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Different Suture Fixation Techniques For Posterior Cruciate Ligament Avulsion Fractures: A Comparative Biomechanical Study In Cadaveric Knees

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Disclosure

All authors have no actual or potential conflicts of interest in relation to this program or presentation.

Introduction

- Posterior cruciate ligament (PCL) avulsion fractures compromise knee stability and require surgical fixation.
- Cortical suspension suture-buttons and screw fixation are widely used for PCL avulsion fixation.

Knowledge Gap, Objective, and Hypothesis

- Knowledge gap
  - The impact of the number of sutures and their configuration on biomechanical performance has not yet been explored.
- Objective
  - The aim of this study is to evaluate the biomechanical properties of four different fixation techniques in PCL avulsion fractures.
- Hypothesis
  - The three suture-based fixation techniques would provide biomechanical properties comparable to conventional antegrade screw fixation.

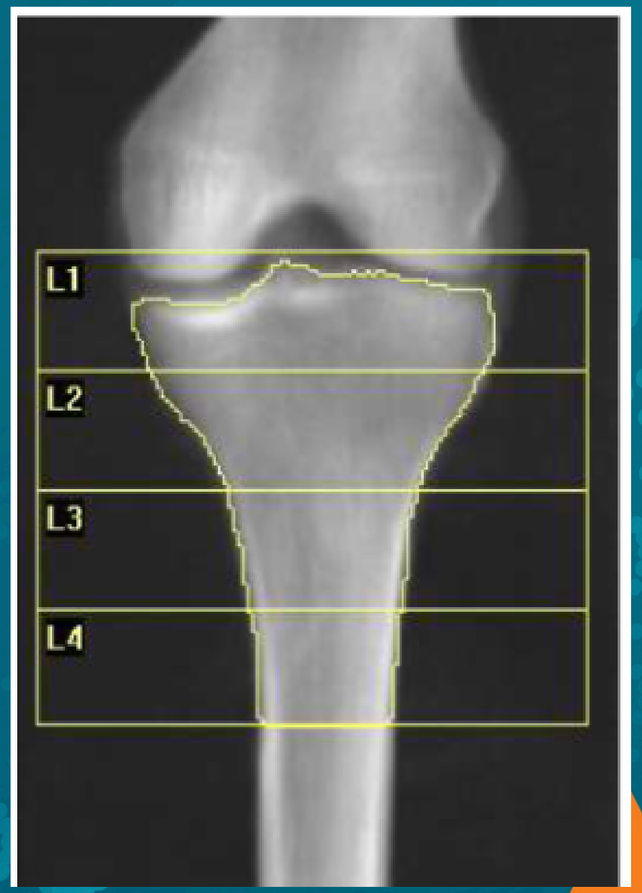
Materials and Methods

Specimen Preparation

- The study is a biomechanics analysis using human cadaveric knee specimens.
- Specimen Details
  - 20 fresh-frozen cadaveric knees with the average age of 68 ± 17.8 years
- Fracture Simulation (PCL avulsion fracture)
  - Uniform bone fragment size: 18mm x 21.5mm x 9.5mm

	Group A	Group B	Group C	Group D	Total	p-value
Age	56.6±17.4	75.8±10.6	67.8±16.6	71.8±23.8	68±17.8	0.382
Gender (M:F)	3:2	2:3	2:3	3:2	10:10	n/a
BMD	0.69±0.13	0.67±0.13	0.64±0.07	0.65±0.24	0.66±0.14	0.958

