of life, aspects that are increasingly emphasized by animal owners. Veterinary prosthetics remains in its infancy and has not yet gained widespread clinical application, largely because quadrupeds generally adapt remarkably well to a three-legged gait. Nevertheless, reports in the veterinary literature indicate a high level of owner satisfaction and favourable outcomes following limb amputation when prosthetic devices are employed (Carberry and Harvey, 1987).

Limb prostheses can enable animals to regain, to a considerable extent, their pre-amputation level of ambulation and activity. Forelimb amputation is generally more debilitating than pelvic limb amputation; consequently, animals with forelimb amputations demonstrate substantially improved mobility when fitted with a prosthesis compared with ambulation without one (Borghese *et al*., 2013). Another important indication for prosthetic rehabilitation is bilateral limb amputation resulting in an inability to ambulate effectively. Successful use of limb prosthesis requires diligent and intensive aftercare by the owner. The prosthesis should be removed and cleaned daily, and the residual limb should be carefully examined for pressure sores, skin irritation, or other complications. Periodic adjustments or refitting may also be necessary to accommodate growth in young animals or changes in muscle mass and limb conformation over time (Desrochers *et al*., 2014). Many of the techniques and materials used in human

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orthotics and prosthetics (H-OP) can be adapted for veterinary applications, with appropriate modifications to account for quadrupedal locomotion and the substantially greater forces generated by veterinary patients compared with humans (Borghese *et al.*, 2013).

Materials Used for Prostheses

1. Exoprosthetic materials: The material and equipments are: carbon fiberblade, polyoxymethylene, polydioxanone, polypropylene fiber, plaster of Paris, adhesives and loop belts, stockings, and slings.

2. Osseointegrated or Endoprosthetic materials: Osseointegration was originally defined as a direct structural and functional connection between living bone and the surface of a load-carrying implant. These are of the following types:

(i) Bio-tolerant type prosthetics: Characterized by distance osteogenesis, the implant is not rejected from the tissue, but it is surrounded by a fibrous connective tissue i.e., gold, cobalt-chromium alloys, stainless steel, polyethylene and polymethy lmethacrylate.

(ii) Bio-inert type: Characterized by contact osteogenesis, the osteogenic cells migrate directly to the surface where they will establish de novo bone formation e.g., titanium and titanium alloys.

(iii) Bio-reactive type: These implants promote new bone formation at the implant–bone interface by facilitating ionic exchange and the development of a chemical bond with bone. A typical example is the rutile-type titanium dioxide (TiO_2) layer that naturally forms on the surface of titanium implants. Although titanium possesses superior mechanical and biocompatibility characteristics compared with many other implant metals, its osteoconductivity is lower than that of calcium phosphate (CaP)-based bioceramics (Kilpadi *et al.*, 2001). CaP-based ceramics are therefore considered bone-bonding materials, whereas titanium is generally regarded as a non-bonding material. Consequently, considerable research has focused on enhancing the bioactivity of titanium and improving the osteoconductivity of the implant surface through various surface modification techniques. Davies (1998) investigated the mechanisms underlying bone healing around implant surfaces and demonstrated that peri-implant bone healing leading to contact osteogenesis, i.e., bone formation directly on the implant surface, can be phenomenologically divided into three distinct phases. These phases provide a framework for experimentally evaluating the biological interactions between the implant surface and the surrounding bone tissue.

Types of Prosthesis

Limb prosthesis can be achieved either by using an exoprosthetic device or an endoprosthetic device. Among these, exoprosthesis remain the most commonly used prosthesis (Wendland *et al.*, 2019). This conventional approach is widely adopted due to its relative affordability, ease of fabrication and non-invasive nature. On the other hand, endoprosthesis, which involves direct integration of the prosthetic device with the residual bone through osseointegration, represents a more advanced and invasive technique (Erazo *et al.*, 2020).

1. Exoprosthesis- Stump Socket Prosthesis (SSP)

Exoprosthesis (also named socket prostheses) are devices that are secured to incomplete limbs to enable locomotion. They do not have any direct structural or functional connection between living bone and the surface of a load-carrying implant. Adamson *et al.* (2005) reported the use of stump socket prosthesis in a 14-week-old female Golden Retriever, born with congenital agenesis of right paw. These consist of five elements, detailed below.

