

# Avoiding the blood supply to the femoral head during cannulated screw fixation: A comparison of two techniques

Brett J. Pettett, MD<sup>a,\*</sup>, Nathan C. Winek, MD<sup>a</sup>, Patrick J. Schimoler, MS<sup>b</sup>, Alexander Kharlamov, PhD<sup>a</sup>, Mark Carl Miller, PhD<sup>a</sup>, Edward R. Westrick, MD<sup>a</sup>

## Abstract

**Objectives:** To compare the strength of the inverted triangle (IT) versus the L-shaped cannulated screw fixation technique for stabilizing a Pauwels 2 femoral neck fracture. To demonstrate the risk to the blood supply to the femoral head from a posterior–superior screw.

**Methods:** The IT construct was compared with the L-shaped design in 10 composite femurs. A Pauwels 2 fracture was made with a 5 mm gap. Each specimen was loaded over 5000 cycles, measuring angular/shear displacement then loaded to failure. The data were analyzed using Mann–Whitney *U* test. Three separate fresh frozen cadavers were injected with low-viscosity epoxy. The intraosseous bloody supply was inspected in each femoral head (no fixation, IT, L-shaped).

**Results:** There was no difference in angular ( $P = .3$ ) or shear displacement ( $P = .99$ ) between either screw design after cyclical loading. Also, there was no statistical difference in load to failure testing between either construct ( $P = .99$ ). The average load to failure in the IT group was 3204.4 N. The average was 3180.2 N in the L-shaped design. We demonstrated the presence of the intraosseous portion of the lateral epiphyseal vessel in the specimen without screw fixation. This was preserved in the specimen with the L-shaped design but absent in the specimen following IT fixation.

**Conclusions:** The strength of the L-shaped construct was not statistically different than the strength of the IT design. The posterior–superior screw may put the main blood supply to the femoral head at risk and should be avoided.

**Keywords:** blood supply, cannulated screw, femoral neck fracture, inverted triangle, L-shaped

## 1. Introduction

Femoral neck fractures are commonly treated with 3 cannulated screws. The most popular pattern for this repair is the inverted triangle with an inferior screw, anterior–superior screw, and posterior–superior screw. Despite significant research and

attention to anatomic reduction of the femoral neck, the complication rate remains high, with nonunion up to 33% and avascular necrosis (AVN) around 16% in displaced femoral neck fractures according to a large meta-analysis.<sup>[1]</sup> Historically, many studies have shown that the main blood supply to the femoral head is from the medial circumflex femoral artery, which branches into the lateral epiphyseal vessels, as shown by Tucker, Trueta, Harrison, and later by Judet.<sup>[2–4]</sup> In 1960, Brodetti placed an implant and injected barium into the arterial tree to show that orthopaedic implant placement could damage the blood supply of the femoral head. He found implant placement in the central area of the femoral neck and head was least likely to affect the blood supply. However, the area that was most likely to damage the lateral epiphyseal vessels was in the superior–posterior quadrant.<sup>[5]</sup> Again in 1960, Claffey performed anatomic studies with the Smith-Petersen nail and found in all specimens that the anastomosis between the lateral epiphyseal vessels and ligamentum teres was severed by the nail in the superior–posterior quadrant of the head and neck.<sup>[6]</sup> We believe that this area could be affected by the posterior–superior screw in the typical inverted triangle screw fixation pattern. A recent study showed that the posterior–superior screw violated the cortex 70% of the time despite appearing radiographically safe, potentially violating the extraosseous blood supply.<sup>[7]</sup> Other researchers have shown that additional screw patterns have similar biomechanical stability, such as the “L” shape. Giordano et al<sup>[8]</sup> studied a design with a posterior–superior, posterior–inferior, and anterior–inferior design and found improved biomechanical properties in comparison to the traditional inverted triangle design. We

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*The authors have no conflicts of interest to disclose.*

*No human subjects or patient data was used in this study. Therefore, informed consent was not required. We utilized cadaveric femurs.*

<sup>a</sup> Biomechanics Laboratory, Allegheny General Hospital, <sup>b</sup> Department of Mechanical Engineering, University of Pittsburgh, Pittsburgh, Pennsylvania

\* Corresponding author. Address: 3045S National Avenue #110, Springfield, MO 65807. Tel: +417-885-3000. E-mail address: Brett.Pettett@Mercy.net (B. J. Pettett).