Demographic data and Bone Mineral Density (BMD) of the specimens

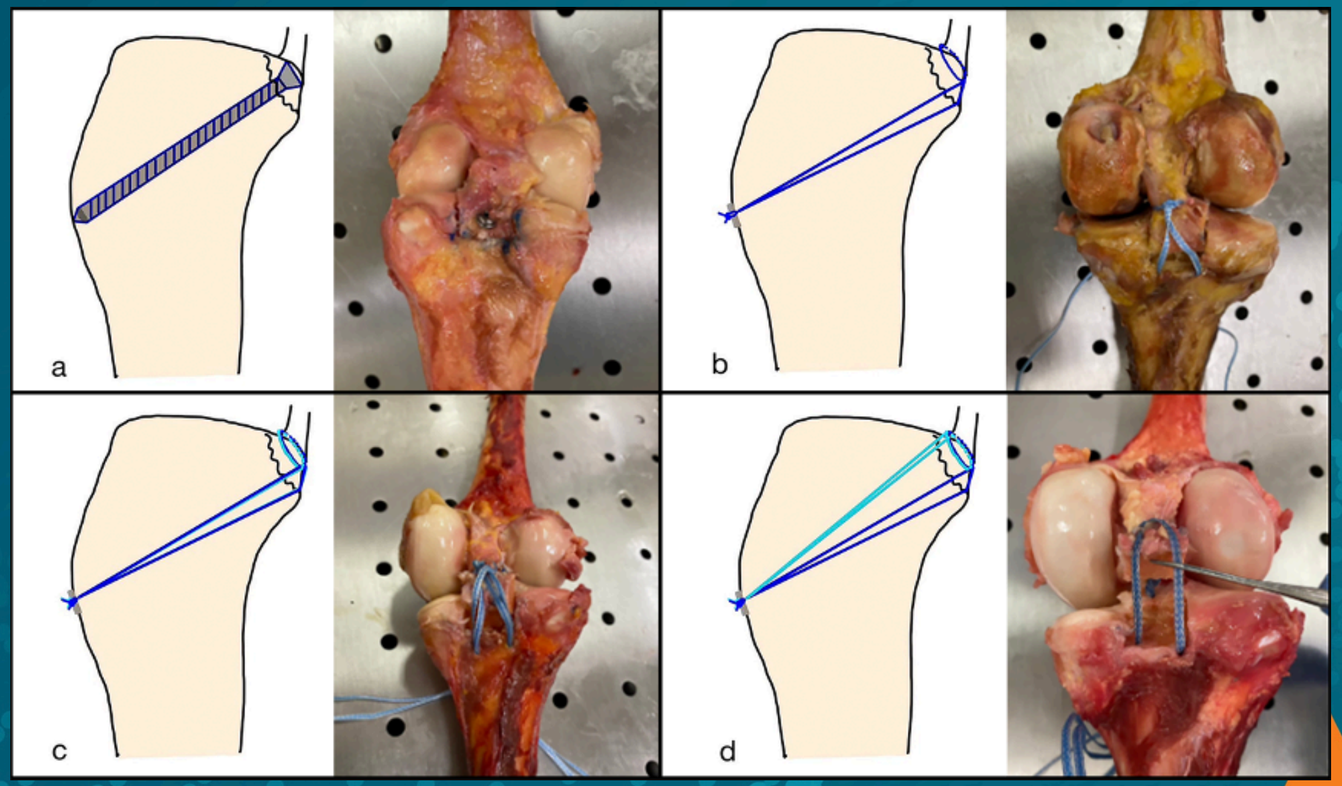


BMD measurement of the proximal tibia using DXA

Materials and Methods - Study group

Study Group
20 cadaveric knees randomly assigned to 4 groups

- Group A: Antegrade screw fixation (control)
- Group B: 1 suture tape, 2 tunnels
- Group C: 2 suture tapes, 2 tunnels
- Group D: 2 suture tapes, 3 tunnels