***(I) The socket*:** he socket is the component that connects the amputated limb to the extension rod. Its design should ensure rigidity, a close and comfortable fit to the contours of the residual limb, and adequate provision for muscle movement. Polypropylene (PP) is commonly used for socket fabrication because of its desirable properties, including good fatigue and chemical resistance, toughness, integral hinge characteristics, and good heat resistance. The socket must be securely attached to the residual limb to provide adequate suspension and stability. This can be achieved by creating a vacuum within the socket, which generates a negative pressure that draws the socket firmly against the limb. In addition, the natural anatomy of the hind limb can be utilized for mechanical suspension, with the tarsal bony prominence acting as a hook-like structure to help secure the socket in position (Fig. 1; Table 1).

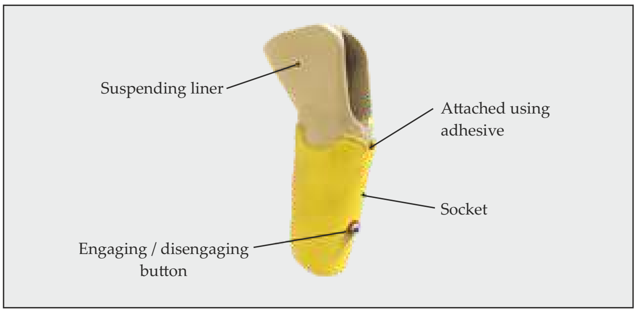

Fig. 1: Socket

Table 1: Socket in detail.

Sl. No.	Item	Funcion	Material	Manufact-uring Precess
1	Suspen-ding liner	To attach the socket to the limb	Silicone rubber	Injection moulding
2	Socket	Provide rigid support to the prosthetic	Polypro-pylene	Vacuum moulding
3	Button	To release air in and out of the socket to ensure vacuum inside	Rubber	Injection moulding (Procurable)

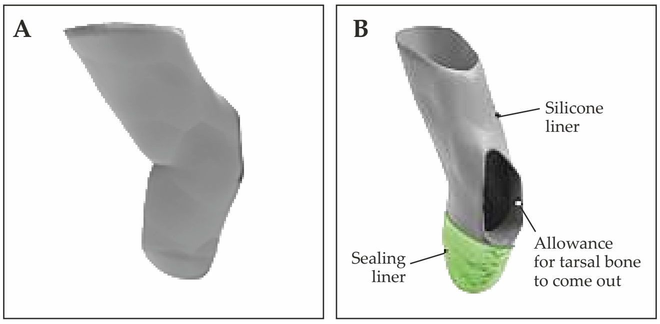

Fig. 2: (A) Silicone rubber lining; (B) Whole liner assembly.

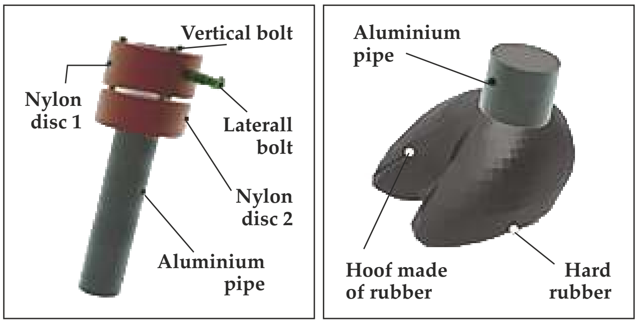

Fig. 3: (A) Extension rod assembly; (B) Hoof

***(ii) The liner*:** The liner is essentially a stocking-like interface made of silicone rubber that is placed between the residual limb and the prosthetic socket. Platinum-cured silicone rubber is commonly used for liner fabrication because of its excellent biocompatibility and skin-friendly properties. It minimizes friction and shear forces between the skin and socket, thereby reducing the risk of skin irritation, pressure sores, and dermatosis. The liner also provides cushioning and helps distribute localized pressure more evenly during dynamic loading, thereby protecting the residual limb. In addition, the liner facilitates vacuum suspension of the prosthesis by creating an airtight interface between the residual limb and the socket (Arauz *et al.,* 2021). A second, smaller silicone-rubber sealing liner may be placed over the primary liner to establish an effective seal and maintain the vacuum required for secure suspension (Figs. 2 A and B).

Studies have emphasized that liner materials should possess suitable compressive elasticity, tensile strength, thermal conductivity and coefficient of friction to reduce skin complications and improve prosthetic acceptance (Cagle *et al.,* 2018). Thermoplastic polyurethane (TPU) has recently gained considerable attention in prosthetic and orthotic fabrication because of its excellent elasticity, flexibility, abrasion resistance and durability. TPU-based liners provide superior cushioning, adaptability and mechanical strength while maintaining lightweight properties (Dagge *et al.,* 2025).

