

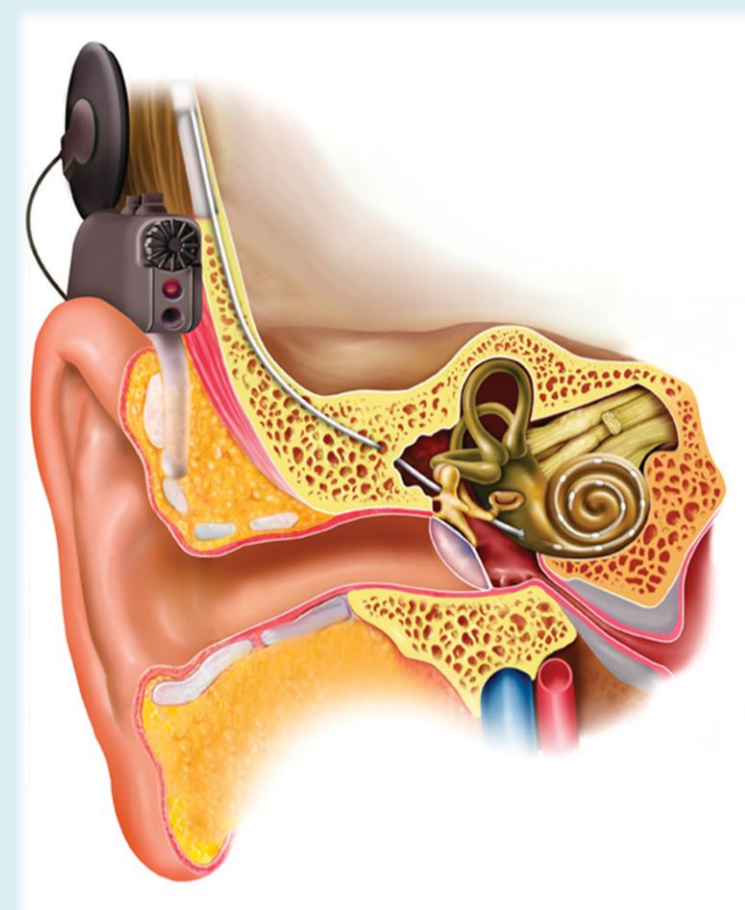
Reducing temperature elevation of bone drilling

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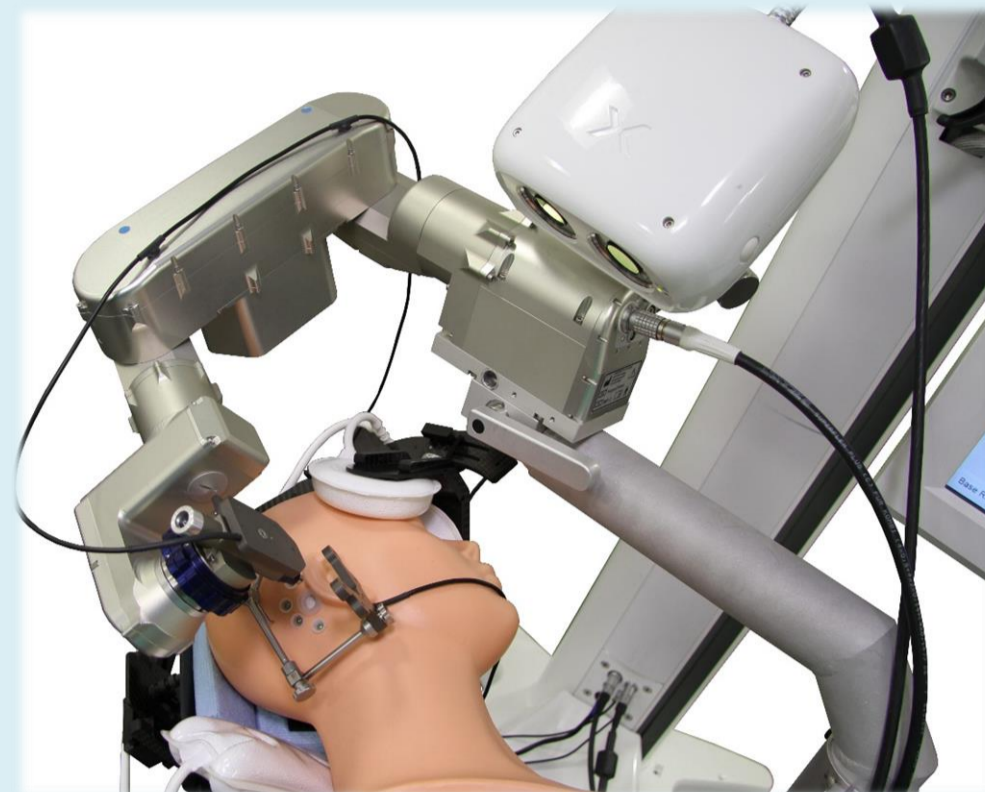
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Hearing Loss
or Impairment