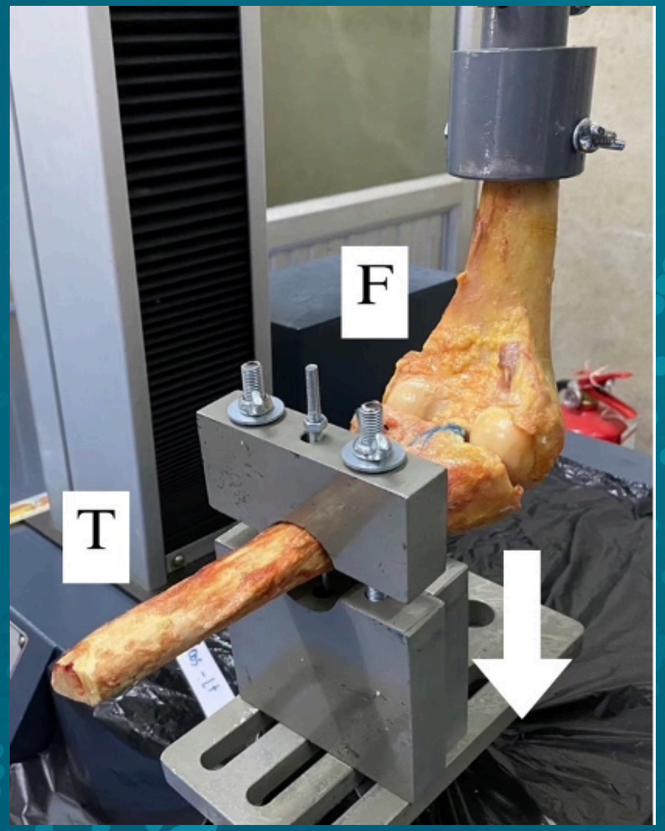
Four different fixation techniques

Materials and Methods - Biomechanical test setup

- Equipment: Uniaxial Testing Machine with NTS LRK-20KN load cell

- Cyclic Loading
  - 500 cycles (10 N to 100 N) at 200 mm/min
  - Measurements:
    - Survived cycles
    - Elongation at cycles 2, 20, 100, and 500

- Load-to-Failure
  - Parameters: Elongation, stiffness, yield load, and maximum load
  - Failure mode: Suture rupture, cut-through, or fragment displacement



Cadaveric knee at 90° flexion in a testing machine; tibia and femur secured, arrow shows force direction

Results - Cyclic Loading Test and Load-to-Failure Test

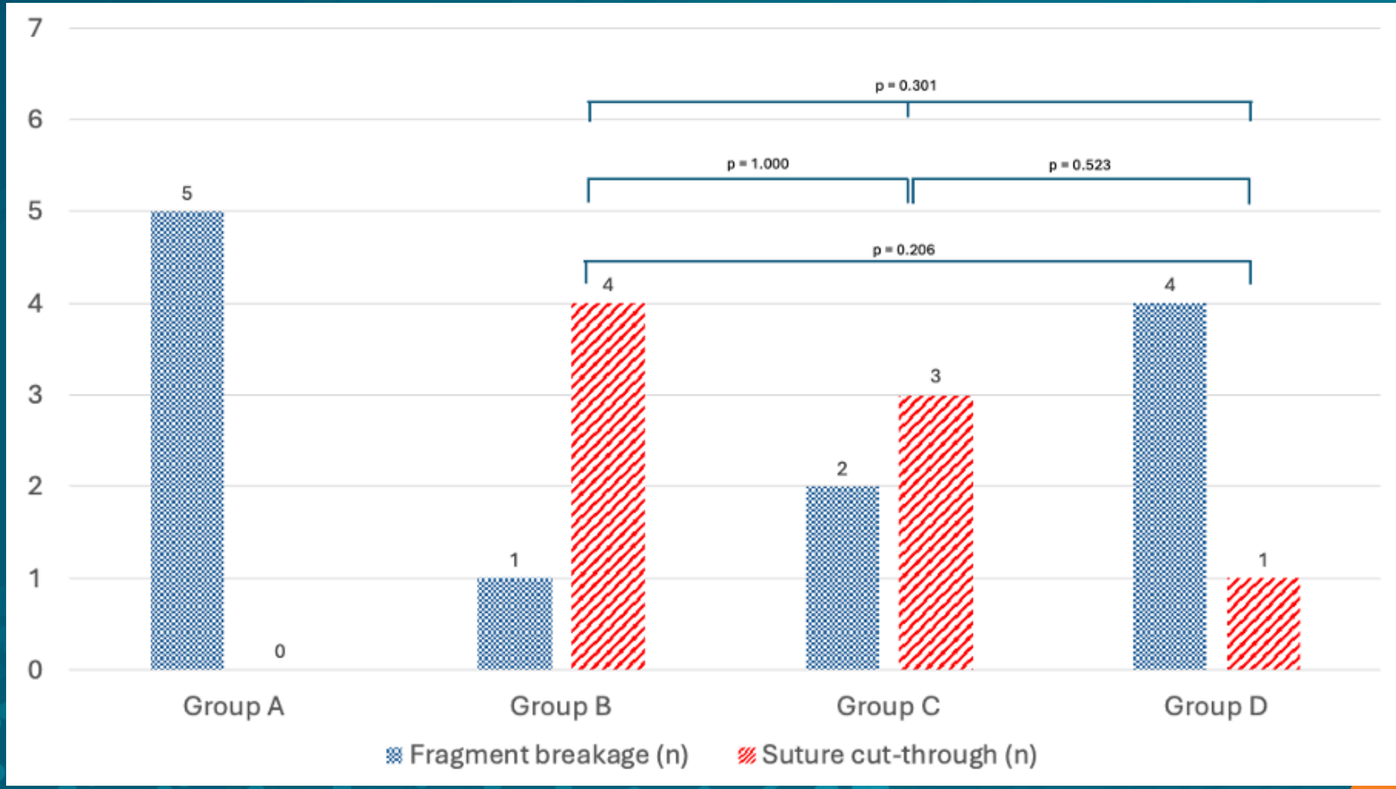
All fixation techniques showed comparable biomechanical properties during cyclic loading and load-to-failure test.