***(iii) Extension rod*:** Extension rod assembly consists of two parts: nylon disc and aluminium pipe. The nylon disc attaches the aluminium rod to the socket. In the assembly there are two nylon discs out of which one rests inside the socket, whereas the other lies outside the socket. The aluminium pipe goes through the nylon discs and socket. The aluminium pipe is further locked by a bolt going laterally through the nylon disc and is bolted at another end. The whole assembly is locked to the socket with three bolts at 120 degrees going vertically through the face of nylon disc (Fig. 3A).

***(iv) Suspension system*:** It sustains the socket in position. They are of three types: self-suspension (utilizing the anatomical geometry), suction suspension (consisting of a suction socket design made of a gel suspension liner) and suspension harnesses (including belts, sleeves, cuffs, straps and wedges).

(v) Hoof: The material used for making hoof is rubber used in heels of sandals, layer by layer the rubber sheets are stacked and glued, which is further sanded to the shape of the hoof. At the bottom of hoof, hard rubber is placed to avoid wearing of the rubber and increasing the life (Figs. 3B and 4).

Considerations for SSP

Level of amputation: If prosthesis is to be considered postoperatively, it should be taken into account by the surgeon before amputation, because it may alter the level of the amputation to allow the residual limb to fit into a prosthetic limb. To suspend prosthesis on the thoracic limb, preservation of 40% of the radius and ulna is required. For the pelvic limb, the medial and lateral malleoli must be preserved at a minimum (Borghese *et al.,* 2013).

Residual limb assessment: The socket of the prosthesis contacts the residual part of the limb and is responsible for transferring forces from limb to prosthesis. Residual limb assessments are needed throughout different stages of prosthesis management, namely, pre-amputation, residual limb maturation, prosthetic design, prosthetic fitting and subsequent clinical

Fig. 4: Final design of the exoprosthesis.

Fig. 5: Casting, moulding and prepration of replica.

follow ups. The basic parameters of the traditional clinical assessment of the residual limb, as per Zheng *et al.* (2001) include residual limb dimensions (length and circumference to determine volume changes), proximal joint mobility (using goniometry so as to record spasticity or joint contracture), peripheral vascular circulation (checking superficial pulse, temperature and colour), neurological condition (sensation of touch and hot-cold discrimination), skin condition (check for abrasion, blister, ulcer, cyst etc.), scar (location, stage of healing and exposure of bone if present), soft tissue firmness (assess manually as firm or flabby) and the condition at the end of the residual limb (rounded ends are preferable to pointed ends).

Proper fit of socket: The comfort of a prosthetic limb and therefore, its usefulness in restoring mobility to the animal depends on the fit of the prosthetic socket. The main challenge in prosthetic socket design is to obtain an appropriate pressure distribution at the limb-socket interface. Such pressure distribution pattern depends mainly on the geometry and biomechanical characters of the residual limb.

Fig. 6: Stump socket prosthesis fitted in cattle (A) and dog (B).

Procedure

The making of exoprosthesis is based on a cast of the limb or a 3-dimensional (3D) rendering that may be based on an image captured by a hand-held scanner or a computed tomography (CT) scan (Marcellin-Little *et al*., 2015). Casting of animal is done either fully awake or under sedation based on clinician or prosthetist preference. Casting is done with plaster of Paris because it is safe, comfortable, rapid and affordable. Most clinicians use fiberglass or semi-rigid fiberglass to cast limbs. Before making cast, stocking or plastic bag has to be applied over the amputee leg. Polypropylene (PP) sheet is heated with hot air gun so that it can be used for moulding over the prepared POP cast. After moulding, the PP mould is kept in prosthetic oven for heat treatment. The prepared socket is then attached with aluminium rod and suspensory system (Figs. 5 and 6).