Cochlear Implant



Minimally Invasive Robotic
Cochlear Implantation

- + reduces hospitalization time
- + saves costs
- Additional risks
 - Thermal nerve damage

Materials

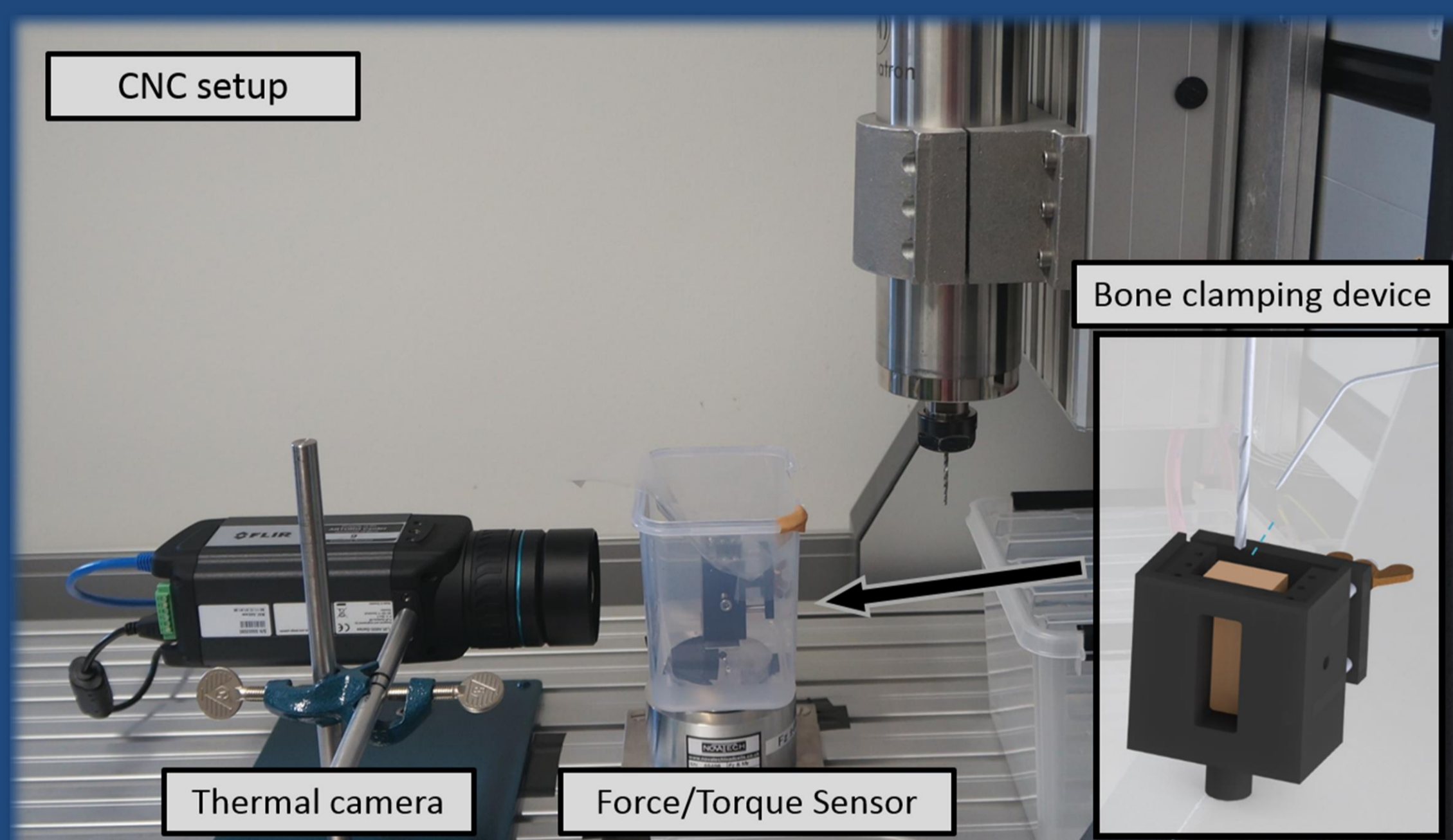
Reducing the temperature
elevation of the drilling process

