

Design considerations and development of cemented hip prosthesis in dogs

T. Sai Kumar¹, Rohit Kumar^{2†}, K.S. Kamalesh Kumar¹, A.C. Saxena³, A.M. Pawde⁴ and Amarpal⁵
ICAR- Indian Veterinary Research Institute, Izatnagar, Bareilly-243122 (Uttar Pradesh)

¹PhD Scholar, ²Scientist, ³Senior Scientist, ⁴Principal Scientist, ⁵Ex-Principal Scientist and Head, Division of Surgery, ICAR-IVRI.

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Designing a cemented hip prosthesis for canine patients requires a careful balance of anatomical accuracy, mechanical stability, and surgical practicality. This short communication outlines the conceptualization and development of modular cemented femoral stems specifically tailored for canine total hip replacement (THR). The design approach focused on optimizing stem geometry, surface characteristics, and cement interdigitation to promote durable fixation and physiological load transfer. Morphometric analysis of canine femora informed dimensional refinement, leading to the creation of four modular stem sizes suitable for a wide range of dog breeds. The stems were manufactured from biocompatible 316L stainless steel and finished with a mirror-polished surface to enhance cement bonding. The resulting design provides a robust platform for subsequent biomechanical testing and clinical evaluation, with the goal of improving the performance and reliability of cemented THR implants in dogs.

Keywords: Cemented hip prosthesis, Dogs

Canine hip dysplasia and the secondary osteoarthritis that follows are among the most prevalent orthopaedic disorders in large-breed dogs, frequently leading to chronic pain, reduced mobility, and diminished quality of life. When conservative management is ineffective, total hip arthroplasty (THA) is considered the gold standard for restoring stable, pain-free joint function (Olmstead, 1995).

Among the available fixation techniques, cemented prosthetic systems remain widely utilized because they provide immediate stability, are relatively straightforward to implant, and perform reliably across a broad range of bone qualities (Fitzpatrick *et al.*, 2012). Nevertheless, the long-term success of cemented femoral components depends critically on factors such as stem geometry, surface finish, cement mantle integrity, and physiological load transfer (Lewis, 1997).

The present work outlines the design and fabrication of a modular cemented femoral stem specifically tailored to canine femoral anatomy. Morphometric data reported by Singh and Kumar (2023) were incorporated to enhance anatomical conformity, ensure optimal cement interdigitation, and promote durable long-term fixation.

Materials and Methods

Morphometric design framework

Morphometric evaluation of canine femora revealed notable breed-related variations in canal curvature, mediolateral width, and overall bone length. These measurements guided the development of four modular femoral stem sizes small, medium, large, and extra-large to suit medium- and large-breed dogs.

Using SolidWorks® 2023, the internal geometry of the canine femoral canal was digitally reconstructed, enabling precise control of stem shape and dimensions (Fig. 1). Parametric modeling allowed iterative refinement of taper angles, neck offsets, neck length, and stem length to optimize mechanical performance while maintaining surgical practicality.

Fabrication and Surface finishing

Femoral stems were manufactured from surgical-grade 316L stainless steel using CNC precision machining. After fabrication, each stem underwent fine polishing and chemical passivation to achieve a mirror-finished surface with an average roughness (Ra) of

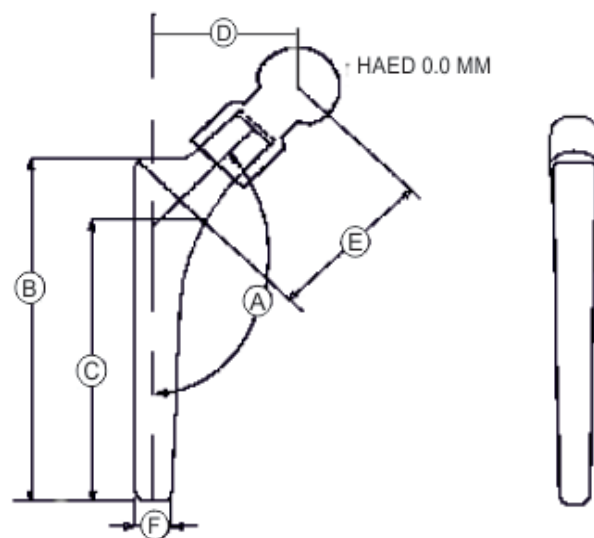


Fig. 1: CAD representation of the modular cemented femoral stem (lateral view, left; axial/profile view, right)

[†]Corresponding author; Email: drrohits.singh@gmail.com

approximately 0.5 μm . This polished finish minimizes cement abrasion and enhances interfacial bonding stability (Lewis, 1997).

The finalized stem configuration was collarless and double-tapered to promote uniform cement mantle formation and reduce stress concentrations. A neck–shaft angle of approximately 134° was selected to replicate natural canine femoral alignment and ensure physiological load transfer when paired with a metallic femoral head and UHMWPE acetabular component.

Design features and Biomechanical rationale

The stem was tapered mediolaterally and craniocaudally to ensure consistent cement coverage and improved rotational stability. A rounded distal tip avoided end-bearing fixation, while the collarless proximal contour allowed full canal seating and smooth stress transfer along the stem–cement interface.

A modular neck system was incorporated to provide intraoperative flexibility for optimizing femoral head placement and soft-tissue tensioning. Stem lengths ranged from 5 to 7 cm, with proximal widths between 11.5 and 14 mm, corresponding to the canal dimensions measured in medium- and large-breed dogs.