	Group A	Group B	Group C	Group D	Total	p-value
Elongation (mm), mean ± SD	10.6 ± 3.4	10.1 ± 2.9	13.9 ± 3.9	21.9 ± 15.9	14.1 ± 9.2	0.144
Load, mean ± SD						
At 5 mm elongation (N)	133.6 ± 80.3	175.0 ± 100.3	101.9 ± 43.3	138.8 ± 127.7	137.3 ± 89.5	0.677
Yield load (N)	404.2 ± 86.4	428.6 ± 197.6	375.6 ± 110.9	393.5 ± 140.2	400.5 ± 130.0	0.944
Maximum load (N)	419.4 ± 92.2	460.5 ± 204.3	397.4 ± 123.2	432.4 ± 166.0	427.4 ± 141.9	0.928
Stiffness (N/mm)	28.6 ± 13.5	30.6 ± 6.3	28.6 ± 12.7	22.8 ± 11.0	27.7 ± 10.7	0.717

Biomechanical properties of different fixation techniques following cyclic loading and load-to-failure tests

Results - Modes of Failures

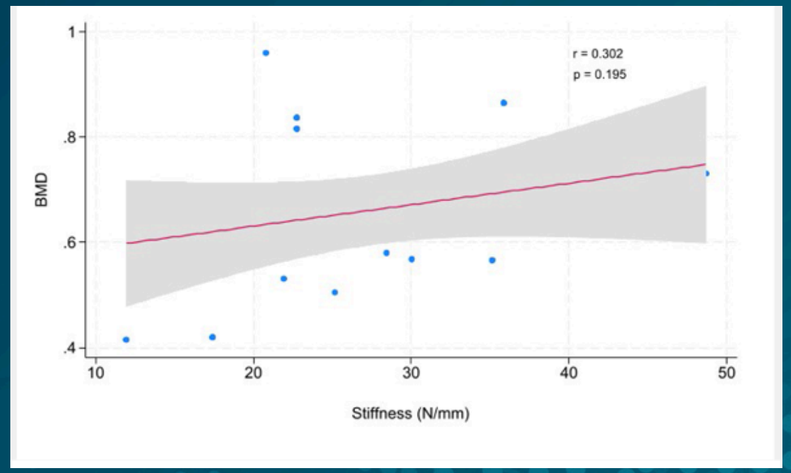
- Mode of Failures : No significant differences between Groups B, C and D ($p > 0.05$)

