Improved Cooling and Automatic Stopping Mechanism for Neurosurgical Drill Optimization

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Introduction

- **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]

Mission Statement

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

Device Concept

- **Cooling Technology** : Optimizing drill bit composition and adding an automated saline dispenser to enhance heat dissipation, preventing tissue damage
- **Auto-Stop Mechanism** : A system that halts the drill motor upon skull penetration, preventing brain injury

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/reattachment to drill
- Current sensor to initiate automatic stopping mechanism with LED lights
- Fully autoclavable

Experimental Design

- **Automated Shut Off Mechanism** : Triggers motor shutdown upon detecting a current spike
- **Software & Testing** : Programmed in C++ (Arduino IDE), with benchtop trials on 8 mm PMMA samples.
- **Protocol** : Used five drill bit materials (carbide, titanium, HS stainless steel, cobalt tipped, surgical steel); 8 trials each for saline/no saline conditions using a drill press + animal craniotomy drill
- **Temperature Measurement** : Used IR camera to record max drill bit temperature during drilling process and 50 second cooldown period

Prototyping/Model

Maximum Temp in °C				
Trial #	**Titanium**	**Cobalt**	**Carbide**	**Steel**
1	30	29.7	29.2	27.5
2	32	28.4	28.4	27
3	29.7	28.8	28.9	27.5
4	28.9	28.8	29.5	27
5	30.2	27.7	30.4	29.8
6	28.2	29.8	28.2	31.8
7	30.6	29.1	26.7	28.8
8	26.2	27.8	28.8	30.8
Avg	29.475	28.7625	28.7625	28.775

Figure 1. Maximum temperature readings in degrees C of each drill bit material type after physical testing using 8mm PMMA samples.

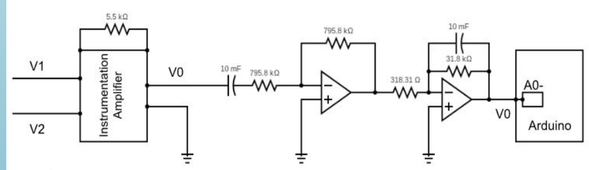

Figure 2. Auto-stop circuit diagram using a 5V microcontroller, Arduino, low-pass and high-pass filters, and a TL072 op-amp.

QR code for project progress and timeline.

Physical Testing

Figure 3. IR camera temperature recording and physical prototyping setup (saline and no saline conditions).

Figure 4. IR camera and physical prototyping setup (bovine bone, no saline). Bones are held in place a clamp.

QR code for reference pictures and videos of prototyping process.

Mechanical Modeling

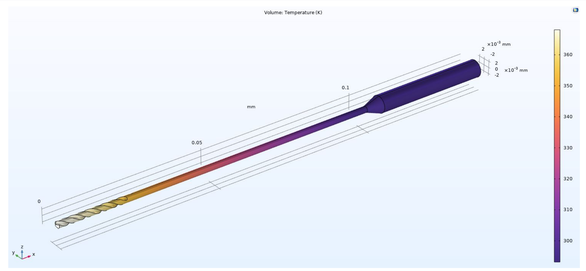

Figure 5. Model of heat generated during rotational friction using COMSOL modeling software. Material of reference is high-strength steel alloy.

Data Analysis

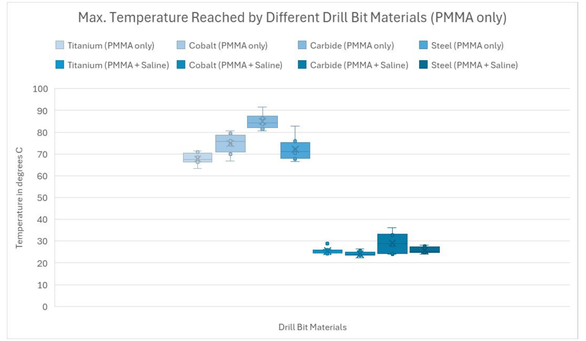

Figure 6. Maximum temperature reached by different drill bits in PMMA only samples and PMMA and saline solution samples, 8 trials per material. Analysis from one-way ANOVA (α-value of 0.00001) found PMMA only had a p-value of $3.73 * 10^{-8}$ and PMMA + saline had a p-value of 0.00729.

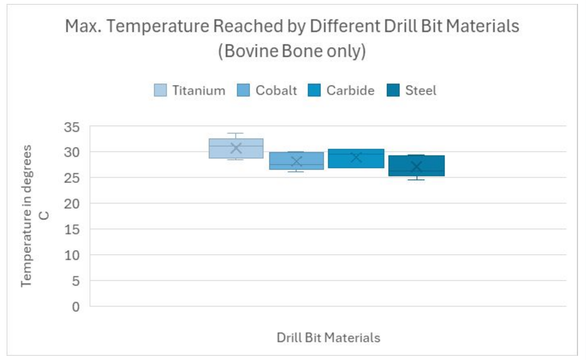

Figure 7. Maximum temperature reached by different drill bits in bovine bone samples, 5 trials per material. Analysis from one-way ANOVA (α-value of 0.00001) found samples had a p-value of 0.0548.

Future Considerations

- Funding discussions with drill manufacturers and research institutions for further development/prototyping of device
- Integrate and test the auto-stop circuit and saline dispersal mechanism
- Condense circuit and saline system
- Performing larger scale PMMA and bovine studies for greater reliability and validity
- Performing cadaver studies prior to clinical studies

References

[1] Caird, J. D., & Choudhari, K. A. (2003). 'Plunging' during burr hole craniostomy: a persistent problem amongst neurosurgeons in Britain and Ireland. British journal of neurosurgery, 17(6), 509–512. https://doi.org/10.1080/02688690310001627722

[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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