Print-A-Punch

Product Design Specification

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Function:

The Print-A-Punch device will serve as a clamping mechanism to secure razor blades in a precise configuration to cut cruciform-shaped soft tissue samples for biaxial testing. The clamping system will enable the consistent cutting of soft tissues, which addresses the challenge of asymmetry that the lab currently has with their biopsy punches. This asymmetry is mainly due to high shear strain and shear forces during testing. These forces lead to inaccurate material property measurements that affect patient-specific models. By ensuring uniformity in the cruciform samples, the system will reduce errors in material property computation, improving the accuracy of mechanical behavior estimations for soft tissues. This approach will serve as a cost-effective alternative to custom steel punches, using 3D printing to enhance accessibility and reproducibility in tissue testing procedures.

Client requirements:

- Device should be reusable
- Device should be able to cut a consistent shape and size of soft tissue sample
- Device must be compatible with generic Stanley-brand razor blades
- Device should be fabricated from stainless steel hardware
- Device must be able to cut through various thicknesses of tissue samples
- Budget of $250

Design Requirements

1. Physical and Operational Characteristics
    a. *Performance requirements*:
        i. Prototype must be able to cut through multiple types of tissue with relative ease, without require excessive force to operate
        ii. Prototype must be able to be replicated by other researchers for laboratory use
    b. *Safety*:
        i. During assembly of punch, blades must be covered or hidden to prevent injury to user
        ii. Device usage must be easy to learn since it is universally available
        iii. Device should pose minimal risk to user during operation
    c. *Accuracy and Reliability*:
        i. The punch must be capable of cutting a minimum of 3 samples before swapping blades is necessary
        ii. Body of punch must have an indefinite lifetime

    iii. Punch must be able to replicate the intended punch pattern on every attempt
    iv. Overall length and width of printed punches should have an error less than 5% [1]
  d. *Life in Service*:
    i. Punch must last indefinitely with the ability to replace blades when dulled
  e. *Shelf Life*:
    i. Punch must not require any unusual storage conditions
    ii. Punch must be able to withstand a large amount of external pressure from a mallet or a press
  f. *Operating Environment*:
    i. Punch must be able to be used on demand with little setup time
    ii. Punch must be able to be used in a laboratory environment
    iii. Punch should be able to withstand sterilization
  g. *Ergonomics*:
    i. Punch must be simple to 3D print on most 3D printers
    ii. Punch must be easy to assemble
    iii. Blades must be easy to bend during replacement
    iv. Punch should include a fast fabrication time of under 5 hours
    v. Razors should be able to be replaced safely in under 5 minutes
  h. *Weight*:
    i. The device will be lightweight in order to be easily transported and shifted when working with small tissue samples
  i. *Materials*:
    i. Main device structure will be 3D printed
    ii. Must not corrode when in contact with tissue storage solution
    iii. PETG or Nylon can be used for 3D printing due to its chemically resistant properties [4]
    iv. Stainless steel hardware should be used to avoid corrosion
    v. Stainless steel razor blades will be used to cut tissue samples
    vi. Materials must be easy to acquire
  j. *Aesthetics, Appearance, and Finish*:
    i. No color or finish preference
    ii. Punch must be appropriate for general laboratory spaces
2. Production Characteristics
  a. *Quantity*:

        i. Punch should be scalable to a variety of different size products for punching different dimension samples
        ii. CAD files and production instructions should be published in final report for public domain
    b. *Target Product Cost*:
        i. Each product should be reasonably cheap to produce (under $10 per device)
3. Miscellaneous
    a. *Standards and Specifications*:
        i. Product's plastic body should comply with ASTM D638-02a, which specifies tensile testing procedures for plastics, ensuring they meet industry requirements in laboratory use [2].
        ii. Device should comply with ASTM D412-06a, as it relates to creation of soft tissue models for biaxial testing, ensuring accurate and reproducible measurements of tensile properties [3].
    b. *Customer*:
        i. Punch is catered toward tissue testing labs and is not intended to be sold for a profit
        ii. Individual punches are to be created at owners expense
    c. *Patient-related concerns*:
        i. Not in the scope of this project
    d. *Competition*:
        i. Print-A-Punch for Uniaxial Testing: Comparable design that uses a dumbbell-shaped punch intended for uniaxial tensile testing, as opposed to biaxial testing [1].

References: (CITE ALL IN IEEE)

[1] S. J. Nelson, J. J. Creechley, M. E. Wale, and T. J. Lujan, "Print-A-Punch: A 3D printed device to cut dumbbell-shaped specimens from soft tissue for tensile testing," Journal of Biomechanics, vol. 112, p. 110011, Nov. 2020, doi: https://www.sciencedirect.com/science/article/pii/S0021929020304346#bi005.

[2] "ASTM: 638: Standard Test Method for Tensile Properties... - Google Scholar." Accessed: Sep. 17, 2024. [Online]. Available: https://scholar.google.com/scholar_lookup?title=Standard%20Test%20Method.

[3] "ASTM: Standard test methods for vulcanized rubber... - Google Scholar." Accessed: Sep. 17, 2024. [Online]. Available: https://scholar.google.com/scholar_lookup?title=Standard%20Test%20Methods.

[4] "Guide to 3D Printing Materials: Types, Applications, and Properties | Formlabs." Accessed: Sep. 17, 2024. [Online]. Available: https://formlabs.com/blog/3d-printing-materials/.