Abstract

Wrist injuries are common in youth "extreme sports" such as snowboarding, skateboarding, and rollerblading. Evaluation of a prototype wrist guard incorporating a viscoelastic cushion and a commercially available guard with rigid volar plate was accomplished using five matched pairs of cadaveric forearms utilizing a drop test apparatus. The prototype wrist guard was shown to be more effective to more commercially available rigid guards at absorbing load and reducing forearm strain in non-destructive tests.

Introduction

• About 30% of all injuries are hand and wrist injuries [1].
• 12% of hand injuries are wrist injuries [2]. Distal radius is a common fracture site often resulting from fall on outstretched hand (FOOSH).
• World Health Organization has fracture prevention among healthcare priorities [3].
• The efficacy of wrist guards is without question. Almost all biomechanical studies showed peak force or strain reduction with use of a wrist guard [4].
• The use of wrist guards is low, reported to be around 16% of snowboarders age 15-18 [5].
• Among reasons cited for not wearing wrist guards are discomfort, bulkiness.
• The long-term goal of this project is to make wrist guards more comfortable and less bulky using viscoelastic protective materials.

In this study, in addition to measures of force and local strain, the mechanism of wrist fracture is studied using x-ray photography and also visible light photography at 1000 fps. The x-ray and also visible light photography was a sensitive measure for bone failure. The failure mode was more controllable and also higher than the volar guard.

Method

Drop Test Apparatus

Figure 1: Schematic of drop test apparatus

• 5 matched-pair specimens (3 male, 2 female, Age = 68±19, Weight = 61±10 kg, T-score = -2.1±12) were tested.
• For non-destructive (ND) drop tests, the drop height was 25 mm and for destructive (D) drop tests, it was 15 cm.

Non-destructive Drop Max Strain

<table>
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<tr>
<th>Height (m)</th>
<th>ND Max Strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25</td>
<td>0.018</td>
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<tr>
<td>0.5</td>
<td>0.034</td>
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</table>

Non-destructive Drop Max Stress

<table>
<thead>
<tr>
<th>Height (m)</th>
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</tr>
</thead>
<tbody>
<tr>
<td>0.25</td>
<td>0.016</td>
</tr>
<tr>
<td>0.5</td>
<td>0.031</td>
</tr>
</tbody>
</table>

High-Speed X-ray Photography

The drop test was photographed with high-speed x-ray and also visible light photography at 1000 fps. The x-ray and also visible light photography was a sensitive measure for bone failure. The failure mode was more controllable and also higher than the volar guard.

Figure 4: Schematic of high-speed x-ray apparatus

X-ray Source

X-ray High Speed Camera

Impact Velocity

Weight Hopper

Load Transfer Plates Assembly

Guide Rails

Pivot Cap

180° Load Cell

Ulnar Load Cell

String Potentiometer

Dose Weight

Drop Tower Assembly

Visible Light High Speed Camera

Results

High-Speed X-ray:Axial compression of the corpus and not hyperextension of the wrist was the reason for failure. Younger patient’s bones failed at the volar cortex first, then dorsal, while older bones failed at the dorsal metaphysis first. The volar splint tended to slip down the arm and appeared to distribute load to the forearm (resulting in both bone forearm fracture in one case).

We also learned that the prototype splint did not compress as much as expected in failure testing suggesting that a more compliant viscoelastic material would absorb more energy.

Maximum Force: The prototype guard resulted in higher force absorption of 18% for ND tests and 3% for D tests (not statistically significant based on t-test).

Maximum Stiffness: Forearm stiffness was defined by dividing the maximum force by the maximum displacement measured in N/mm. The prototype guard, again, showed higher energy absorption capability with 83% increase in stiffness for ND tests (significant) and 3% increase in D tests (not significant).

Figure 5: Comparison of maximum stiffness between prototype and volar wrist guards

Figure 6: Representative axial force–time histories for non-destructive (ND) and destructive (D) drop tests of matched pair cadaveric arms with volar and viscoelastic prototype wrist guards.

It was verified that strain was a sensitive measure for bone failure. The failure point appeared as a sharp drop in the strain time history at about 5 ms after the impact.

Figure 7: Comparison of maximum force between prototype and volar wrist guards

Future Work

Based on the measurements of this study and the data collected for unprotected arms, a validated finite element model of the forearm will be developed for designing and improving viscoelastic wrist guards.

Acknowledgment

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References


Figure 8: Comparison of maximum stiffness between prototype and volar wrist guards

Figure 9: Comparison of maximum principal strain in radius and ulna in non-destructive tests.