Investigation of Distal Radius Fracture due to Fall on Out-stretched Hand and Evaluation of Protection with Wrist Guards

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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 equally to more effective than 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 listed 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 13-18 [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 **high speed x-ray**.

Method

Drop Test Apparatus

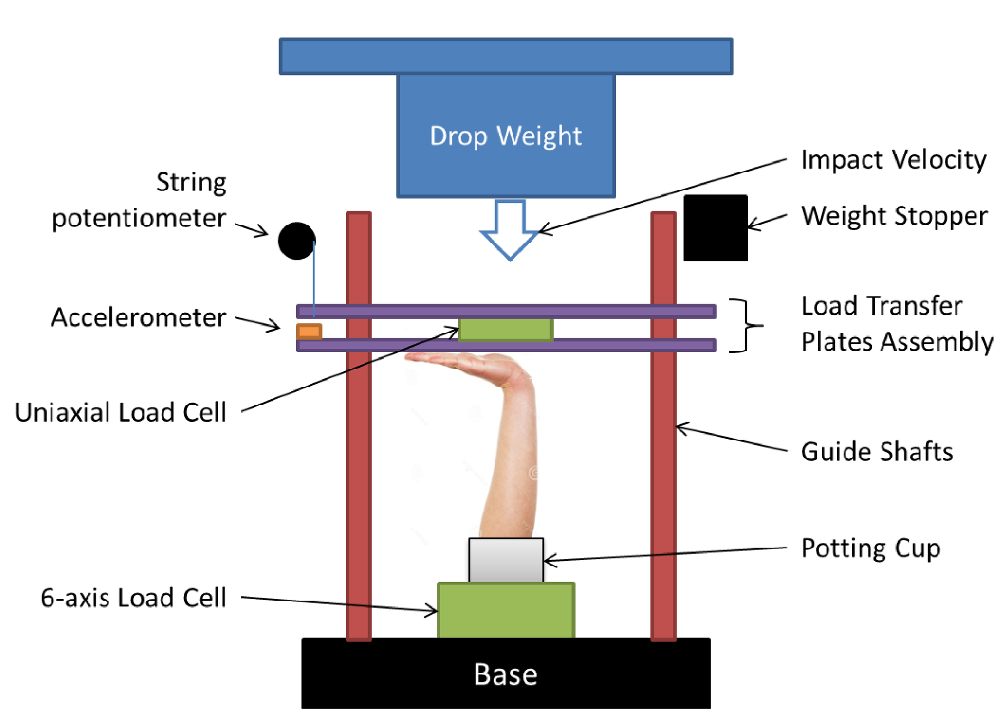

Figure 1: Schematic of drop test apparatus

- 5 matched-pair specimens (3 male, 2 female, Age = 68±9, Weight = 63±10 kg, T-score = -1±1) were tested.
- For **non-destructive (ND)** drop tests, the drop height was 25 mm and for **destructive (D)** drop tests, it was 15 cm.
- These heights with 45 kg drop weight resulted in 0.7 and 1.7 m/s impact velocities and 11 J and 71 J impact energies respectively.

Types of Wrist Guards

Figure 2: Two different types of wrist guards used in this study: a prototype with viscoelastic foam core and thin rigid shell (left) and a commercially available guard with rigid volar plate (right).

Strain Measurement

- Deformation in distal radius and ulna near the wrist was determined using strain gage rosettes.
- Strain measurement provided a local measure near the point of interest and was sensitive to the long bones failure. Bone failure was indicated by a drastic change in the measured strains.

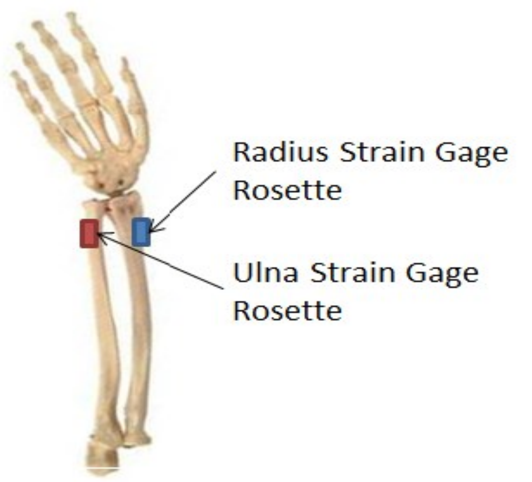

Figure 3: Schematic of location of strain measurement sensors on distal radius and ulna

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 results is important to determine the mechanism of failure for different levels of applied axial force.

