# Evaluating Length: The Use of Low-dose Biplanar Radiography (EOS) and Tantalum Bead Implantation

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**Background:** Low-dose biplanar radiography (EOS) is an appealing imaging modality for use in children given its low radiation and ease of use. The goal of this study was to determine the accuracy and reliability of EOS compared with CT scanogram for measurement of leg length and to assess interrater and intrarater reliability of measured interbead distances for EOS and CT scanogram after insertion of tantalum beads into lamb femurs.

**Methods:** Tantalum beads (0.8 mm) were inserted into the cortex on both the medial and lateral sides of 10 skeletally immature lamb femurs. CT scanogram and EOS imaging were obtained. Measurements of total length and distance between bead pairs were recorded on anteroposterior and lateral views by 2 orthopaedic surgeons on 2 separate occasions. Pearson correlations were performed for statistical comparisons.

**Results:** EOS measurements showed near-perfect correlation to those of CT scanogram ($r > 0.96$, $P < 0.001$). Intrarater reliability was excellent for all measurements with EOS ($r > 0.98$, $P < 0.001$) and CT scanogram ($r > 0.99$, $P < 0.001$) as was interrater reliability for EOS ($r > 0.98$, $P < 0.001$) and CT scanogram ($r > 0.99$, $P < 0.001$).

**Conclusions:** EOS is comparable with CT scanogram in the assessment of limb length and the distance between 2 radiopaque markers. Reliability was excellent for all measurements. The combination of EOS imaging and tantalum bead implantation may be an effective way to evaluate physeal growth following procedures such as epiphysiodesis and physeal bar resection.

**Level of Evidence:** Level II—diagnostic.

**Key Words:** EOS, tantalum beads, CT scanogram, length measurement, pediatric, validation

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Limb-length discrepancy is a common condition treated by orthopaedic surgeons. It may be the result of congenital abnormalities or acquired etiologies such as infection or trauma. Children with a clinically significant limb-length discrepancy, and those with conditions likely to cause one, require frequent imaging to monitor growth and alignment, to plan for future treatments, and to determine the efficacy of treatments rendered. Accurate and reliable measurements are essential to recommend and conduct appropriate surgical interventions at the optimal time. Computed tomography (CT) scanogram is the current gold standard for measuring limb-length discrepancy; however, the use of low-dose biplanar radiography (EOS) is gaining popularity in pediatric orthopaedics.[1–9] In the only direct comparison study of EOS and CT scanogram, EOS was shown to be more accurate in the assessment of overall limb length than CT scanogram.[1]

Implantation of tantalum beads is a well-established technique for measuring implant motion as visualized with radiostereometric analysis (RSA) imaging in the setting of total joint arthroplasty.[10] In this context, their use can measure changes in implant position to within 0.1 mm.[11] More recently, beads have been used following percutaneous drill epiphysiodesis to measure physeal arrest in children.[12] To our knowledge, tantalum bead implantation in conjunction with CT scanogram and EOS imaging has not previously been described. The purposes of this study were 2-fold: (1) to determine the accuracy of EOS compared to CT scanogram for total length and inter-bead distances, and (2) to assess the interrater and intrarater reliability of measurements on both EOS and CT scanogram.

## METHODS

This study was Institutional Review Board and International Animal Care and Use Committee (IUCAC) exempt as it did not involve humans or live animals. Ten skeletally immature cadaveric lamb femurs were procured. Tantalum beads (0.8 mm) were inserted into the femoral cortex using a tantalum bead inserter (UmRSA; RSABiomedical, Helsingborg Arena, Sweden). Two beads were placed medially and 2 laterally to create a near-near and far-far configuration, which allowed for easy identification of the beads on the lateral view (Fig. 1). A single 5.0 mm half pin was then inserted into the proximal femoral shaft from posterior to anterior and

