Testing the Hydrolysis-Driven Degradation of Sutures: Impacts on Tensile Strength Over Time

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Background

- This study aims to evaluate the **rate of tensile strength loss** in sutures subjected to **hydrolysis**, providing surgeons with critical data to predict and mitigate risks associated with suture degradation in high-stress environments such as the **fascia layer**.
- The fascia layer is a **connective tissue structure** that underlies the skin, separating muscles and internal organs while providing **support and elasticity**. It plays a critical role in wound healing by mobilizing cell types and structural components to repair tissue.
- Sutures degrade primarily through **hydrolysis or enzymatic processes**, depending on their composition. Absorbable sutures, such as synthetic polymers, break down over time, with **tensile strength decreasing as hydrolysis progresses**. This process can be accelerated in **high-moisture environments** like the fascia layer.
- In procedures such as spinal surgeries, rapid suture degradation can lead to the **reopening of wounds**, **delayed healing**, and **potential infections**. These complications increase patient discomfort and necessitate revisions, highlighting the need for reliable data on suture performance.
- When sutures are wetted, they undergo **hydration-induced changes**, such as swelling, which can improve their **ability to withstand higher tensile loads**. This behavior makes it critical to incorporate **in-vivo-like simulations in research**, as such models better replicate the conditions sutures face within the body and provide more **accurate predictions** of their performance during healing.

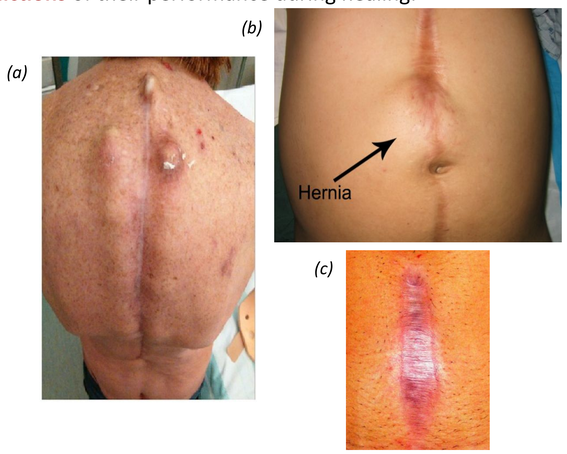

Figure 1: The worldwide occurrence of loosening sutures and early degradation. *Figures a & b* represent herniation in the fascia layer and *Figure c* shows stretching of the dermis and epidermis.

Methods

Suture Tensile Testing

- The two main test types for the project are single-suture and multi-suture tensile tests. These were conducted using a **stainless steel fixture** designed to simulate the naturally rounded portions of the fascia layer. The tests adhered to **ASTM D2256-02 standards** for tensile properties, ensuring consistent and reliable results.
- To accommodate varying suture materials and clinical applications, the **crosshead motion rate** was set within the standard range of **10–500 mm/min** dependent on the suture size being tested. This provided an appropriate simulation of the forces applied during sutures' real-life use.
- Sutures were tested with a **gauge length of 25–50 mm**, replicating typical surgical applications. A minimum of **five specimens per test type** was used to ensure statistical reliability and to align with the guidelines for tensile testing of sutures.

Suture Degradation Testing

- A **custom degradation chamber** was designed to replicate in vivo conditions. The chamber consisted of a fish tank placed inside a scientific oven maintained at **body temperature (37°C)** and the sutures submerged in **phosphate-buffered saline solution** to simulate the physiological environment. This approach ensured a realistic assessment of how sutures degrade under **consistent environmental conditions**.
- Sutures were pre-tensioned to **10N, 25N,** or **40N**, corresponding to the sizes of sutures tested (**2-0, 1-0,** and **0**, respectively). This maintained realistic load conditions throughout the degradation period, reflecting the **forces sutures typically experience in clinical scenarios**.

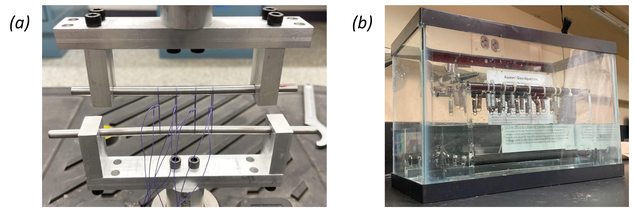

Figure 2: The testing setup used to understand the strength of sutures in-vivo. *Figure a* represents the stainless steel fixture used to test multiple sutures breaking stresses. *Figure b* represents the setup used to simulate in-vivo conditions to quantify degradation.

References

[1] ASTM International. "ASTM D2256-02: Standard Test Method for Tensile Properties of Yarns by the Single-Strand Method." Available at ASTM Standards.
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[3] Ye, H., & Rinkevich, Y. (2023). Fascia Layer—A Novel Target for the Application of Biomaterials in Skin Wound Healing. International Journal of Molecular Sciences, 24(3), 2936. https://doi.org/10.3390/ijms24032936
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Results

- The degradation study lasted **five weeks**, beginning immediately after the sutures were tied.
  - **Week 0 tested dry sutures**, while sutures were retrieved from the degradation chamber for testing at Weeks 1, 2, 3, and 4.

Key Findings (*Figure 3*)

- A notable **increase in suture strength** was observed between **Week 0** (dry state) and **Week 1** (wetted state), confirming that wetted sutures are stronger than dry ones.
- Strength **decreased** progressively from Week 1 onward, correlating with time spent under **tension** and **hydrolytic degradation**.

Consistency and Realism in Testing

- Sutures were tied and prepared by a **professional surgeon** in a sterile setting, ensuring **consistency** in knotting technique and clinical **relevance**.

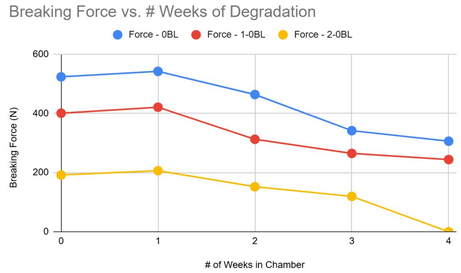

Figure 3: Plotted data from hydrolyzed suture degradation tests from all five weeks of testing.

Conclusions and Future Work

- The study demonstrated that **hydration improves suture strength**. Sutures showed increased tensile strength after initial exposure to moisture, with Week 1 strength surpassing that of dry sutures.
- **Degradation reduces tensile performance**- exposure to simulated in vivo conditions resulted in a progressive decline in tensile strength, highlighting the impact of hydrolysis on suture integrity.
- Future work for this project could include **in vivo studies**, **dynamic loading scenarios**, and a **chemical analysis of the degradation**.
  - This can be to validate findings with **animal or human** trials to strengthen the clinical applicability of the results.
  - Simulate **cyclic loading** conditions to **mimic movements experienced during healing**, providing a deeper understanding of suture behavior under real-world stresses.
  - Examine **molecular changes** in the sutures during hydrolysis to better understand the **mechanisms behind strength loss**.