Knot too Tight... Knot too Loose

The Knotorious Five

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October 3, 2025

Overview

1. Establish Need
2. Current Suturing Training Systems
3. Design Requirements for New Training System
4. Measurement Methods for Knot Tightness
5. Knot Characteristics Provide an Advanced Feedback System
6. Future Work: Divide and Conquer

Suture Feedback Training System

Client Background:

Dr. Margene Anderson, Veterinary School of Medicine

Impact:

$1.75 - $1.83 per stitch [1]

$50 - $1,000 per procedure [2]

Problem Statement:

Develop a real-time feedback system that measures plastic deformation of suture knots to improve instruction of optimal suture tension for students

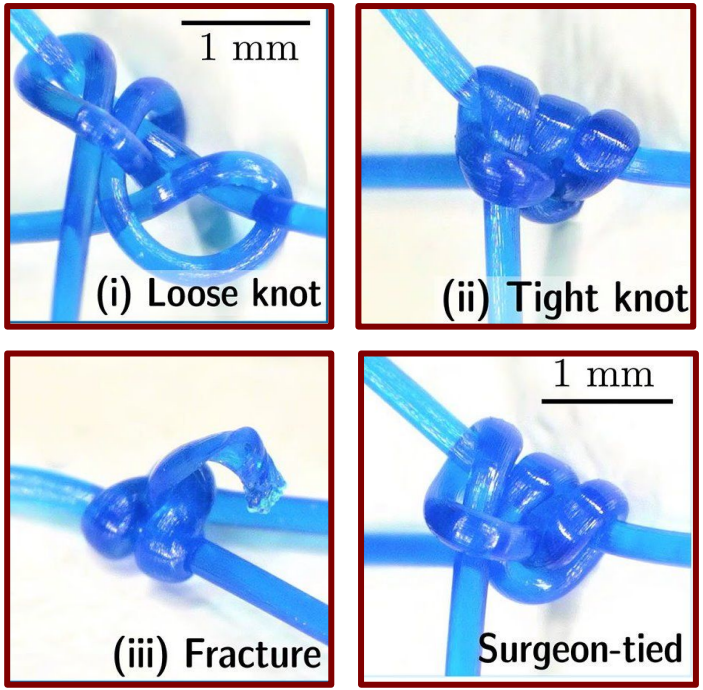


Figure 1: Various suture knot tension [3].

Competing Force Analysis Designs

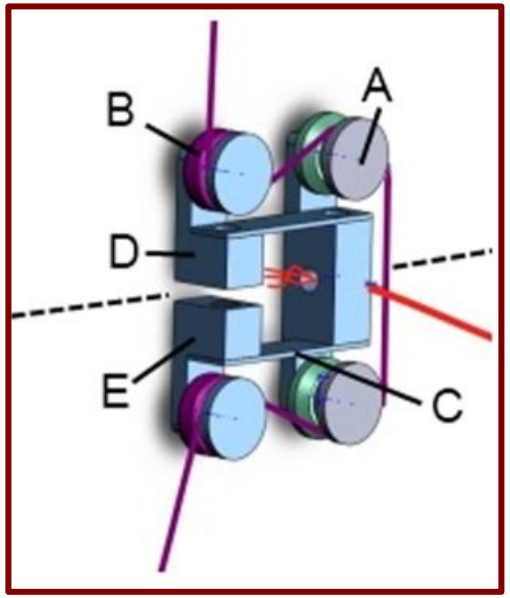


Figure 2: Hook in Force (HIF) Sensor [4].

