JOURNAL OF RESEARCH IN VETERINARY SCIENCES
2023; 1(1): 37-40.
10.5455/JRVS.20230804124126

RESEARCH ARTICLE

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An easy surgical approach to acetabular/iliac fractures combined with an innovative 3-D-based shelf implant in a dog bony pelvis model

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ABSTRACT

This study demonstrated an easy surgical approach for surgical procedures managing the ilium and acetabulum. Orthopedic implants are frequently used to restore broken bones to their natural anatomical and functional positions. The present study describes the method of manufacturing a novel shelf implant specific for acetabular-iliac fractures in vitro on bony pelvis model.

ARTICLE HISTORY

Received August 04, 2023
Accepted August 25, 2023
Published September 06, 2023

KEYWORDS

3-D printing; innovative plate; pelvic fractures; hip dysplasia surgical approach

Introduction

The pelvic bones in dogs are places prone to fractures or defective conformations which necessarily are subjected to surgical intervention. Fractures comprise approximately 46% of pelvic bone fractures [1]. Fractures of the ilium and acetabulum comprise 46% and 12% of pelvic fractures, respectively [2]. Traumatic injuries from motor vehicles and gunshot accidents, falling from a height, and other traumas are the common causes [3,4]. Hip joint mal-conformation during growth with subsequent surgical management should also be considered [5,6]. Many surgical approaches to the pelvic bones of dogs have been used [7]. Although choosing the best surgical approach is crucial for orthopedic surgeons, most of them are looking for the easiest and convenient way without influencing the vital structures to reach their injured target bones besides finding an ample space for using their tools without adding unnecessary trauma. Therefore, one of the objectives of this study was select an easy and convenient surgical approach to the pelvic spectrum of the hip articulation in dogs.

Surgical management of acetabular and iliac fractures usually involves open reduction and contoured-plate application [8–10]. However, none of them is properly fit to ensure anatomical reduction [11] with subsequent implant-related sequelae [9,11–13]. The principal features essential for the success of an orthopedic implant are its shape, dimensional accuracy, and adequate mechanical properties [14]. Since acetabular fractures are demand perfect reduction and rigid immobilization to minimize development of degenerative joint disease, custom-made implants developed with subsequent marked decreased complication rates [15–17].

The second objective of this study, was to design a custom-made implant using digital part information through 3-D printing additive process computer aided design (CAD) models and manufacture using selective material to fabricate a device that fit the acetabular/iliac disorders in dogs.

Materials and Methods

This study utilized canine cadavers in accordance with the institutional animal ethics and guidelines of New Valley University. A sound bony pelvis of an adult mongrel weighed 25 kg was also used for computer tomography (CT) (Siemens Healthcare Co.) and for the developed device demonstration.

Approach to the body of the ilium and acetabulum

Anatomical consideration

A curved concave skin incision began from the iliac crest, cross the hip joint and ends at the point of

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the ischium caudally. The turned-off skin flap lips exposed the thick layer of the superficial gluteal fascia which was dissected to discover the deep fascia covering the gluteal tensor fascia lata and biceps femoris muscles. The ilium gluteal surface, ischiatic spine, and the hip joint are covered by the triple heads of the gluteal muscles, i.e., superficial, middle, and deep, which attached to the greater trochanter of the femur. The greater trochanter was osteotomized by placing the osteotome on its lateral surface. The osteotomized trochanter was turned up dorsally with its gluteal attachments. The sciatic nerve was taken away during the dissection. At this stage, the shaft of the ilium and acetabulum were clearly exposed to carry out any surgical interventions (Figs. 1 and 2). In routine surgical closure, the greater trochanter was re-attached to its bed by 2 K wires combined with a tension band wiring. The superficial gluteal and tensor fascia lata were anchored in their original insertions. The subcutaneous fascia and skin were closed in separate layers.