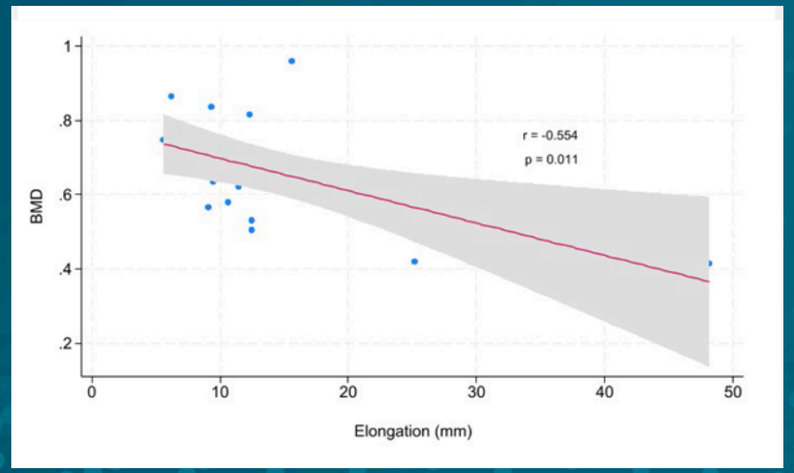


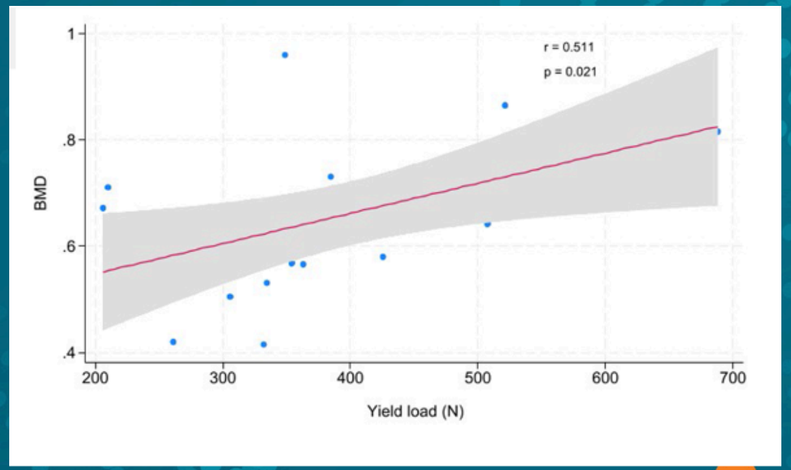
Distribution of failure modes across all fixation groups.
Failure modes: fragment breakage and suture cut-through

Results - Correlation between BMD and biomechanical properties

- BMD and Yield Load
  - Positive Correlation r = 0.511
  - p = 0.021
- BMD and Elongation
  - Negative Correlation r = -0.554
  - p = 0.011
- BMD and Stiffness
  - No Correlation
  - p = 0.195







Scatter plots and correlation between BMD and stiffness, elongation and yield load

Discussion and Conclusion

Discussion:

- The three-tunnel suture-based technique (Group D) mainly failed due to fragment breakage, not suture cut-through.
- Higher bone mineral density (BMD) correlated with increased yield load and reduced elongation across all fixation methods, suggesting better outcomes for patients with higher BMD.

Conclusion:

- Suture-based fixation techniques matched conventional screw fixation performance for PCL avulsion fractures.
- More suture tapes or tunnels did not enhance load-to-failure resistance.
- BMD's correlation with biomechanical properties emphasizes the need to consider bone quality for fixation strength and rehabilitation planning.

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