Drill bit design

Custom made single
flute helical drill bit

Process parameters

Irrigation
Interval drilling

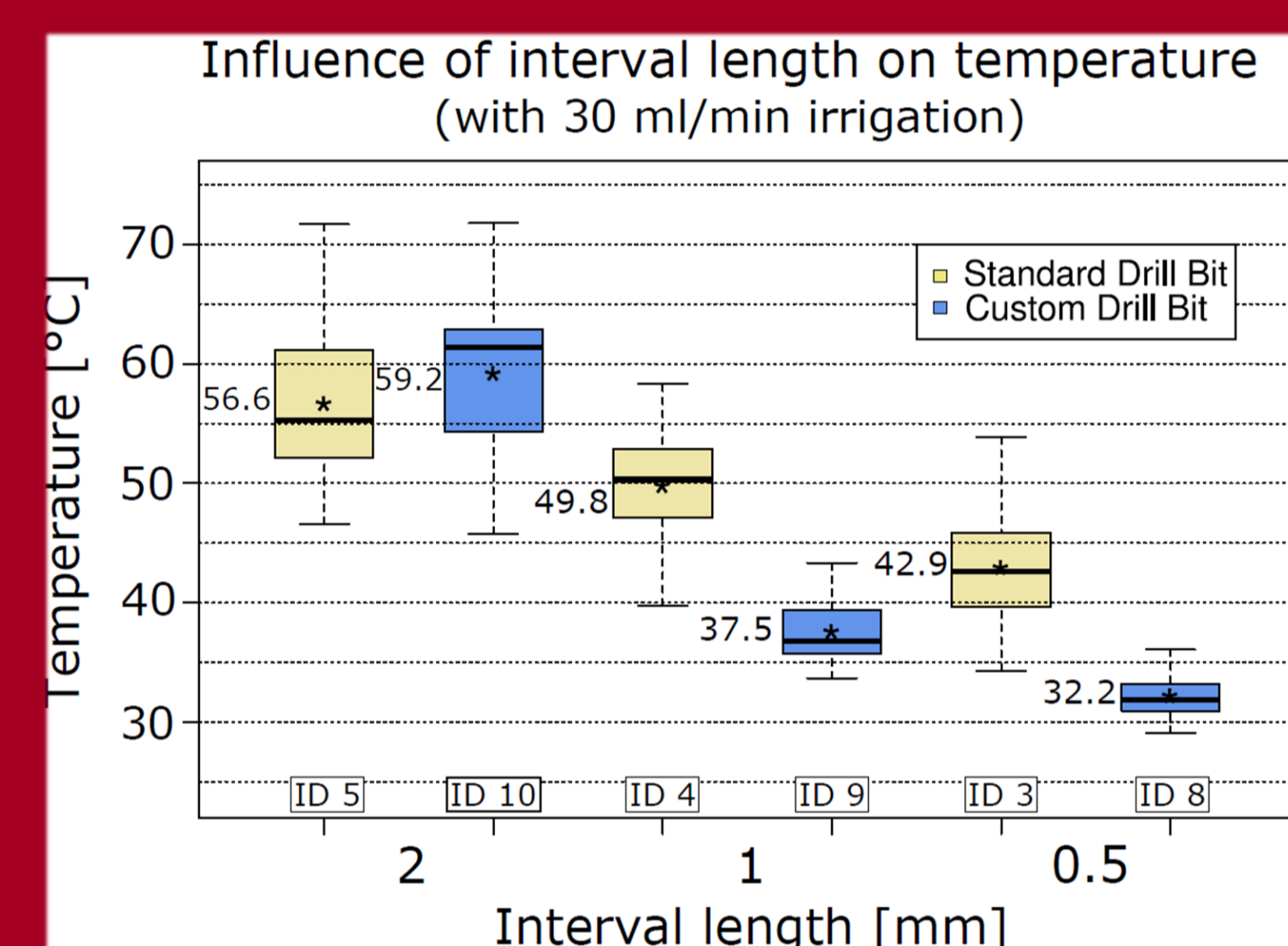
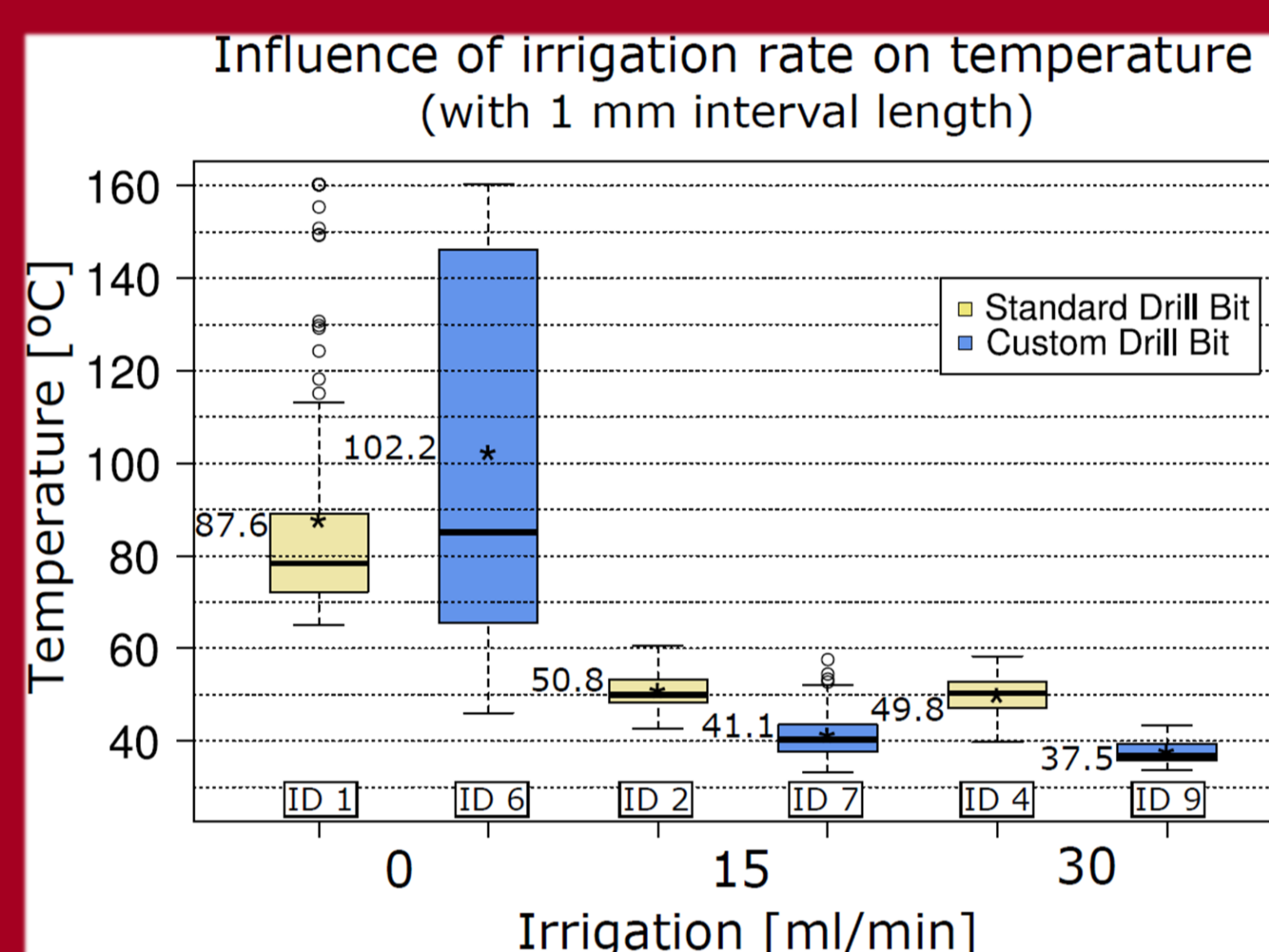