Custom-made acetabular-iliac implant

This work was started by a CT scan of the entire pelvic half (120 KV, 250 MAS, 0.6 mm slice thickness). The CT scans were segmented to design the 3-D implant CAD. Solid-work application program which is powered by Dassault system 3-D experience platform to design the 3-D shelf implant modeling (SolidWorks, MA, USA). The 3-D printed acetabular rim with its adjacent iliac body was then designed as an implant modelling which preceded the computer numerical control automated machine to create the customized dynamic compression plates plate (Fig. 3). Medical grade stainless steel 3161 alloy, 3 mm thickness with ultimate tensile strength 80 MPa was the material of the implant's manufacturing with subsequent hot isostatic pressing and polishing. The implant incorporated four ellipsoid holes (two at each end, 10 mm apart) to fit four stainless steel-based alloy screws for implant-bone fixation (Fig. 4). The implant was then tried and fixed on the acetabulum and ilium of the bony model to evaluate its compatibility. The innovative plate had a short tail extension with two holes for fixation into the body of the ilium (Fig. 5).

Results

For surgical exposure for acetabular-iliac fractures that require plating, an easy craniolateral approach to the hip with adequate exposure was made after osteotomy of the greater trochanter. A custom-made orthopedic implant based on specific anatomical and CT-based pelvic bone segmentations were manufactured which is suitable for acetabular/iliac fractures or in connection with pelvic corrective osteotomies. The innovative device had a sickle shape and provided with four ellipsoid holes (two

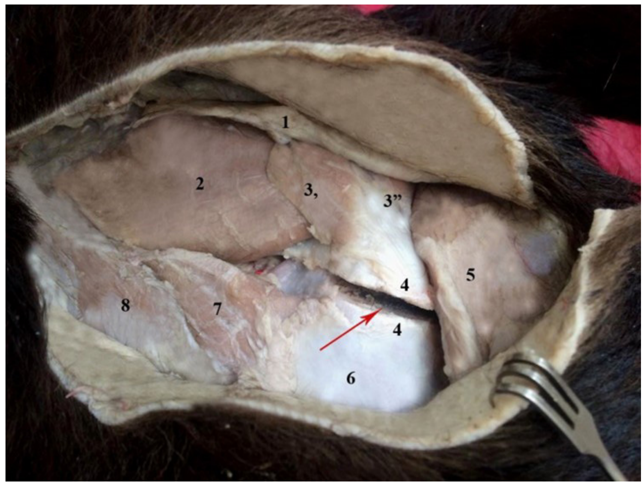

Figure 1. A photograph showing dissected gluteal region (left side). (1) Superficial gluteal facia, (2) middle gluteus muscle, (3') superficial gluteus muscle (cranial belly), (3") superficial gluteus muscle (caudal belly), (4) greater trochanter (cut), (5) biceps femoris muscle, (6) facia lata, (7) tensor facia lata muscle, and (8) sartorius muscle. The red arrow indicates the line of trochanteric cut.