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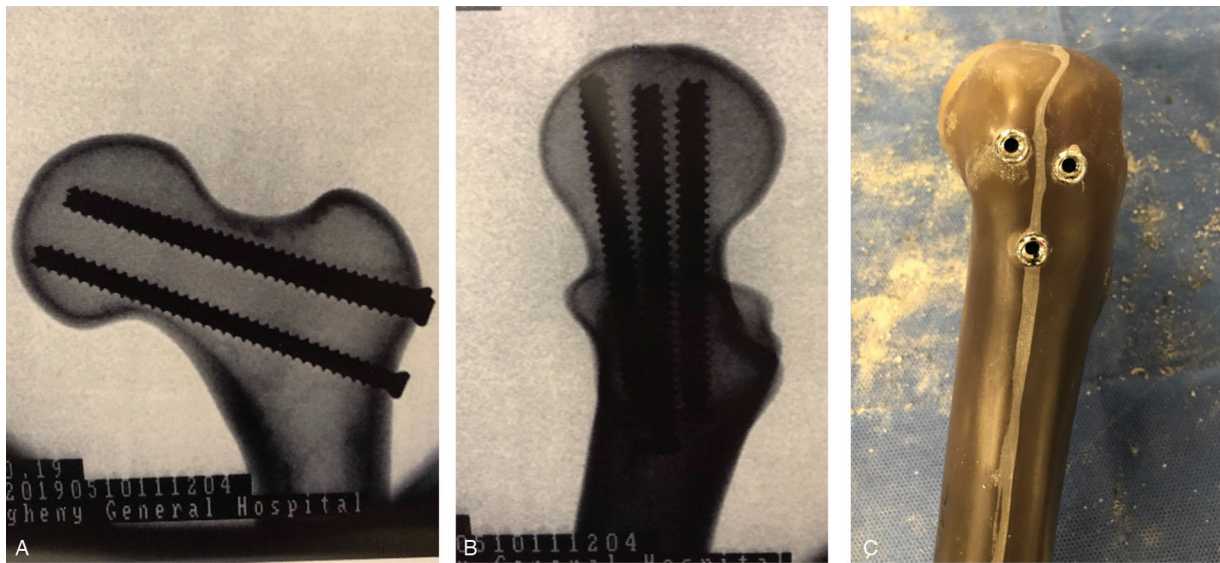


Figure 1. Inverted triangle example (A: X ray ap, B: X ray lateral, C: photo).

propose that the posterior–superior screw of any pattern may jeopardize the main blood supply to the femoral neck and head. We hypothesize that an alternative “L” shaped design with an anterior–superior screw, anterior–inferior screw, and posterior–inferior screw will protect the blood supply more consistently without sacrificing stability of the construct and will maintain firm biomechanical fixation.

**2. Materials and methods**

**2.1. Biomechanical**

Ten large fourth-generation composite femurs with a 16 mm hollow intramedullary canal were obtained (Pacific Research Laboratories, Vashon Island, Washington). These synthetic femurs had simulated cortical bone made from short fiber filled epoxy with a density of 1.64 g/cc and had solid rigid polyurethane

foam cancellous core (density 0.27 g/cc). Previous testing has shown these composite femurs to have biomechanical properties similar to cadaveric bone.<sup>[9]</sup>

Using fluoroscopy, 5 femurs were randomly selected and had three 7.0 mm fully threaded cannulated screws inserted in the inverted triangle pattern (anterior–superior, posterior–superior, central–inferior) (Fig. 1). The 5 remaining femurs had three 7.0 mm fully threaded cannulated screws inserted in the L-shaped pattern (anterior–superior, anterior–inferior, posterior–inferior) (Fig. 2). An osteotomy at 50° was then performed using an oscillating saw and an osteotome to create a Pauwels 2 fracture pattern at the middle of the neck (OTA/AO 31B2.1q). A second osteotomy was performed to create a 5 mm gap (Fig. 3).