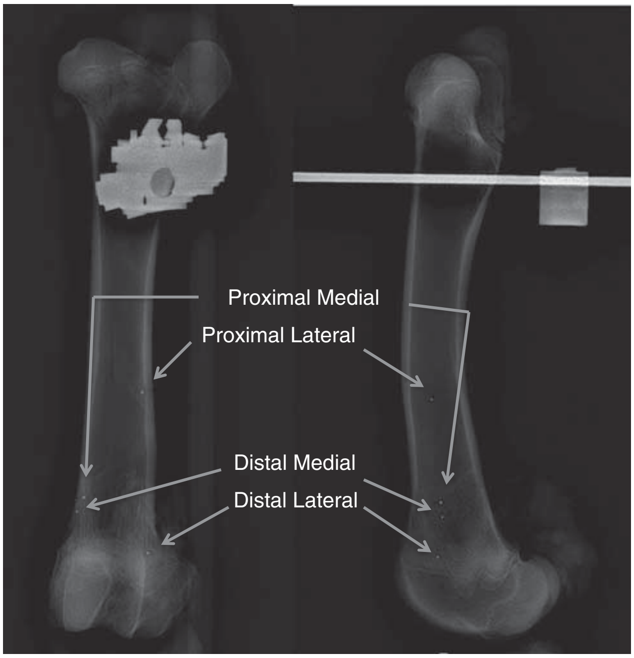


**FIGURE 1.** Anteroposterior and lateral EOS image showing near-near and far-far configuration of beads.

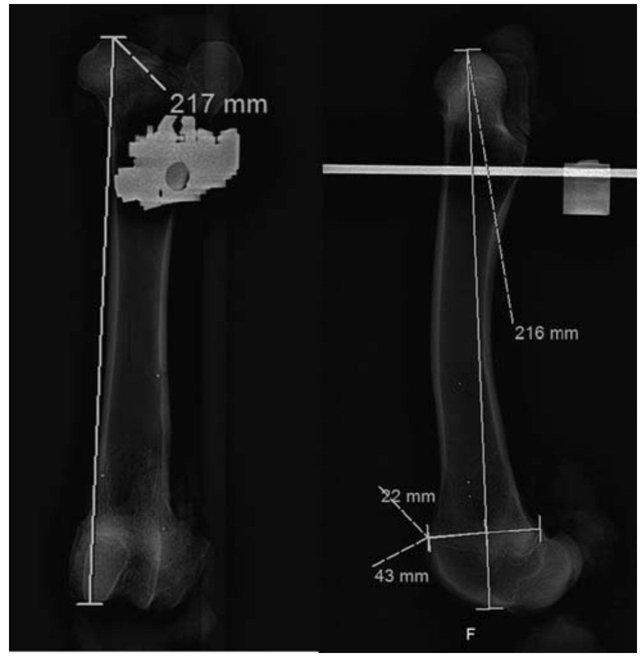


**FIGURE 2.** Technique for total length of femur measurement on lateral imaging.

the femur was attached to an external fixator frame such that the femur could be imaged in an upright position with the EOS scanner (EOS; EOS Imaging Inc., Cambridge, MA). A plumber's level was utilized to align the femur perpendicular to the floor in both the anteroposterior (AP) and lateral planes. After acquisition of EOS imaging, the femurs were removed from the frame, the half pin was removed, and the specimen was laid supine for CT scanogram imaging (Philips Brilliance CT 64, Amsterdam, The Netherlands). Again, a plumber's level was used to ensure the specimen's appropriate position within the gantry. Both the CT and EOS machines were set at pediatric doses. CT used 80 kVp and 30 mA and EOS used 55 kVp and 80 mA.

## Length Measurements and Analysis

All imaging was saved in our institution's picture archiving and communication system (PACS) with unique nonsequential accession numbers. The master file that contained the relationship between images was kept in a secure location, not accessible to the orthopaedic surgeons making measurements. Measurements were performed by a fellowship-trained pediatric orthopaedic surgeon (E.R.D.) and a senior orthopaedic resident (M.R.G.), on 2 separate occasions at a minimum of 2 weeks apart. Measurements for each specimen included: total AP and lateral bone length and medial and lateral interbead distance on AP and lateral views. Total femur length on the AP view was measured from the top of the femoral head, to the most distal aspect of the medial femoral condyle. Because of significant anterior bowing of the lamb femur, total length on the lateral view was defined from the top of the femoral head to the distal aspect of the condyles along a line bisecting the distal physis. Interbead distance was measured from the middle of 1 bead to the middle of its pair (Fig. 2).

EOS was compared with CT scanogram using pairwise Pearson correlations. Interrater and intrarater reliability were also assessed using pairwise Pearson correlations. All analyses were performed using STATA 12.0. Statistical significance was set at $\alpha = 0.05$.

## RESULTS

Six measurements were made for each imaging modality and each specimen on 2 separate occasions by both reviewers resulting in a total of 480 measurements for analysis. EOS measurements showed near-perfect correlation to CT scanogram with $r > 0.96$ ($P < 0.001$) for all variables. According to the Landis' criteria, interrater and intrarater reliability were excellent for both total length and intrabead distance on both EOS and CT scanogram ($r > 0.99$ and $P < 0.001$)[13] (Appendix, Supplemental Digital Content 1, http://links.lww.com/BPO/A36). Tantalum beads were visible 100% of the time for both reviewers and for both imaging modalities.

## DISCUSSION

When choosing an imaging modality to assess osseous injury, deformity, or alignment, clinicians must balance the need for accurate measurements with the need to minimize radiation. This concept, known as ALARA (as low as reasonably achievable), is particularly important in skeletally immature patients who may be as




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much as 10 times more sensitive to radiation than adults.[14] Recently, there has been increased interest in the use of EOS in pediatric populations due to the excellent imaging accuracy and lower radiation dose than either conventional radiographs or CT scanogram.[1,2,15,16] Outside of radiation doses, the use of plain radiographs and CT scanogram in the assessment of leg-length discrepancy present other challenges. Plain radiographs can be time consuming. A study by Dietrich et al[2] showed that, although EOS imaging has a higher financial break-even point than plain radiographs (4077 vs. 2602 exams/y), it has a lower cost per patient due to shortened examination times.