Although SSPs can significantly improve the quality of life of amputees, their use is often associated with complications such as skin necrosis, infection, friction at the limb–prosthesis interface, stump pain, soft-tissue injury, inadequate control, and fitting difficulties (Tomaszewski, 1982). Most of these complications arise at the stump-socket interface and are primarily attributable to the inability of the soft tissues of the residual limb to adequately withstand and distribute the mechanical loads associated with weight bearing. Adamson *et al*. (2005) reported the use of a hinged prosthesis in a dog following amputation of the digits and metatarsal pad, thereby eliminating

Fig. 9: A hinged prosthesis used to replace the digits and metatarsal pad of pelvic limb (Adamson *et al.*, 2005).

the need for a conventional stump-socket interface. The prosthesis consisted of two passive hinges, two plastic shells lined with soft material and secured with hook-and-loop fasteners, and a rubber sole with a non-skid textured surface. A silicone liner was incorporated to protect the skin within the prosthesis (Fig. 7).

2. Endoprosthesis - Osseointegrated Prosthesis

Another approach to limb prosthesis that eliminates the need for a conventional stump-socket interface was described by Blunn and Pendegrass (2011), in which the artificial limb is directly attached to the residual bone through osseointegration (Fig. 8). Osseointegration was originally defined as a direct structural and functional connection between living bone and the surface of a load-bearing implant (Brånemark *et al*., 1977). Subsequently, the concept has been refined, and an implant is considered osseointegrated when there is no progressive relative movement between the implant and the bone with which it is in direct contact (Brånemark, 1983).

Types of osteointegrated implants

These implants follow the general concept of a metal-based intramedullary stem connected with a coupling element, which protrudes the soft tissue layer of the stump to provide an attachment for an external artificial limb. The fixation of the intramedullary stem with the bone remnant is realized by a different method for different implants. The various types of osseointegration implants in use today are as follows:

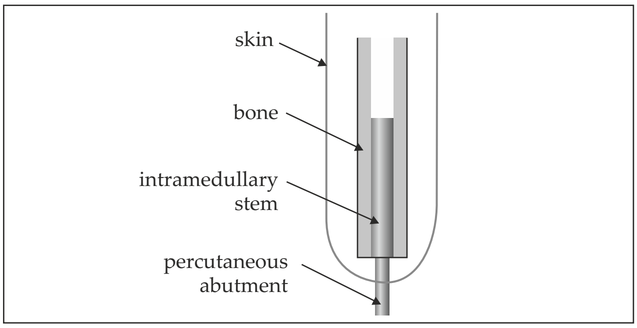

Fig. 8: Schematic representation of direct prosthesis fixation implant (Tomaszewski, 1982).

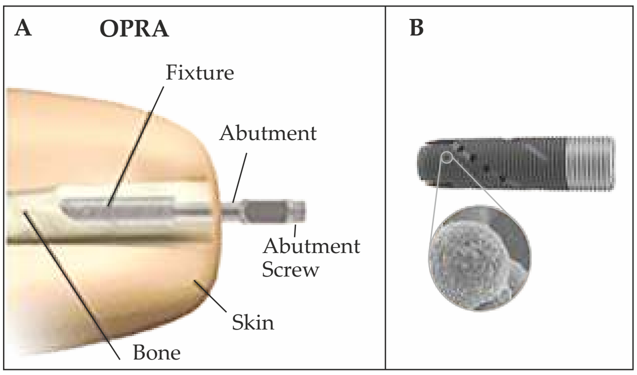

Fig. 9: Schematic image of (A) OPRA implant system; (B) OPRA fixture (Thesleff *et al*., 2018).

(I) Osseointegrated prosthesis for the rehabilitation of amputees (OPRA): The OPRA implant system mainly consists of three components: An externally threaded, cylinder-like, fully implanted component known as a 'fixature', where osseointegration takes place (Figs. 9 and 10).

The system consists of a percutaneous component, termed the 'abutment', which is press-fitted into the distal end of the fixture and serves as the attachment point for the limb prosthesis. An 'abutment screw' passes through the hollow centre of the abutment and secures it to the fixture through proximal thread engagement with the fixture and contact of the screw head with the distal end of the abutment. Thus, mechanical loads are transferred sequentially from the limb prosthesis to the abutment, from the abutment to the fixture, and finally from the fixture to the surrounding bone (Thesleff *et al*., 2018).

Surgical procedure: Consists of two stages during the first surgery, the implant is introduced into the medullary cavity and left unloaded for 6 months. During that time bone-implant integration is expected to occur and the patient is usually able to use a traditional prosthetic system (although some adjustments might be needed). In the second stage the skin penetrating shaft is attached to the intramedullary fixation. After wound healing, the patient takes part in a rehabilitation programme, during which loading of the implant is gradually increased and after 6 months full load bearing is allowed.