The femurs were subsequently transected 22 cm distal to the greater trochanter and embedded in fiberglass resin (3 m Bondo) in PVC tubes. They were then placed in a load frame (MTS Bionix

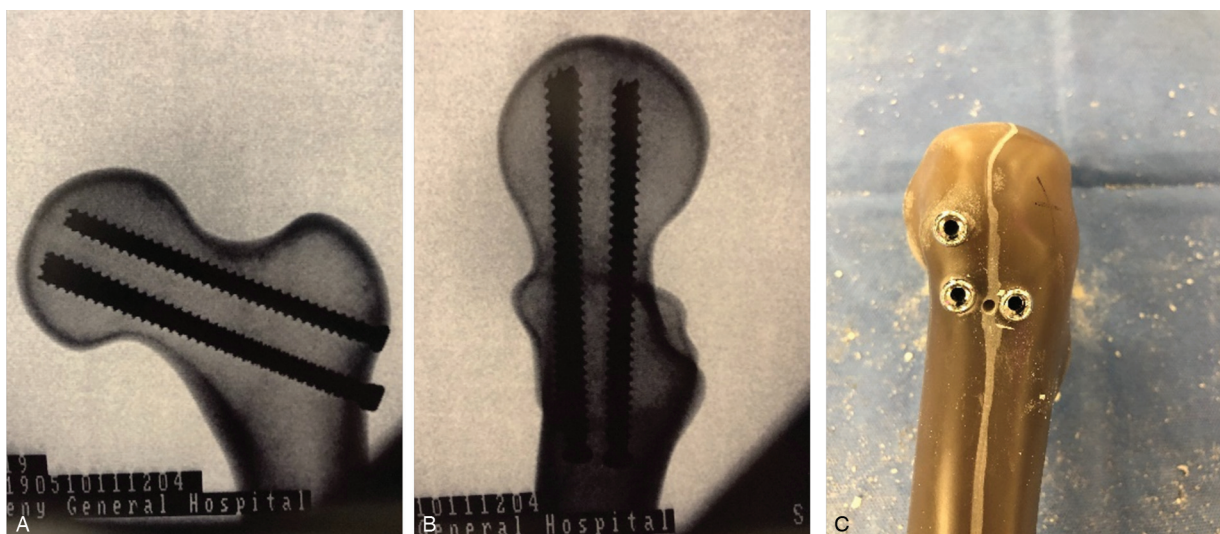


Figure 2. L-shape example (A: X ray ap, B: X ray lateral, C: photo).



Figure 3. Femurs mounted.

858) at a 15° angle from the vertical so that application of a vertical load vector represented a single leg stance, similar to previous studies (Fig. 3).<sup>[8,10–13]</sup>

First, the specimens were preconditioned with 4 cycles at 0.1 Hz from 200 to 1400 N, where the peak load represents the highest multiple of bodyweight on 1 leg in a loading/unloading cycle.<sup>[14,15]</sup> We used a 2-camera video tracking system (Spicatek DMAS) and spherical beads on the specimens to track the angular and shear displacement across the fracture site. The specimens were loaded at 2 Hz for 2500 cycles from 200 to 1400 N. We then repeated the 3 cycles at 0.1 Hz to detect any angular or shear displacement; these values were again recorded. Next, we repeated the 2500 cycles at 2 Hz before performing the final 3 cycles at 0.1 Hz for the final data acquisition of fracture site displacement. Lastly, each specimen was loaded to failure.

## 2.2. Anatomic

Three cadaveric specimens, including the hemipelvis to the distal femur with surrounding soft tissues, were obtained. They were screened for any major cardiovascular disease and any surgery involving the hip. The external iliac artery was identified and irrigated with normal saline until the venous return was clear. The popliteal artery, external iliac vein, internal iliac vessels along with any other identifiable vessel leaking saline were subsequently tied off while irrigation was continued. A windlass tourniquet was applied over the distal femur using traction rope to increase back pressure. The internal iliac artery was cannulated and injected with ultralow viscosity epoxy resin (Biodur E20, Biodur Products, Heidelberg, Germany), following a previously established technique to visualize extraosseous blood supply.<sup>[16]</sup> This low viscosity epoxy was chosen to overcome the high failure rate of the Spalteholz technique.<sup>[17]</sup> Approximately 400 cc of blue