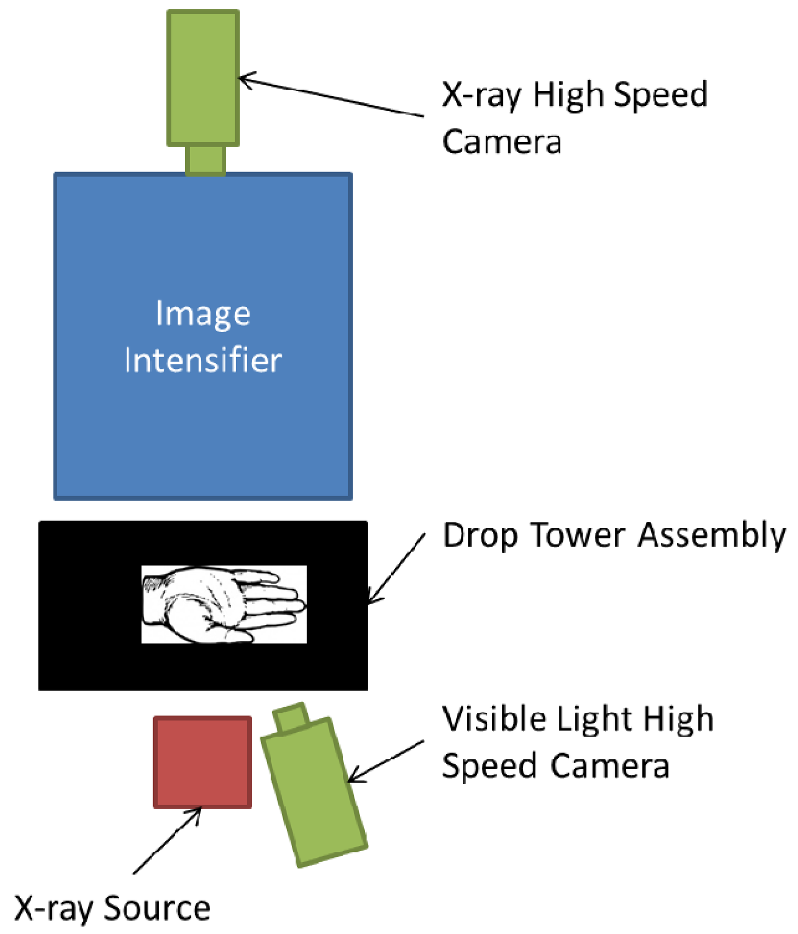

Figure 4: Schematic of high-speed x-ray apparatus

Results

High Speed X-Rays: Axial compression of the carpus and not hyperextension of the wrist was the reason for failure. Younger patient’s bones failed at the volar cortex first, then dorsally, 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.

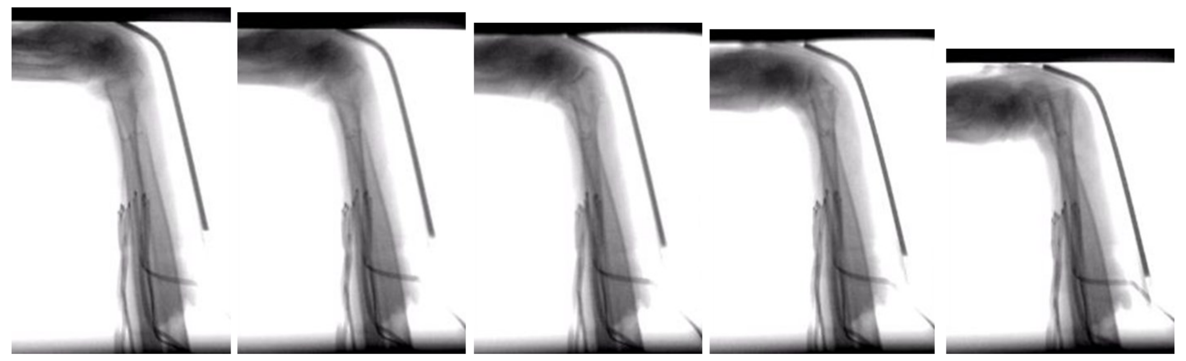

Figure 5: Representative snap shots at 1 ms interval of high speed x-ray video at 1000 fps of destructive drop test with volar wrist guard

Force Time Histories: The volar guard did not react as fast for low energy impacts. Also prototype showed almost constant force for about 50 ms during which the foam is being compressed. Energy absorption capability of the prototype guard was more controllable and also higher than the volar guard.