(ii) Implant supported prosthesis (ISP): The ISP device system is similar to the OPRA except that the former uses a cobalt-chromium-molybdenum stem covered with a highly porous metal structure. Further, the ISP implant needs to be left unloaded for 6-8 weeks only, after which the second stage of skin penetrating shaft insertion is carried out. After slow increase in loading, full load bearing is allowed after 1 month.

(iii) Intraosseous transcutaneous amputation prosthesis (ITAP): It comprises of a titanium alloy (Ti_6Al_4V) stem for intraosseous (intramedullary) placement, a perforated umbrella-shaped flange seated subcutaneously for skin in-growth and a distal

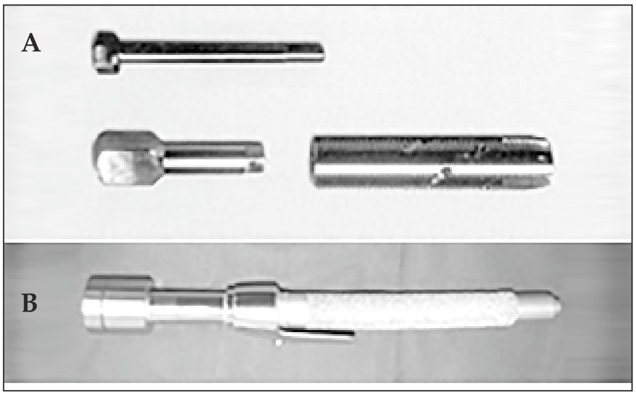

Fig. 10: Implant devices for the OPRA system (A); and the ISP Endo-/Exo- prosthesis (B).

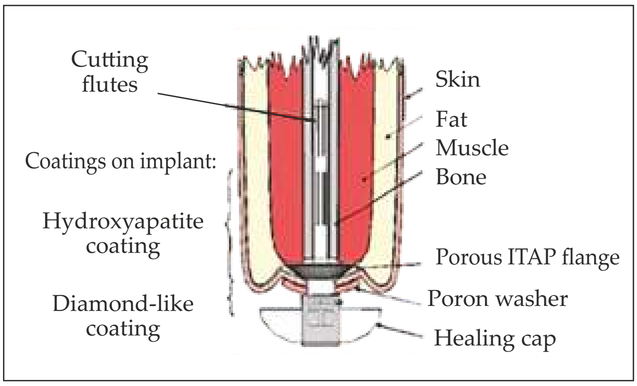

Fig. 11: Schematic view of the ITAP implant (Thesleff *et al.*, 2018).

Fig. 12: Radiograph of ITAP; and ITAP implant

extracutaneous peg that functioned as a link between the stem and flange portion and the exoprosthesis attachment (Figs. 11 and 12).

Challenges and complications of endoprosthetics

Principal challenges with percutaneous trans-skeletal fixation implants are to secure and durable fixation of the prosthetic shaft in the medullary canal of the bone and reliable shielding of the implant against possible ascending infections arising from the dermal interface (Aschoff *et al.*, 2010). A variety of complications occur as a result of these challenges, including: (i) *Infections-* The percutaneous part of a direct fixation implant is a potential site for infectious complications. These occur in approximately 40% of patients (Aschoff, 2009; Tillander *et al.*, 2010). Most are superficial; however, severe implant infections can also occur- about 18% (Tillander *et al*., 2010); (ii) *Peri-prosthetic bone loss-* Due to high stiffness of the implants, there is change in bone loading as compared to the intact situation. This leads to a bone remodelling response, reduces prosthetic support, decreases bone strength and leads to implant loosening (Tomaszewski, 1982); (iii) *Bone failure:* The stiffness mismatch between implant and bone, peak stresses at the distal ends due to the geometry of the intramedullary shaft, and high loading arising during walking and falling accidents occasionally leads to bone fractures; (iv) *Implant failure***-** Excessive or fatigue loading sometimes leads to bending or fracture of the skin penetrating part of the OPRA implant.