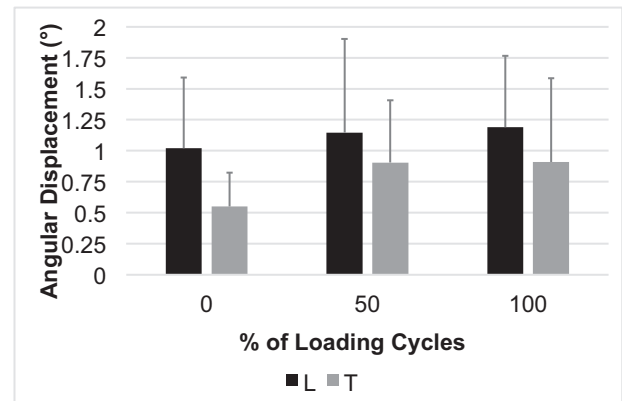


Figure 4. Average angular displacement during cyclical loading.

epoxy was injected into each specimen. The specimen was placed in the refrigerator at 38° Fahrenheit for 4 to 7 days for optimal polymerization. All soft tissues were removed. Using fluoroscopy, 3 cannulated screws were placed in the inverted triangle orientation in one of the specimens. In the second specimen, 3 cannulated screws were placed in the L-shaped pattern. Each of the screws were placed by an orthopaedic trauma fellow. These screws were removed. Each of the three specimens were then fixed to the table with a vice, and an oscillating saw was used to cut the femoral head in 5 mm slices perpendicular to the axis of the femoral neck. Using visual inspection, the intraosseous arteries were visualized at the head neck junction.

## 2.3. Statistical Analysis

The angular displacement, the shear displacement and load to failure were compared using Mann–Whitney nonparametric tests with the significance level of 0.05. A post-hoc power analysis was planned to determine the number of specimens required to determine any difference based on the effect size resulting from the biomechanical testing. The 2 techniques were expected to produce similar strength and stiffness measures because the cross-sectional areas of the screws crossing the fracture site were identical. Thus, no preliminary power analysis was performed.

## 3. Results

During biomechanical testing, there were no failures during cyclical testing. The average angular displacement at 5000 cycles of loading for the inverted triangle specimens was 0.91° versus 1.2° in the L-shaped design. There was no difference in angular displacement ( $P = .30$ ) between either screw design after cyclical loading at any time point (Fig. 4). The average shear displacement for both groups was 1.1°. There was no difference between either screw design at any time point,  $P = .99$  (Fig. 5). When the specimens were loaded to failure, 4 specimens in each group failed due to shear. One in each group failed due to angular displacement. The mean load to failure was 3204.4 for the inverted triangle and 3180.2 for the L-shaped design. There was no significant difference in load to failure,  $P = .99$  (Fig. 6).

The extraosseous lateral epiphyseal vessels were identified entering the posterior–superior quadrant of the femoral head transitioning to the intraosseous blood supply (Fig. 7). Intraosseous epoxy was found in 3 specimens tested. At the head–neck



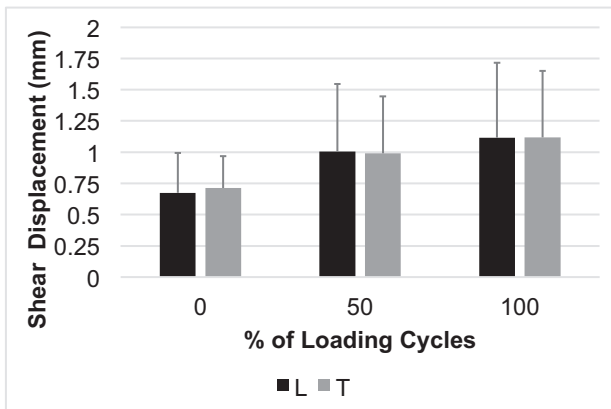


Figure 5. Average shear displacement during cyclical loading.

