Optimizing Femoral Derotational Osteotomy: A Mathematical Approach Leveraging Ellipsoidal Geometry

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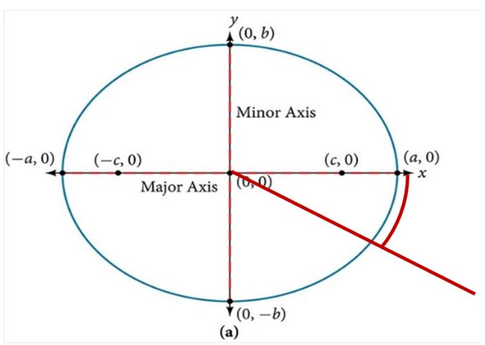
Introduction

Femoral derotational osteotomy (FDO) is a common surgical procedure used to correct rotational deformities of the femur, often seen in conditions such as cerebral palsy, femoral anteversion, or retroversion. Despite the numerous techniques available for FDO, there is no consensus on a superior method. This study aims to address this gap by developing a novel approach that uses a mathematical model to achieve precise and efficient femoral rotation. The model leverages the natural ellipsoidal geometry of the femur's cross-section between the lesser trochanter and distal head of the femur to guide our novel approach.

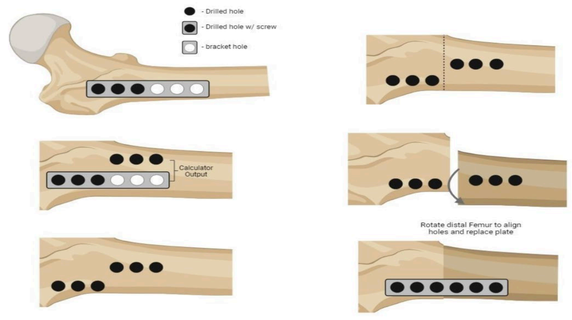


Methods

The ellipsoidal geometry of the femur allows the use of a novel surgical technique that depends on a mathematical model that determines the arc length of an ellipse based on a provided angle and the major and minor diameter of the ellipse. These inputs translate to the predetermined rotation and coronal and sagittal diameters at the osteotomy site, respectively.

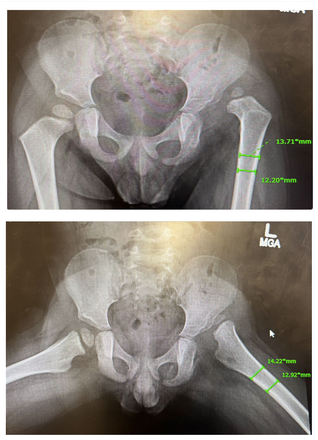
$$\int_0^t \sqrt{\{a^2 sin^2 t + b^2 cos^2 t\}}\, dt$$

The model output provides a horizontal distance from the lateral aspect of the femur for planned screw holes distal to the osteotomy. The proximal screw holes are drilled orthogonal to the lateral aspect. After these are drilled, the bone is osteotomized and the plate is then applied using the pre-drilled screw holes. The surgical approach is illustrated in the figure.



Results: Online Calculator

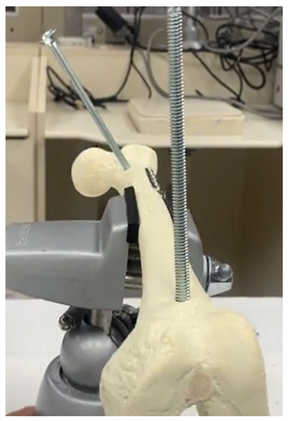
Target Temporal Rotation	Result
1°	0.2mm
3°	0.7mm
5°	1.1mm
7°	1.6mm
9°	2.1mm
11°	2.5mm
13°	3.0mm



Results: Sawbone Study

We have tested our method using sawbones with 15, 30, 45, and 60-degree rotations and derotations. Results showed high accuracy, with 75% of trials falling within 3° of the targets, and all within 5°. Our average degree error within one standard deviation was 2.29° ± 1.81°.

Replicate	Degrees Off Desired Rotation
15AR1	3
15AR2	-1
15AR3	-4
15PR1	3
15PR2	3
15PR3	2
30AR1	1
30AR2	4
30AR3	1
30PR1	0
30PR2	-4
30PR3	3
45AR1	5
45AR2	1
45AR3	0
45PR1	1
45PR2	1
45PR3	1
60AR1	-5
60AR2	0
60AR3	3
60PR1	1
60PR2	1
60PR3	7



Conclusion

We recognize that the use of this mathematical model requires complex mathematics, so to reduce that barrier and error from incorrect arithmetic, this model has been developed into an online calculator that only requires the above-mentioned inputs. Notably, this novel approach is easily applicable in any environment, including resource- limited practice settings since all measurements can be determined intraoperatively. Our next step is validating our surgical approach intraoperatively and comparing surgical outcomes to current surgical approaches.