Construction and Simulation of a Finite Element Model of Knife-slashing Head for Forensic Practice

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Summary

Knife trauma frequently occurs in forensic practice. This study aims to analyze the biomechanical response characteristics of skull trauma under knife-induced injuries and quantitatively assess the injury risk using the Abbreviated Injury Scale (AIS). The finite element model (FEM) was validated by slashing 3D-printed skull experiment, and the biomechanical responses of the frontal bone, left and right parietal bones, and occipital bone were further investigated at different slashing speeds using a kitchen knife and a machete. The slashing force, energy, stress distribution, wound depth, and injury risk boundary increase with speed. The machete generated higher slashing force and stress concentration than the kitchen knife, while the kitchen knife generated greater wound depth and injury risk. Slashing speed, knife type, and the targeted skull region may influence wound dimensions and injury risk. And a slashing impact of 10 J may reach the risk boundary for AIS 3+ injury.

Introduction

Knife attacks are common forms of crime especially in those gun-controlled countries. Heads are often be slashed in fatal cases. It is needed to quantify the relationships between wound dimensions and mechanical variables of the knife slashing in the forensic investigation. This paper is aimed to develop a FEM of knife-slashing head and simulate the process of wound formation and then simulate the wound dimensions caused by different slashing conditions.

Methods

This study conducted slashing experiments on a PVC dummy and a 3D-printed skull, and developed a skull FEM. The geometric model of head was introduced from the THUMS human body model launched by Toyota. The FEM of the head was then developed after refining and discretizing the geometric model. After assembling the models of the head and knife, simulation of the knife slashing the head was performed based on data from previous human slashing a dummy [1]. The slashing experiment on the 3D-printed skull provided wound dimensions to validate the FEM, while the slashing of the dummy's skull provided data, such as slashing speed and location, which were used as boundary conditions for the FEM simulations. Subsequently, we conducted FEM-simulations to comprehensively quantify the biomechanical responses and injury risks under different slashing conditions.

Results and Discussion

Figure 1 shows examples of using the knives to slash frontal bone. As the slashing speed increased, the average maximum slashing force of the kitchen knife and machete increased by approximately 2-2.5 times. Slashing energy was 33.2 J and 32.8 J. The average maximum slashing force of the machete was 28% higher than kitchen knife. The slashing forces applied to the frontal, right parietal, occipital, and left parietal bones were 6.4 kN, 3.0 kN, 2.3 kN, and 3.1 kN, respectively.

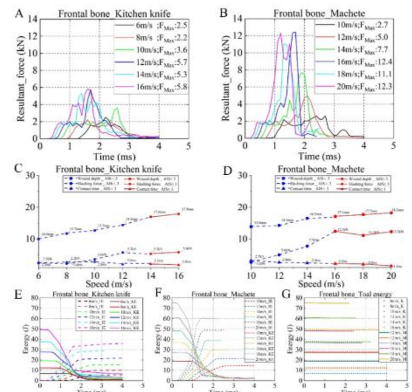

Figure 1: Mechanical variables and boundaries for AIS 3+ injury risk of slashing on frontal bone using a kitchen knife and a machete.

The kinetic and total energy gradually increase with slashing speed. Both knives exhibit a trend of increasing wound depth and AIS score as slashing speed increases. The average wound depth nearly doubles from 13.0 mm at low speed to 24.8 mm at high speed, indicating that slashing speeds influence wound depth. Besides, the kitchen knife-induced wounds are generally deeper than the machete at the same speeds, and the knife type difference in wound depth was 17.8%. This may be related to the different blade geometries and sharpness.

It was revealed that slashing different skull regions exhibits varying AIS score (injury risk). The occipital bone exhibits deeper wounds and AIS 3+ injury risk, and the frontal, parietal bones show shallower wounds and AIS 3+ risk. The wound depth of occipital bone was 21.4% higher than frontal bone.

Conclusions

The FEM of knife slashing head can quantify the relations among knife, slashing, and injury risk. The slashing speed, knife type, and the slashed region influence wound dimensions and injury risk. The kitchen knife generates more severe wounds than the machete, and slashing different skull regions causes varied mechanical responses and AIS scores.

Acknowledgments

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References

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