With regard to CT scanogram, supine positioning may result in external rotation of the lower limb and can lead to oblique imaging. Further, when assessing for discrepancies in the length of long bones on CT, foot deformities are not accounted for in a non–weight-bearing position and the legs overlap limiting evaluation in the sagittal plane. EOS's biplanar imaging addresses these issues by permitting the patient to stand during imaging and by allowing for the patient to position one leg slightly in front of the other, which permits unobscured orthogonal views of the limbs in the desired AP and lateral planes.

The results of this study show that total leg-length measurements performed with EOS imaging are comparable with those performed with CT scanogram, the current gold standard for the assessment of leg-length discrepancy. These results support those of Escott et al[1] who compared the accuracy of EOS and CT scanogram in the measurement of a single composite limb of a known length. We have expanded upon their results by showing excellent interrater and intrarater reliability with limbs of various sizes.

While total bone and limb lengths can be measured equally with CT scanogram and EOS, no method exists to directly measure growth at the physis. Currently, the measurement of physeal growth is limited by the lack of anatomic landmarks. The surgical implantation of a landmark provides an accurate, reproducible, quantitative method to assess physeal growth after injury or surgical manipulation. Tantalum beads, which are small, inert, and radiopaque, have been used for several decades as landmarks in other circumstances, such as in the assessment of component position and wear after total joint arthroplasty.

Prior authors have used tantalum beads in combination with RSA to monitor growth after epiphysiodesis.[12,17–19] This method, although permitting 3-dimensional analysis of the relationship between the epiphysis and metaphysis, can be cumbersome, as it requires the use of an external calibration cage for image capture, and RSA analysis software.[17] To our knowledge, our study is the first to demonstrate the reproducibility of measurements between 2 beads placed within cortical bone through CT scanogram and EOS imaging. We believe that the use of tantalum beads in combination with either EOS or CT scanogram will provide an easy and accurate assessment of physeal growth following injury or surgery about the physis.

The implantation of metal about the physis to monitor growth is not novel, as the implantation of small segments of K-wire about the physis, used to monitor growth following procedures such as physeal bar resection, has previously been described. The potential benefits of tantalum beads over K-wire fragments include that they are nonmagnetic, MRI compatible, and that there is a simple method for their insertion. Further studies will be needed to validate the use of this technique in the clinical setting.

EOS does have limitations, most notably its expense. As previously mentioned, those centers with the capability of performing EOS have a higher break-even point when compared with standard radiographs.[2] Two additional studies have concluded that the use of this technology is not cost-effective and that, despite its lower radiation dose, its use does not constitute an improvement in quality of life.[15,16,20] It should, however, be noted that these results are based on reviews of available literature and upon a decision analytic model, not on long-term clinical and financial data.

We acknowledge that our study has limitations, including the use of skeletally immature lamb femurs and not those of humans. These specimens were chosen due to the fact that lamb models have been previously utilized as a representation of human osseous pathology. The results of this study can reasonably be extrapolated into clinical scenarios.[21–27] In addition, while we attempted to ensure that all femurs were parallel to the EOS gantry while secured within the external fixator with the use of a level, it is possible that slight deviations occurred and imaging was not truly perpendicular in either the AP or lateral plane. This, however, would not have altered our interrater and intrarater reliabilities and, if anything, would have resulted in lower correlation between CT scanogram and EOS.

In this study, we placed tantalum beads at various proximal and distal locations about the femur, and not all examples were centered about the physis. However, beads can easily be placed in both diaphyseal and metaphyseal bone, and the accuracy and reliability of measuring distance between beads should remain unchanged regardless of what structure the beads are centered around. Although we did not test the beads in vivo, and cannot directly comment on safety, negative sequelae have not been reported in previous clinical reports.[12,17–19] Lastly, we did not determine the true length of each femur using a caliper; however, a comparison between caliper measurements, CT scanogram, and EOS has already been performed, rendering this step unnecessary.[1]

The implantation of tantalum beads in pediatric patients may be reasonable when suitable bone landmarks are not present, and accurate serial length measurements are required, such as about an injured or surgically treated physis. There are a number of companies producing tantalum beads. Although the UmRSA beads used in this study are intended for research purposes in the Canadian/US market, they are used for clinical purposes in other parts of the world. Halifax Biomedical Inc. (Mabou, Nova Scotia, Canada) produces tantalum beads that are FDA approved in the United States, as well as approved for clinical use in Canada and Europe. The UmRSA beads were selected for this study due to lower cost, and over a decade of research and clinical experience with UmRSA beads in adult populations at our hospital.

In conclusion, EOS is comparable with CT scanogram in assessing total limb length and in measuring the distance between radiopaque transphyseal markers with excellent interrater and intrarater reliability. The benefits of EOS compared with CT scanogram include a potentially lower radiation dose and faster acquisition times, evaluation of the legs in a weight-bearing position, and biplanar acquisition. The combination of EOS imaging and tantalum bead implantation in selected situations may allow for accurate and reliable measurement of both overall limb length as well as physeal growth. The greatest benefit of this technique may be in monitoring growth following injury or surgery about the physis. Further investigations are necessary to determine whether this measurement technique will be of significant clinical utility.

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