MODAL ANALYSIS OF MEDICAL DEVICES DURING ORTHOPEDIC OPERATIONS

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Introduction

The conventional method of manually drilling during hip fracture repair poses risks of unstable fixation and potential vascular damage. This research seeks to explore a secure and user-friendly approach using robot assistance to automate bone drilling. It aims to accurately detect critical bone drilling stages in real-time, ensuring safety and precision throughout the hip fracture fixation procedure.

Methods

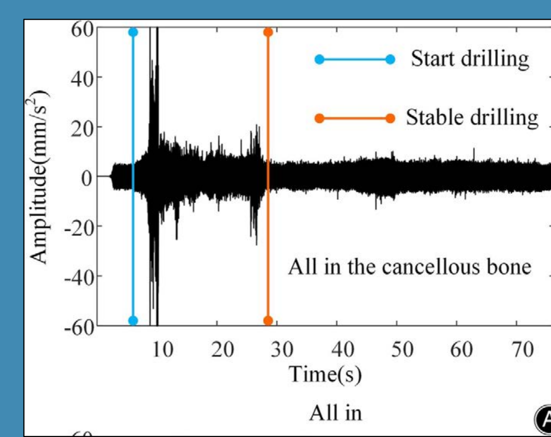
A robotic system designed for drilling holes in the femoral neck was tested on four fresh pig femurs using three drilling modes: "all-in" (AI), "in-out-in" (IOI), and "percutaneous fixation" (PF). Vibrations from the drill handle were recorded by a high-frequency accelerometer and transferred to a computer for analysis. Five drilling states were identified, including idle, initial drilling, within cancellous bone, exiting the femoral neck, and within cortical bone. The vibration signal was analyzed using fast Fourier transform (FFT) to extract harmonic distribution, which was crucial for distinguishing drilling states. A statistical test compared the first harmonic amplitude across drilling states. A neural network classifier, trained on frequency spectra, accurately identified drilling states in real-time. Testing on four specimens confirmed the system's ability to recognize these states reliably.

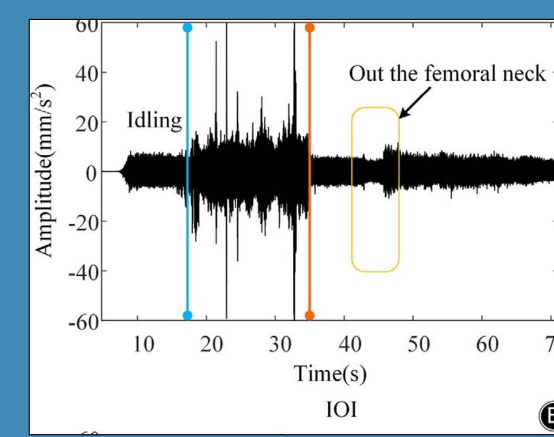
Results

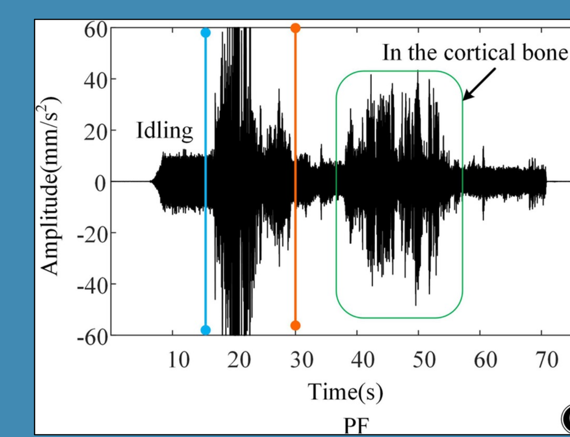
- Harmonic distributions of drilling vibration were significantly different across drilling modes in each specimen ($p < 0.05$).
- Average recognition accuracies of drilling states for all four specimens exceeded 84%.
- The three defined drilling modes were distinguished with extremely high accuracies.
- Recognition accuracies for "in the cancellous bone" were as follows:
  - Specimen 1: 83.2%
  - Specimen 2: 84.8%
  - Specimen 3: 92.9%
  - Specimen 4: 84.7%
- Recognition accuracies for "out the femoral neck" were as follows:
  - Specimen 1: 98.2%
  - Specimen 2: 88.4%
  - Specimen 3: 95.8%
  - Specimen 4: 88.8%
- Recognition accuracies for "in the cortical bone" were as follows:
  - Specimen 1: 94.6%
  - Specimen 2: 80.8%
  - Specimen 3: 95.5%
  - Specimen 4: 85.8%