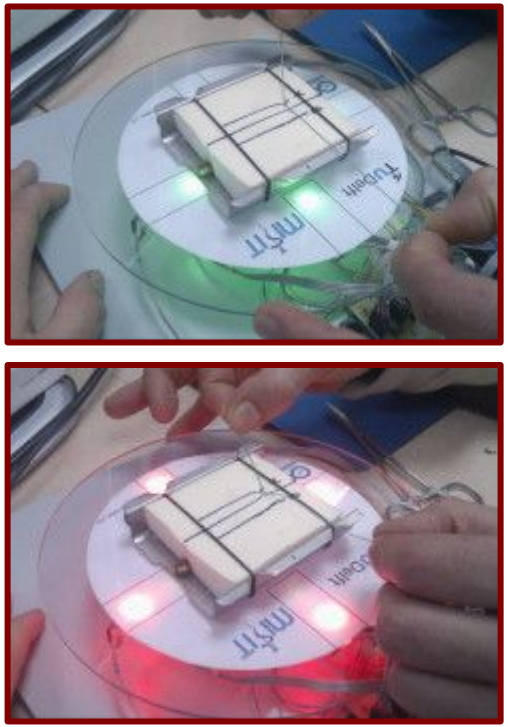
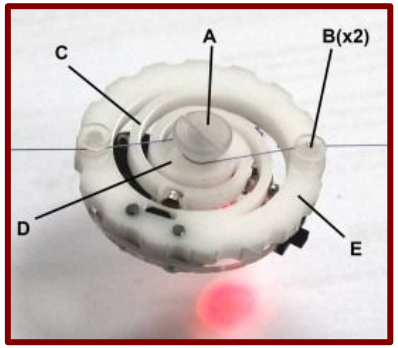


Figure 3: ForceTRAP [5].



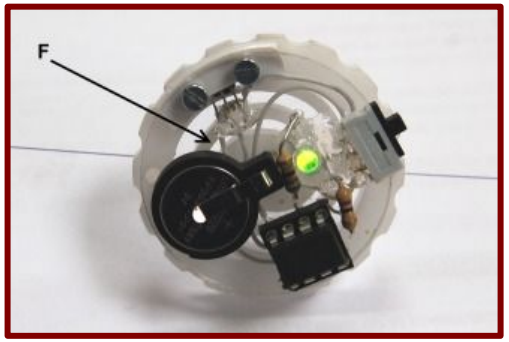


Figure 4: Wheel Sensor [4].

Product Design Specifications

	Design Specification	Design Criteria
1	Provide objective, real-time feedback on suture tension → Feedback latency ≤ 3 seconds	Functionality
2	Minimally disruptive to suturing process → Device adds ≤ 15 seconds to suturing time	Workflow Integration
3	Able to withstand repeated use in training → Survive ≥ 500 training cycles without failure	Durability
4	Allow calibration of different suture types → Support at least 3 commonly used suture diameters (2-0, 3-0, 4-0)	Adaptability
5	$250 Initial budget	Affordability

Measurement Methods for Knot Tightness

Visual Characterization of Knot Quality

Logic: Proper suture tension checked manually by tightness of final throw

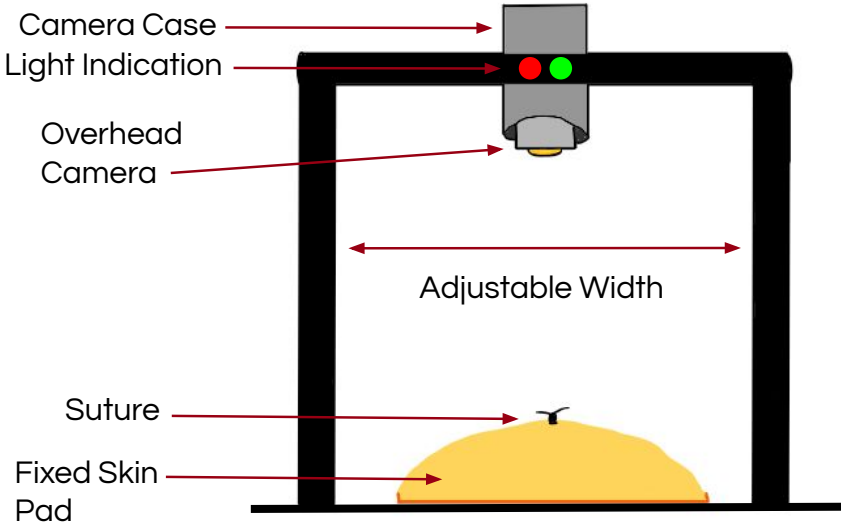


Figure 5: Optical tension measurement design concept.