Cement fixation and Implant seating

A minimum cement mantle thickness of 2 mm was maintained circumferentially to achieve uniform stress distribution (Olmstead *et al.*, 1983). Fixation was performed using PMMA bone cement (Simplex P, Stryker, USA). Cement was introduced in a retrograde manner with a cement gun, followed by stem insertion during the doughy phase to prevent air entrapment and microvoid formation.

A distal cement restrictor was used to control cement flow and ensure adequate pressurization. The polished stem surface facilitated smooth insertion and enhanced cement interdigitation, promoting a stable and void-free stem–cement interface.

Results and Discussion

Preliminary Implantation Outcomes

Preliminary implantation trials conducted on canine cadaver femora demonstrated excellent anatomical compatibility and mechanical stability of the modular cemented femoral stem. All stems achieved full medullary canal occupancy with a uniform circumferential cement mantle, ensuring optimal fixation and stress distribution. The cement–stem interface exhibited no detectable rotational play, confirming effective mechanical interlock and stable engagement within the cement mantle.

The polished double-tapered design facilitated smooth insertion and promoted uniform cement interdigitation without void formation. Radiographs verified that the collarless configuration permitted



Fig. 1: CAD representation of the modular cemented femoral stem (lateral view, left; axial/profile view, right)

complete canal seating and appropriate axial alignment within the femoral cavity (Fig. 2). Overall, the stems offered favourable intraoperative handling characteristics, including predictable seating depth and ease of implantation, supporting their suitability for further biomechanical and clinical evaluation.

Biomechanical considerations of cemented fixation

Cemented fixation confers immediate mechanical stability through interlocking of polymethyl methacrylate (PMMA) with cancellous bone, enabling early postoperative mobility and effective load sharing across the bone–cement–implant complex (Lewis, 1997; Fitzpatrick *et al.*, 2012). The present stem design leverages these advantages through refinement of stem geometry, taper configuration, and surface finish to achieve consistent cement mantle thickness and physiological stress transfer.

Compared with monolithic stems, the modular structure provides important intraoperative flexibility. Interchangeable neck and stem components enable adjustments in femoral offset, limb length, and soft-tissue tension parameters critical for optimizing postoperative joint stability and gait restoration (Liska, 2010; Vezzoni *et al.*, 2015). Additionally, modular systems reduce inventory requirements and enhance adaptability to diverse canine morphologies, an important consideration in regions with large breed variability such as India.

Design features and mechanical rationale

Double-tapered femoral stem configurations promote favorable compressive radial stresses within the cement mantle, improving load-bearing efficiency and minimizing micromotion at the stem–cement interface (Harrigan and Harris, 1991). The use of surgical-grade 316L stainless steel provides a balance of mechanical strength, corrosion resistance, and cost-effectiveness, making it suitable for veterinary orthopaedics where titanium or cobalt–chromium alloys may be less economically feasible (Chacón *et al.*, 2022).

The mirror-polished surface (Ra H" 0.5 µm) reduces frictional wear and decreases cement abrasion, thereby lowering the risk of cement mantle microcracking during cyclic loading (Saha and Pal, 1984). This smooth finish also facilitates controlled insertion, allowing improved cement interdigitation and reduced porosity at the interface.

Maintaining a uniform cement mantle of approximately 2 mm is essential for effective stress absorption and prevention of stress risers at the bone–cement interface (Olmstead *et al.*, 1983; Perren *et al.*, 2010). The use of a distal restrictor and controlled pressurization during cement application enhanced mantle uniformity and mechanical interlock, contributing to improved fatigue resistance and long-term fixation. The elastic modulus of PMMA (~2–3 GPa), closely matching that of cancellous bone, provides controlled load transfer and minimizes localized stress concentrations that may predispose to microfracture formation (Kuhn *et al.*, 2022).

Anatomical adaptation and Implant compatibility

The stem design was informed by breed-specific morphometric variations in femoral canal curvature and width. Such anatomical differences necessitate precise dimensional scaling to prevent over-reaming or inadequate canal fill, both of which compromise cement mantle integrity and rotational stability (Singh and Kumar, 2023). The four-size modular range developed in this study allows the surgeon to select an implant that achieves an ideal canal fill ratio while preserving consistent cement thickness and alignment (Cross *et al.*, 2000).

Cemented fixation remains particularly advantageous in older or osteoporotic dogs, in whom reduced bone quality can limit the success of press-fit cementless stems. Immediate PMMA-mediated fixation supports early weight-bearing, accelerating functional recovery (Vezzoni *et al.*, 2015). Nonetheless, complications such as aseptic loosening, cement mantle fracture, and prosthetic luxation remain potential concerns. The collarless, double-tapered configuration used in this design aims to mitigate these risks by promoting uniform stress distribution and minimizing micromotion at the stem–cement interface.

Future directions

While preliminary findings are promising, comprehensive biomechanical validation is required. Future studies should evaluate fatigue strength, torsional resistance, and micromotion under cyclic loading using cadaveric femora and finite element modeling. Subsequent *in vivo* trials will be essential to assess biological response, gait restoration, and complication rates relative to conventional monoblock designs.

The modular cemented femoral stem developed in this study integrates anatomical accuracy, mechanical efficiency, and surgical practicality. By combining morphology-driven design with optimized cemented fixation principles, it represents a significant advancement toward cost-effective, durable, and patient-specific solutions for canine total hip arthroplasty, with the potential to enhance clinical outcomes and inform future implant innovations in veterinary orthopaedics.

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