Overcoming the complications

The main problems encountered with transcutaneous devices are due to epithelial down growth, creating a pocket, which is favourable for bacterial proliferation and tissue infection. Pendegrass *et al.* (2006) analysed the skin-bone interface around deer antlers, and found that the surface of the pedicle was highly porous with a larger mean pore diameter when compared with the antler and the epithelial layer interfaced with the pedicle bone without signs of down growth. This explains how natural transcutaneous structures are viable without these problems. Attempts were made to create such a biomimetic intraosseous transcutaneous amputation prostheses (ITAP) (Blunn and Pendegrass, 2011). The ITAP attempt to overcome the problems associated with infection, seen in other osseointegration implant procedures, by integrating dermal and epidermal tissues with the implant, creating a soft tissue seal around the implant (Levy, 1995). The endoprosthetic portion of the ITAP is designed to have dual biological functions viz. to promote osseous as well as dermal integration at the limb-implant interface so as to achieve a permanent biological seal; and a mechanical function viz. coupling of the limb to the exoprosthesis (Fitzpatrick *et al.*, 2011).

Custom manufacturing

The device can be custom manufactured for animals comprising of a titanium alloy (Ti_6Al_4V) stem for intraosseous (intramedullary) placement, a perforated umbrella-shaped flange seated subcutaneously for skin in-growth and a distal extracutaneous peg that functions as a link between the stem, flange portion and the exoprosthesis attachment. Hydroxyapatite coating is made on the flange and part of the intraosseous stem. A wide range of exoprosthetic designs were tried ranging from blade design to rocker design (Fig. 13).

The carbon fibre blade design (Fig. 13A) was found to contribute to stress loading of the distal extent of the initial ITAP device, resulting in fracture of the ITAP at its osseous exit aperture proximal to the flange. The design with two concentric metallic cylinders and an interposed collapsible silastic rubber insert (Fig. 13B) acted as a spring to absorb ground reaction forces, but was considered too rigid as it resulted in a jerky rather than confluent thoracic limb gait pattern. The material chosen for the third prosthesis was a form of polyoxymethylene (POM) known as Delrin because of ease of machining and favourable fatigue properties. Initially an arc of Delrin (Fig. 13C) was used, which was expected to deflect on loading. Another design using Kevlar™, a registered trademark for a para-aramid synthetic fiber, impregnated with air-bubbles

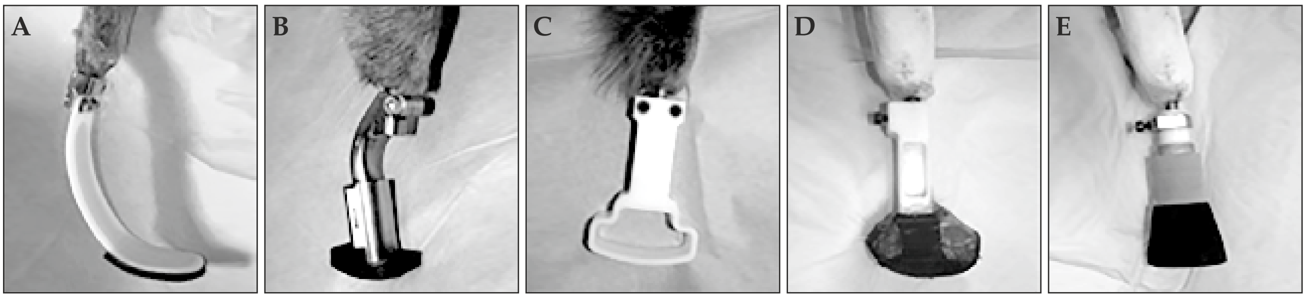

Fig. 13: Range of exoprosthesis designs.

and shock-absorbing foam-beads was used (Fig. 13D). The most recent design of exoprosthesis used involved a Delrin shaft to the base of which, a semi constrained multidirectional foot component was attached (Fig. 13E).

Procedure of ITAP

Amputation of the affected limb is carried out using standard procedures taking care to leave sufficient amount of diaphysis of long bone for insertion of the intraosseous portion of the prosthetic. Amputations at the level of mid to distal third of radius-ulna and/or tibia with about 0.5-2 cm of soft tissue extending beyond the level of transverse osteotomy are ideal (Fitzpatrick *et al.* 2011). The distal diaphysis of the remaining bone is then prepared for insertion of the endoprosthesis. A recipient tunnel is created using a drill bit followed by reaming of the tunnel. The sharp bone edges at the distal cut are smoothed using a rotary drill. Next, fin-shaped radial indentations, identical in size and topography to that of the implant are created using a customised cutting tool impacted into the canal using a mallet. The implant is then impacted into the distal bone so that the base of the flange is flush with the osteotomy surface. Muscle and fascia are then sutured to the underside of the flange and subdermal adipose tissue is dissected from the dermis and apposed with consistent tension to the domed ITAP flange so as to form a circumferential seal around the external metal peg. This is achieved by using simple interrupted sutures of 2 metric polydioxanone circumferentially through the flange pores and skin edges and then using horizontal mattress sutures between the apposing skin edges to tension them around the exposed peg (Figs. 14 and 15).