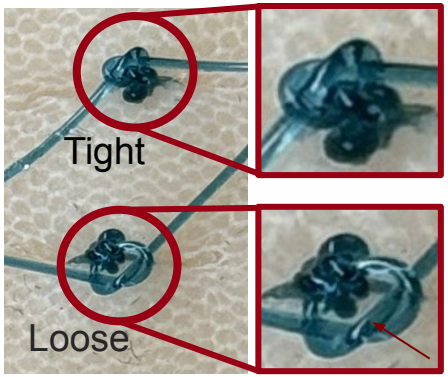


Figure 6 : Square knot comparison.

Design Concept: Automate assessment using machine learning model to detect proper knot tension

PRO	CON
No interference with suturing technique	Image training → Difficult to provide real-time feedback

Displacement as an Indicator of Plastic Deformation

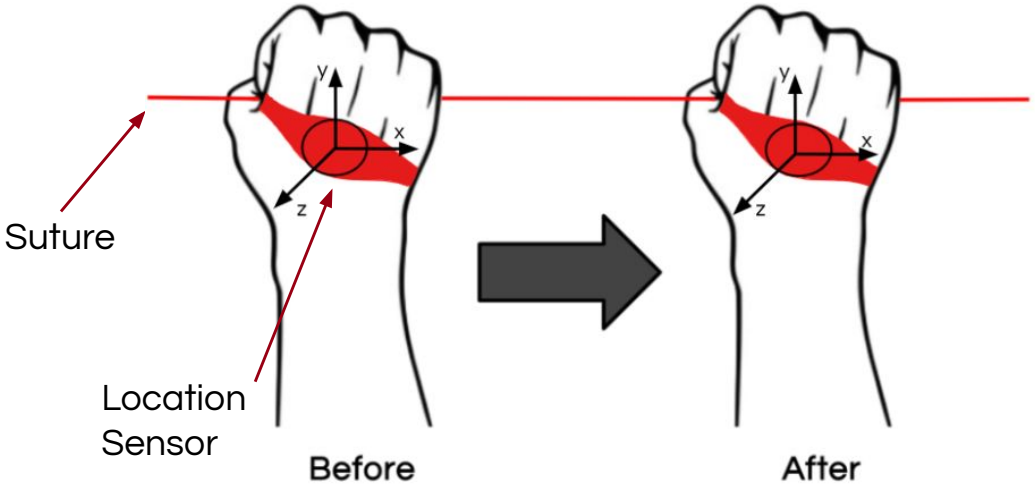


Figure 7 : Design concept with location sensor to measure displacement.

PRO

Simple measurement strategy

CON

Slipping of suture

Tension/Force as an Indicator of Plastic Deformation

Tension: the pulling force through a string

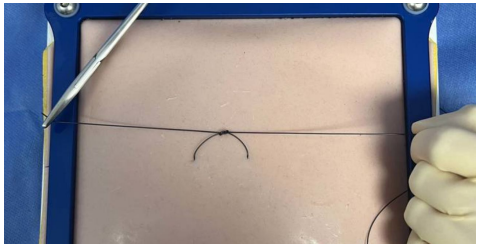


Figure 8 : Technique for securing a square knot [6].

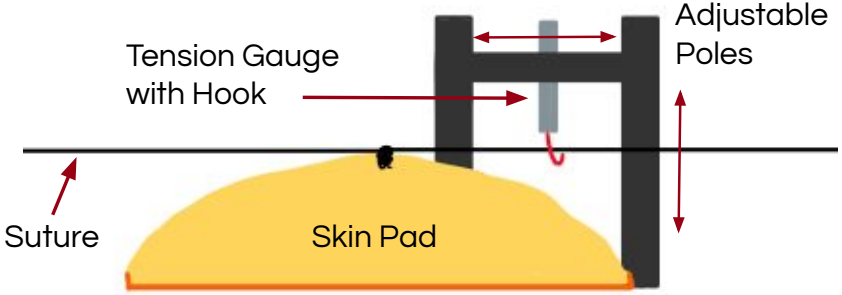


Figure 9 : Design concept measuring tension.