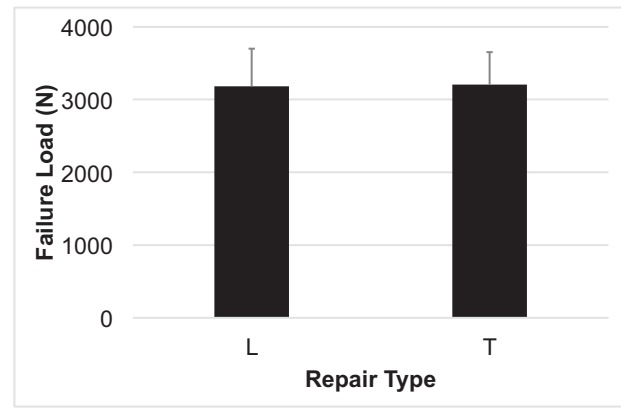


Figure 6. Average load to failure.

junction where the lateral epiphyseal vessels enter the femoral head, intraosseous epoxy was found at the posterosuperior head in the specimen without screw fixation and in the L-shaped design (Fig. 8). However, epoxy was not found in the posterosuperior quadrant of the head–neck junction in the specimen with the inverted triangle fixation (Fig. 9).

#### 4. Discussion

Avascular necrosis after internal fixation of intracapsular femoral neck fractures remains a problem in all patient populations. The rate of AVN after operative fixation of displaced femoral neck fractures is higher in younger patients (<60 years = 20.6%) than older patients (60–80 = 12.5% and >80 = 2.5%).<sup>[18]</sup> Even in nondisplaced fractures, the rate of AVN in some studies is significant at 19.5%. However, it has been reported that only 20% of those with AVN require further surgical treatment.<sup>[19]</sup> The 2 main determinants in osteonecrosis in young patients are thought to be initial displacement and the quality of the reduction.<sup>[20]</sup> There is a paucity in the literature on the effect of implant placement on the blood supply to the femoral head

despite a known anatomic relation and the importance of blood supply in femoral neck fractures.

The lateral epiphyseal vessels are considered to be the main bloody supply to the femoral head and enter the neck at the posterior–superior junction.<sup>[5]</sup> A recent cadaveric study showed that the posterior–superior screw of the inverted-triangle configuration violates the cortex of the femoral neck up to 70% of the time.<sup>[6]</sup> This violation is concerning because a breach in the posterior–superior cortex could theoretically damage the entering extraosseous lateral epiphyseal arteries. Extrapolating from this concern, our study shows that avoiding the placement of the posterior–superior screw had no ill effect on the biomechanical stability of a Pauwels II femoral neck fracture. In addition, we were able to demonstrate the intraosseous portion of the lateral epiphyseal vessel and that screw placement may sacrifice this intraosseously. Violation of the intraosseous or extraosseous lateral epiphyseal vessel during surgical fixation of femoral neck fractures could be another reason for the persistently high osteonecrosis rates reported in the literature.

Both screw configurations had load to failure strengths consistent with previous reports in the literature. Many studies