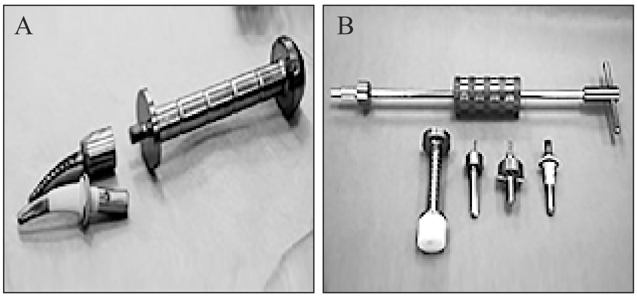

Fig.14: Instruments for medullary canal preparation for (A) straight; and (B) curved ITAP device implanta-

Postoperative care

A light support bandage should be applied immediately postoperatively and changed every 3 days for 18 days. Oral antibiotics and non-steroidal anti-inflammatory drugs (NSAIDs) should be administered for 14 days, while a topical antibiotic should be applied at the skin–ITAP interface during each bandage change. Physiotherapy, including passive range-of-motion exercises, may be initiated from postoperative day 7, while hydrotherapy can be introduced from day 18 and continued for up to 6 weeks following fitting of the exoprosthesis. Radiographic evaluation should be performed periodically to assess osseointegration of the implant. Thickening of the endosteal and periosteal surfaces of the cortical bone surrounding the endoprosthetic stem within the diaphysis is considered indicative of osseointegration and associated bone remodelling (Fig. 16).

Fig. 15: (A) Myoplasty under the ITAP flange; (B) Preparation of skin for attachment to the subdermal ITAP flange by careful dissection of subcutaneous adipose and connective tissue; (C) Apposition of skin over the flange with tension sutures apposing skin edges without applying direct tension on the flange-skin margins (Fitzpatrick *et al.*, 2011).

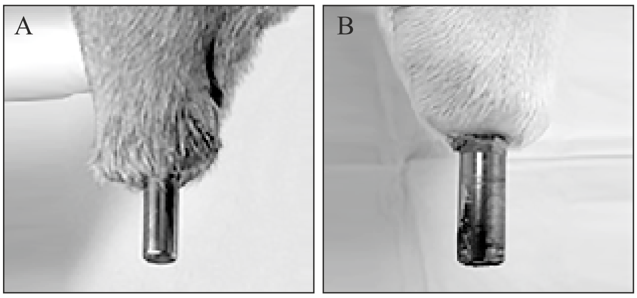

Fig. 16: Skin-ITAP interface after healing at 14 weeks (A) and 28 weeks (B) postoperatively (Fitzpatrick *et al.*, 2011).

Fig. 17: A donkey with prosthetic 'Krishna Limb'

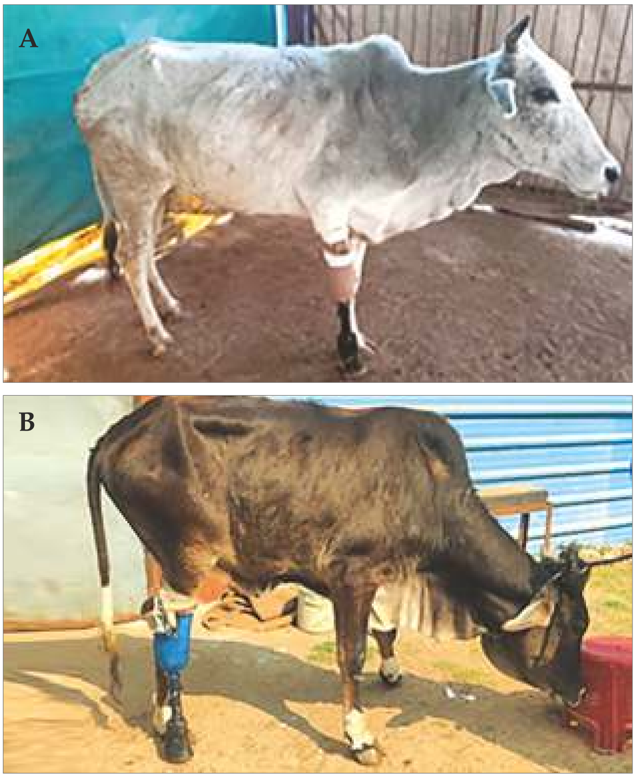

Fig. 18: Cattle with prosthetic forelimb (A) and hind limb (B).