Methods

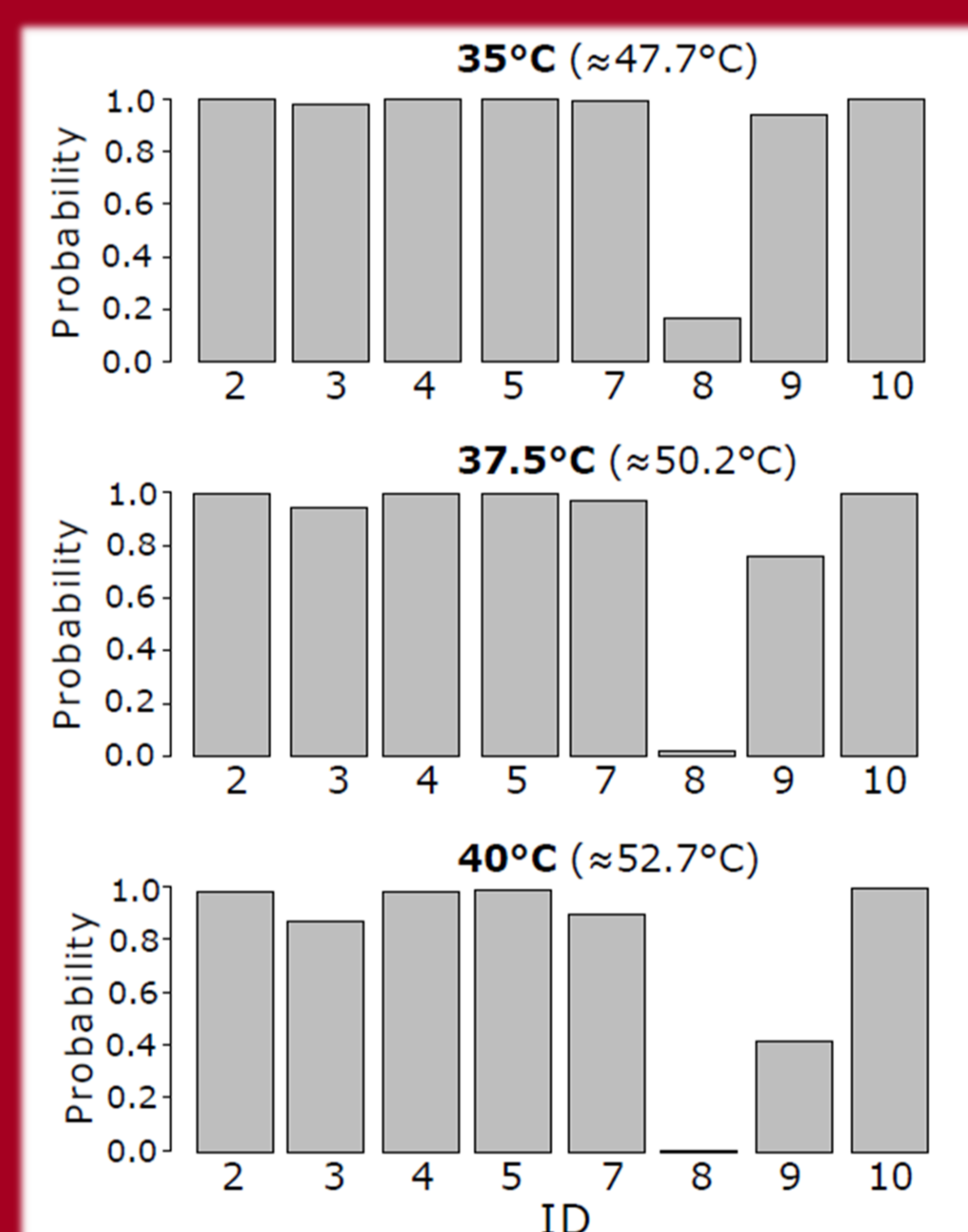
Design of experiments: **Three different irrigation rates** were tested in combination with **three different continuously drilled interval lengths** (with total drill bit extraction in-between). **Two different drill bits** were tested: Standard surgical Synthes and custom designed single flute helical drill bit. Each parameter combination was conducted eight times for both drill bits.

Interval \ Irrigation	0 ml/min	15 ml/min	30 ml/min
0.5 mm			X
1 mm	X	X	X
2 mm			X

Results



Probability of thermal damage



The results show that irrigation has a major effect on temperature reduction, where the effect of flute clearing is more important than actual cooling. Due to the low thermal conductivity of bone, drilling in intervals is in general beneficial for limiting the accumulation of heat and allowing the bone to cool down in-between intervals while improving chip evacuation as well as flute cleaning when the drill bit is extracted. Flute clogging with bone chips has been found to be the reason for the above-average peaks of temperatures, forces and torques which leads to excessive temperature rise.

Discussion

- Measuring of temperature elevation during the drilling process without difficult placement of thermocouples
- New drill bit design has a significant lower torque and thrust force compared to the standard drill bit (due to higher rake angle)

Conclusion and Outlook

- The combination of **high irrigation rate** (30 ml/min, 18 gauge needle) and **small continuously drilled interval** (0.5 mm) prevents flute clogging and limits the accumulation of heat within the bone
- The temperature elevation can be **kept below critical thermal threshold** when this parameter combination is used with the **new drill bit design**
- **Drilling process** can be **further optimized** by using a previously introduced **thermal model** which uses the torque and force signal to predict the temperature elevation of the drilling process in real-time

References:

- Bell, A self-developed and constructed robot for minimally invasive cochlear implantation, Acta oto-laryngologica 132: 2012
 Lee, An experimental investigation of thermal exposure during bone drilling, Medical Engineering & Physics, 34 (10): 2012
 Feldmann, Temperature Prediction Model for Bone Drilling Based on Density Distribution and In Vivo Experiments for Minimally Invasive Robotic Cochlear Implantation, Annals of Biomedical Engineering: 2016