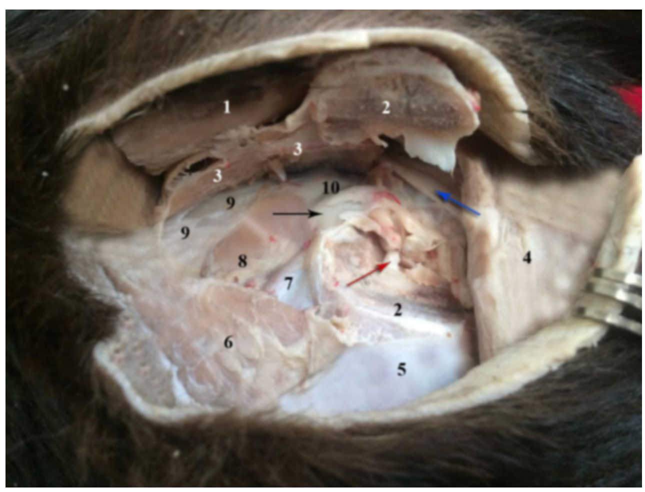

Figure 2. A photograph showing deep dissected gluteal region (left side). (1) Middle gluteus muscle, (2) greater trochanter (dorsally turned after osteotomy), (3) deep gluteus muscle, (4) biceps femoris muscle, (5) facia lata, (6) tensor facia lata muscle, (7) rectus femoris muscle, (8) articularis coxae muscle, (9) shaft of ilium, and (10) acetabulum. The black arrow indicates the head of femur covered by joint capsule. The red arrow indicates the tendon of insertion of internal obturator and gemelli muscle. The blue arrow indicates the ischiatic nerve.

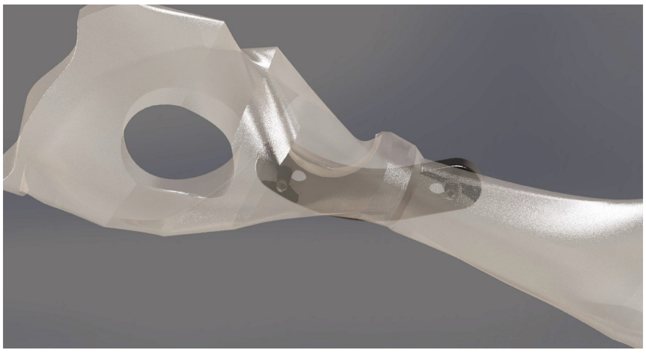

Figure 3. 3-D implant CAD design.

Figure 4. The custom-made acetabular/iliac device.

Figure 5. The device after fixation.

at each end). The short tail extension was devoted to be fixed to the ventral ilium.

The study has succeeded for creation of 3-D acetabular/iliac customized and compatible implant protype. The developed plate has four holes (two at each end) for screw fixation.

Discussion

The pelvic bones in dogs are places prone to fractures and defective conformation and in turn to surgical intervention for repair. Therefore, looking for an easy and feasible anatomical approach to pelvic bony components which are frequently involved is the primary surgeon's option. In the present study, craniolateral approach to the hip with subsequent blunt dissection to reach the greater trochanter of the femur which is osteotomized and turned dorsally with its gluteal attachments was preferable for adequate, clear, and convenient exposure of the acetabulum and ilium in dogs. Several approaches were previously tried [3,4,18–20].

As the manufacture of orthopedic implants requires extreme precision, however, the current availability of technology and materials that go in this industry made their manufacture are in hand and at low costs accessible. Recently, the current trend began towards the benefits of allocating implants in the field of orthopedic and dental surgery, due to its promising and satisfactory results, and here came the movement in the same direction by the present study by achieving a customized implant device for acetabular/iliac disorders. The innovated device was designed on CT-based pelvic bone segmentations and extended the acetabular rim. Moreover, the short ilium extension of the device adds the ventral ilium which is the tension surface of the ilium [11] for good fixation, particularly in cases of triple pelvic osteotomy. The present device had the potential to distribute load and resistance forces, providing the plate's bone purchase, minimizing the chance of implant failure and the costs. Stainless steel was the used material which has the affordability, cheap, and ductility.

Quite recently, patient-specific 3-D printed shelf implants were successfully used for the treatment of hip dysplasia without complications and could be a reliable solution of acetabular/iliac fractures [21–23]. In this respect, other methods have been created and tried for treatment of hip dysplasia in dogs [24,25]. This study has confirmed the potential for manufacturing such orthopedic implants and in turn minimizing the costs which is greatly demanded in developing countries. However, further clinical studies are necessary to validate the innovative device.

Conclusion

An easy minimally invasive surgical approach to the acetabular/iliac components was satisfactory and convenient via trochanter process osteotomy. A customized 3-D shelf implant could be manufactured and utilized in terms of sustainability and economy in expenses initiative.

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