Future prospects of limb prosthetics in India and Abroad

In India

India's first prosthetic limb for animals in Jaipur: Dr. Tapesh Mathur is credited with making the 'Krishna Limb', India's first prosthetic limb for animals (Fig. 17). He has been designing prosthetic limbs for animals since 2015 and helped various states to adapt prosthesis (Mathur, 2017).

Fig. 19: Tiger with prosthetic forelimb.

In Jabalpur (Madhya Pradesh)**:** First time in Madhya Pradesh, the prosthetic limb was prepared by Dr. Shobha Jawre and team along with IIITDM for the cattle (Gupta *et al.*, 2024) (Figs. 18 A and B).

In Thrissur (Kerala)**:** College of Veterinary Science, Mannuthy with the support of KIT-CAT Orthotics and Prosthetic Centre in Thrissur prepared an artificial limb above the hock joint for Vechur cow (Ramavarman, 2022).

Jivdaya Charitable Trust: Dr. Shara Shah performed surgery on a puppy and on an adult dog to provide them with an artificial limb (Unnithan, 2014).

Pune Hospital gifts an artificial limb to a three-legged cow: The cow was able to stand and walk with artificial leg (Sadadekar, 2020).

In a world's first, a tiger received a prosthetic leg**:** Dr. Shushrut Babhulkar, a Nagpur-based orthopaedic surgeon in 2016 adopted Saheb Rao, the seven-year-old Indian tiger with gangrene in left forelimb living in captivity at the Wildlife Rescue Centre at Gorewada Zoo. The limb was created in consultation with IIT Mumbai, and AO Foundation in Germany (Fig. 19) (Ras, 2019).

Pawsitivity' Project- This group of class 10 girls from a Gurugram (Haryana)-based school prepared 3D-printed artificial legs for dogs (Figs. 20 A and B) (Chakrabarty, 2020).

In Abroad

Twin prosthetics- London**:** Fitzpatric was the first surgeon in the world to fit twin prosthetics to a cat (Fig. 21).

The elephant Mosha that was injured by a landmine, had her prosthetic leg attached at the Friends of the Asian Elephant Foundation in Lampang, Thailan on June 29, 2016 (Fig. 22) (Harris, 2016).

Stumpy the kangaroo**:** A veterinary medicine professor and licensed human prosthesis orthotist joined forces to create an appendage that worked similarly to the artificial limb used by amputee runners (Fig. 23) (**Wolfe, 2014)**.

Fig. 22: 3D-printed artificial legs developed for dogs (A), by school girls (B).

Fig. 23: A cat fit twin prosthetics.

Fig. 25: A kangaroo with limb prosthesis.

Fig. 24: An elephant with prostheticlimb.

Fig. 26: The bionic dog with limb prosthetics.

Naki'o, the four-legged prosthetic dog: The "bionic dog" can run, play, and even swim just like any other pup (Fig. 24) (Colorado, USA).

Conclusions

The field of orthotics and prosthetics has been well established in human medicine for several decades; however, the use of prosthetic limbs in veterinary practice, particularly in India, has remained relatively limited. With recent advances in veterinary medicine and prosthetic technology worldwide, the application of these technologies in animals is rapidly expanding. This has led to the emergence of veterinary orthotics and prosthetics (V-OP) as an evolving area of veterinary healthcare. Prosthetic limbs can improve weight bearing, reduce excessive stress and compensatory loading on the remaining limbs, and thereby enhance mobility and potentially improve the longevity and quality of life of affected animals. Although exoprostheses are relatively easy to apply, their clinical use may be limited by complications associated with the stump-socket interface and difficulties in achieving optimal fit and control. Advances in prosthetic technology have subsequently led to the development of endoprostheses, which establish a direct, bone-anchored interface between the implant and the residual bone. This approach can enhance prosthetic stability and proprioception while eliminating many of the complications associated with conventional socket-based systems. By integrating precision engineering with advances in veterinary medicine, these technologies have the potential not only to restore a more natural appearance but also to substantially recover functional limb use.

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