Improved Cooling and Automatic Stopping Mechanism for Neurosurgical Drill Optimization

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Introduction

Target Issues:

- **Neural damage** through loss of drill control and plunging (21% of neurosurgeons reported plunging during surgery [1])
- **Overheating** (temperature greater than 47 degrees C for more than 1 min) at the drill site leading to tissue necrosis [2]
- Neurosurgeons require greater convenience and faster speed during surgeries

Mission Statement

Develop a neurosurgical drill to improve precision and patient safety during craniotomies

Device Concept

- **Cooling Technology** : Optimizing drill bit composition and shape to enhance heat dissipation, preventing tissue damage
- **Automated Stop Mechanism** : A self-regulating system that halts the drill upon skull penetration, preventing brain injury

Prototyping/ Model

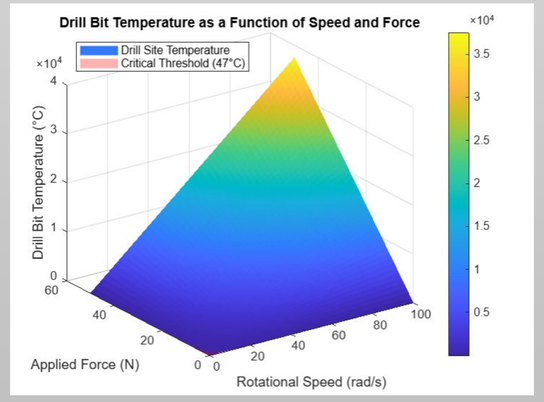

Figure 1. MATLAB graph depicting impact of varying perpendicular force (N) and rotational speed (rad/s) on drill site temperature (C)

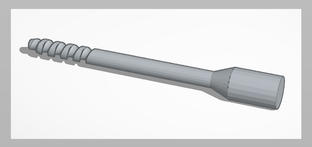

Figure 2. Proposed drill bit design

Project Planning

QR code to current Gantt chart reflecting project planning and progress.

Design Inputs

Table 1. Design metrics for enhanced drill bit.

Metric Name		
Heat Dissipation	Skull penetration	Eco-friendly
Sterilization Compatibility	Ergonomics	Weight
Durability	Precision and Control	Drill Bit Types
Cost-effectiveness	Longevity	Safety
Automated stop mechanism	Replaceable drill bit	Effectiveness

Table 2. Customer metrics for enhanced drill bit.

Metric Name		
Convenient	Streamlined Design	Ergonomic
Easy to learn/use	Minimalistic Design	Durable
Effective	Light/weighted correctly	Precise
Safe	Antibacterial	Easy to sanitize

Product Architecture

Main Mechanisms:

- **Cooling technology** using altered shape and composition of drill bit to best dissipate heat without requiring coolant
  - Keeps temperature of drill site below the temperature threshold of tissue damage
- **Auto-stop** to prevent plunging using electrical resistance-based technology

Technical Models

Thermal Dissipation Mechanism

$$(T_i - T_u) = \frac{Q_v}{k*A}$$

Thrust Force Equation

$$F_t = C * f * D^n * v^m$$

Manufacturing

- Medical grade titanium (Grade 5 Ti-6AL-4V) / Medical grade aluminum (6061 aluminum alloy) drill bit (5mm diameter, 150mm long)
- Medical grade titanium cylindrical latch (20mm diameter with 3mm rectangular protrusions to fasten to drill)
- Synthetic diamond coating
- In-bit pressure/force/resistance sensor
- Arduino Uno, Motor controller

Estimated per-unit cost ranges from $500 - $600
Estimated retail value of $8000-10000

Final Product Specifications

- Weight of drill + drill bit: 1000 g
- Drill bit: 5mm diameter, 150mm length
- Drill bit contains a notch at the attachment site for easy removal and reattachment to drill
- Pressure sensor to initiate automatic stopping mechanism
- LED light indicators connected to pressure sensor.
- Fully autoclavable

Design Status/ Future Work

Market size:

- **Neurosurgery** : estimated to be $3425.1 million and expected to reach $5280.8 million by 2034
- **CAGR**: 4.6% from 2024 to 2034 for the global neurosurgery market
- **Current Status:** Conducting research on technical needs and specifications and conducting customer discovery interviews

- **Future Plans:**
  - Prototyping of drill bit design (3D printed using ABS filament) for optimal dissipation of heat and functioning automatic stop mechanism
  - Market research
  - Applying for IP rights
  - Design finalization, creation of metal drill bit and testing of main mechanisms

References

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[2] Islam, M.A.; Kamarrudin, N.S.; Daud, R.; Mohd Noor, S.N.F.; Azmi, A.I.; Razlan, Z.M. A Review of Surgical Bone Drilling and Drill Bit Heat Generation for Implantation. Metals 2022, 12, 1900. https://doi.org/10.3390/met12111900

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