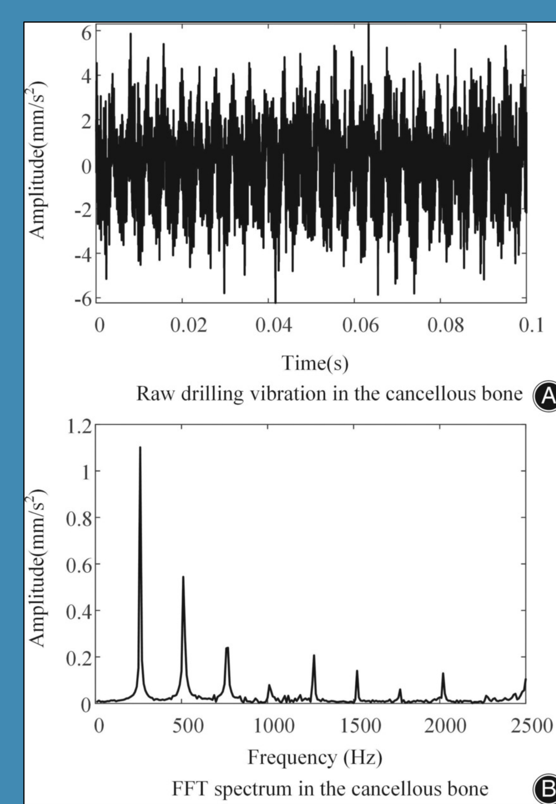
Conclusion

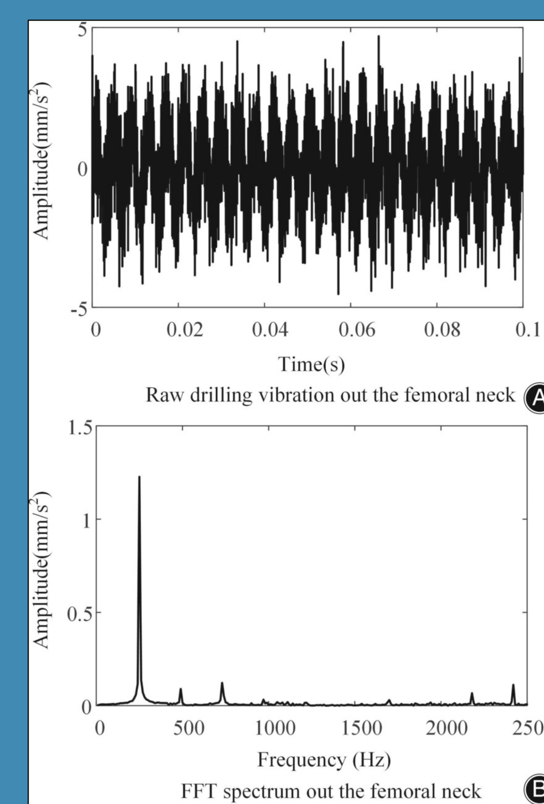
The suggested technique utilizing robots can promptly identify five essential stages of bone drilling with exceptional precision in real-time, preventing inadequate fixation and safeguarding the lateral epiphyseal artery from harm.

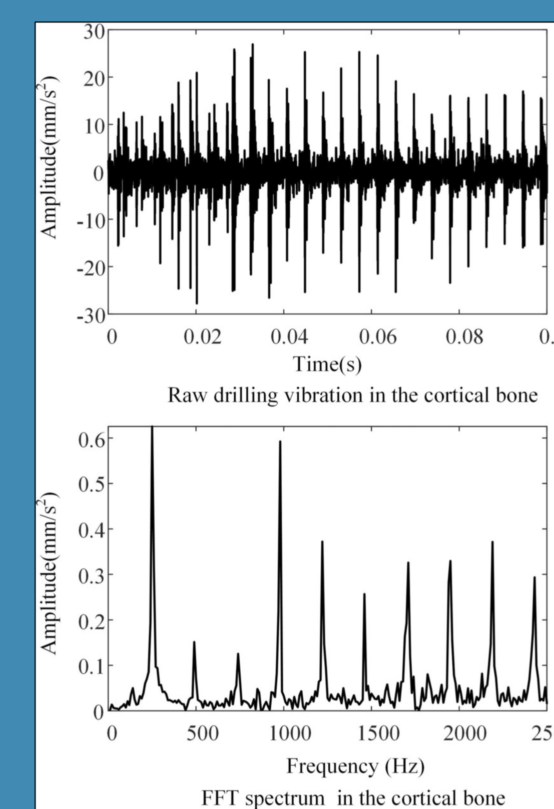












Discussion

In the realm of orthopedic surgery, where precision and safety are paramount, this study embarked on a journey to revolutionize the bone drilling process during hip fracture fixation. With an unwavering commitment to enhancing patient outcomes, the researchers meticulously crafted a cutting-edge robot-assisted technique. This method not only simplifies bone drilling but also boasts the remarkable ability to discern critical bone drilling states in real-time with unparalleled accuracy.

Across a series of meticulously conducted experiments involving four specimens, the researchers meticulously documented the recognition accuracies for various bone states. From the cancellous bone to the cortical bone, each distinct drilling state was scrutinized, yielding recognition rates ranging from 80.8% to an impressive 98.2%. Remarkably, the average recognition accuracy across all specimens surpassed a commendable 84%, underscoring the robustness of the proposed technique.

Beyond its technical prowess, the significance of this advancement in surgical technology cannot be overstated. By potentially reducing the incidence of weak fixation and minimizing the risks associated with damaging critical anatomical structures such as the lateral epiphyseal artery, this innovative approach holds the promise of transforming orthopedic surgery for the better.

Looking ahead, the researchers are poised to expand the horizons of their investigation. By incorporating cases of osteosclerosis and osteoporosis into their study, they seek to further validate and refine the efficacy of their groundbreaking robot-assisted method. Through continued research and innovation, they endeavor to usher in a new era of orthopedic surgery characterized by heightened precision, improved patient outcomes, and enhanced safety standards.

Work Cited

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