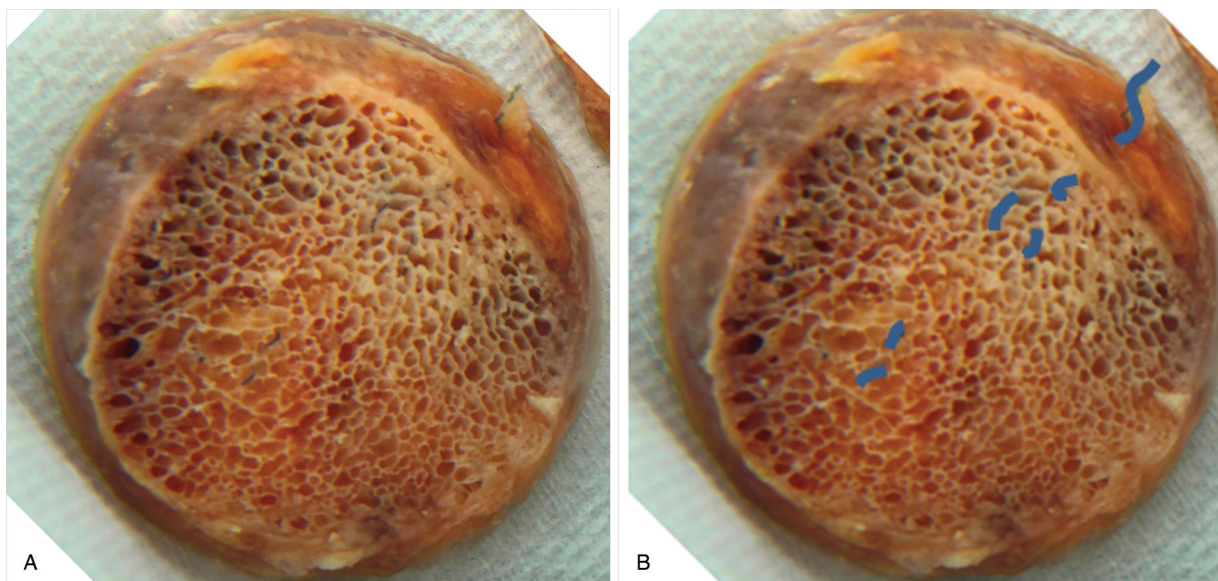
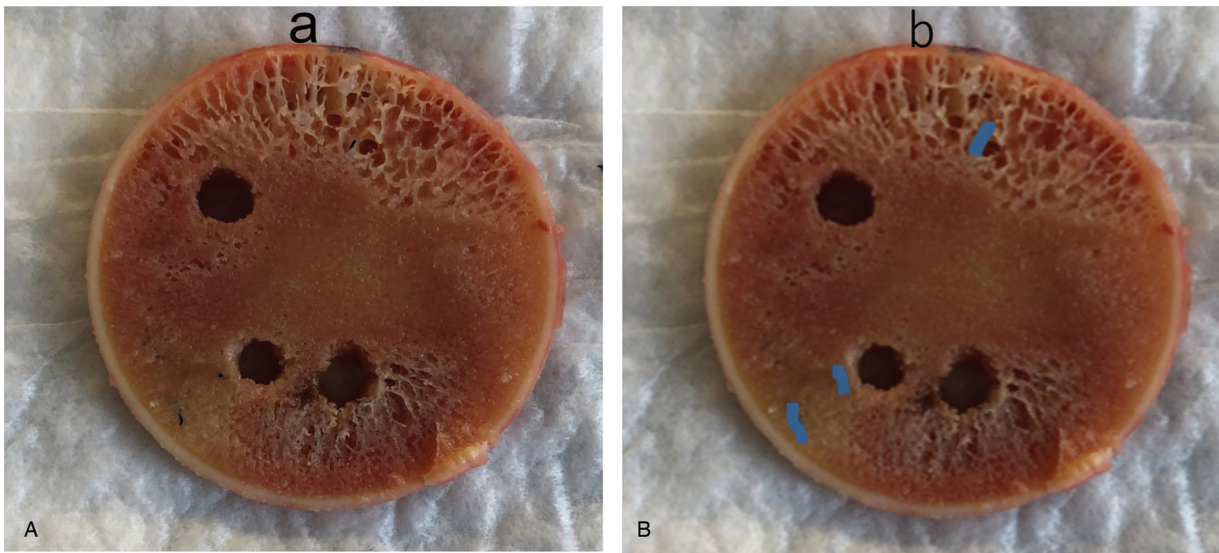


Figure 7. Specimen without screw fixation (superior at top, posterior at right).



**Figure 8.** Specimen with L-shaped design (superior at top, posterior at right) (A: photo, B: highlighted photo).

have examined various screw configurations previously. But to our knowledge, this is the first study to investigate an L-shaped screw design that avoids the posterior–superior screw. There are, however, limitations to this study. We used synthetic bone with a density similar to young adults. This makes translating our results in an osteoporotic patient difficult. Examination of our cadaveric specimens suggests that the posterior–superior screw can affect the intraosseous portion of the lateral epiphyseal vessel. However, anatomic variations between individuals were not accounted for with the small number of cadavers examined. We cannot verify that the absence of intraosseous vessels in the posterior–superior head–neck junction of the inverted-triangle specimen was definitively due to screw placement as opposed to anatomic variation or study methodology.

In conclusion, osteonecrosis of the femoral head after surgical fixation remains high. The quality of the reduction and initial displacement remain the main 2 risk factors for osteonecrosis and the rate of revision surgery. However, we suggest that implant placement may have a previously unreported effect on these complications. An L-shaped screw design avoids the posterior–superior screw placement and is biomechanically similar to an inverted triangle in patients with average bone quality. Further studies should investigate the biomechanical stability of this novel configuration in an osteoporotic model and should compare AVN rates with cannulated screw fixation that avoids the posterior–superior quadrant of the femoral head and neck.

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**Figure 9.** Specimen with inverted triangle design (superior at top, posterior at right) (A: photo, B: highlighted photo).

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