Force: the intensity of the push or pull of an object

Force sensing resistor (FSR):

Resistance
↓
Electrical signal
↓
Force

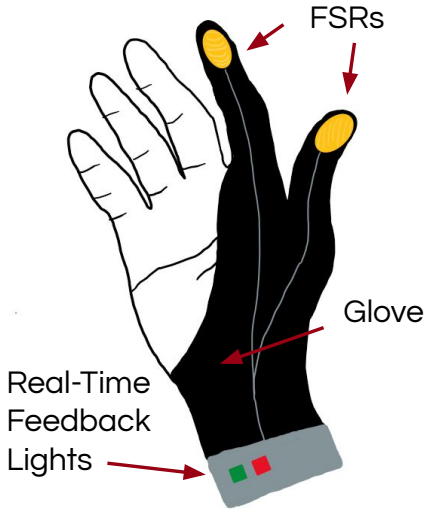


Figure 10 : Design concept measuring force.

PRO

Simpler method to quantify knot tightness

CON

Interference with the suturing technique

Knot Characteristics Provide an Advanced Feedback System

Force or Tension	Displacement	Knot Characteristics
Feasibility	**Feasibility**	Workflow Integration
Affordability	Affordability	Durability
Adaptability	Durability	Adaptability
Workflow Integration	Workflow Integration	**Feasibility**
Durability	Adaptability	Affordability

Future Work: Divide and Conquer

Preliminary Prototyping

- Digitalize force sensor
- Knot identification
  - AI image training

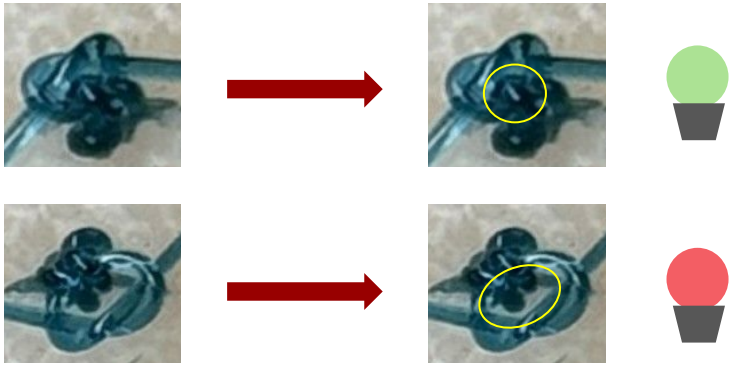


Figure 11 : AI model goal output.

Testing

- MTS testing on suture strengths
- Perform pressure sensing testing to determine:
  - Resistor value
  - Sensor placement
  - Force conversion
- Validation of AI model
  - Validate against a dataset of new images
  - Test cameras to capture process

Acknowledgements

Advisor

Dr. Wally Block

Clients

Dr. Margene Anderson

Dr. Paul Merkatoris

Dr. Sara Colopy

School of Veterinary Medicine
UNIVERSITY OF WISCONSIN-MADISON

References

[1] R. K. Elmallah et al., “Economic evaluation of different suture closure methods: barbed versus traditional interrupted sutures,” Ann. Transl. Med., vol. 5, no. Suppl 3, p. S26, Dec. 2017, doi: 10.21037/atm.2017.08.21.
[2] Medico, “Veterinary Suture by MedicoGrp: Dog Stitches Cost Guide,” Medico. Accessed: Sept. 17, 2025. [Online]. Available: https://medicogrp.com/dog-stitches-cost/
[3] “The ideal surgical knot (according to science),” *Healthcare-in-europe.com*, Jun. 12, 2023. http://healthcare-in-europe.com/en/news/ideal-surgical-knot.html (accessed Oct. 01, 2025).
[4] T. Horeman, E. Meijer, J. J. Harlaar, J. F. Lange, J. J. van den Dobbelsteen, and J. Dankelman, “Force Sensing in Surgical Sutures,” *PLoS ONE*, vol. 8, no. 12, p. e84466, Dec. 2013, doi: 10.1371/journal.pone.0084466.
[5] "Visual Force Feedback Improves Knot-Tying Security - ClinicalKey.” Accessed: Sept. 21, 2025. [Online]. Available: https://www-clinicalkey-com.ezproxy.library.wisc.edu/#!/content/playContent/1-s2.0-S1931720413001852?returnurl=null&referrer=null
[6] K. Coleman, “All tied up: A review of Suture Knots,” Securos Surgical, https://www.securos.com/insights/all-tied-up-a-review-of-suture-knots (accessed Jul. 13, 2022).

Questions?