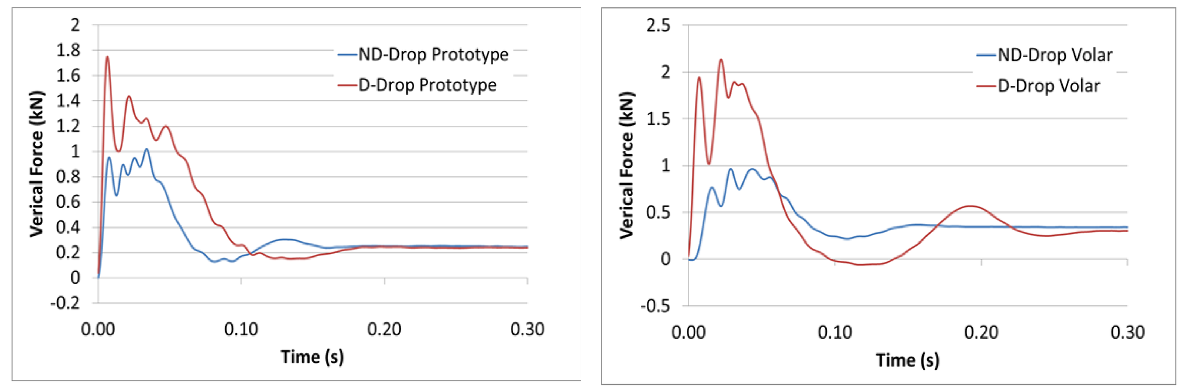

Figure 6: Representative axial force time histories for non-destructive (ND) and destructive (D) drop tests of matched pair cadaveric arms with volar and viscoelastic prototype wrist guards.

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.

Maximum Forces: 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).

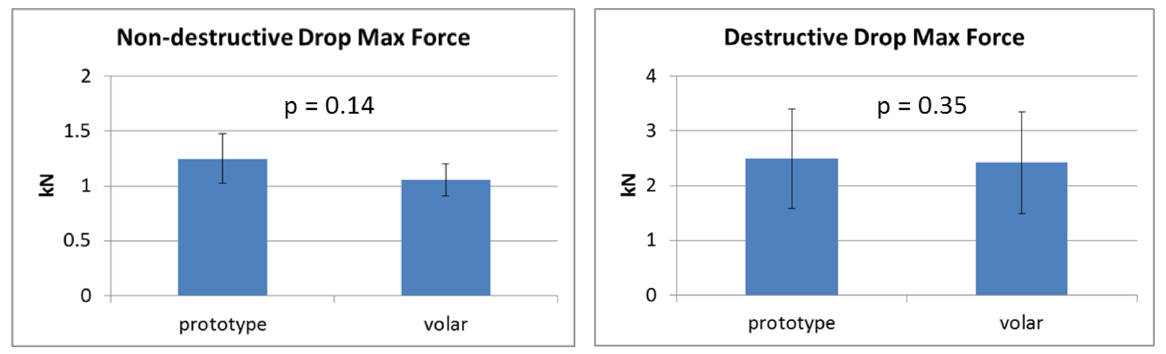

Figure 7: Comparison of maximum force between prototype and volar wrist guards

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 9% increase in D tests (not significant).

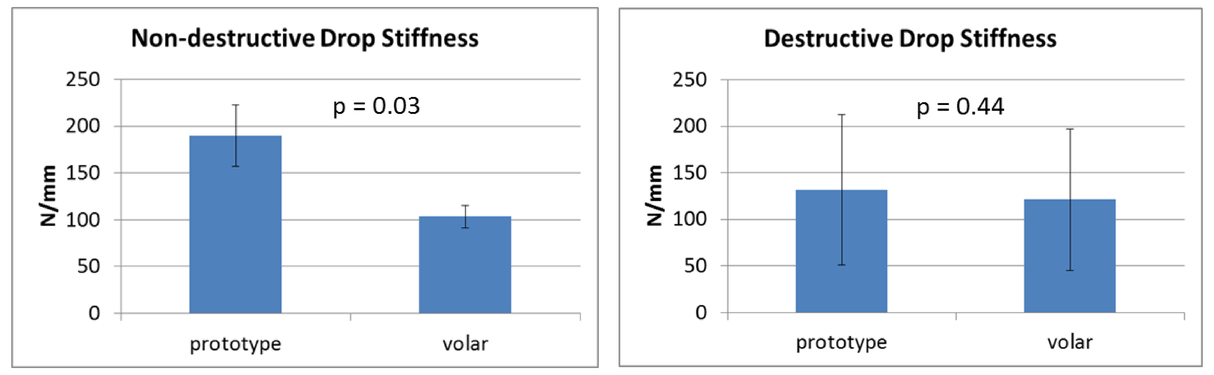

Figure 8: Comparison of maximum stiffness between prototype and volar wrist guards

ND Test Maximum Strain: This measure compares bone responses in the elastic regime. In the case of the volar guard, maximum strains in radius and ulna were both higher than in the prototype, i.e., the long bones were more susceptible to failure.

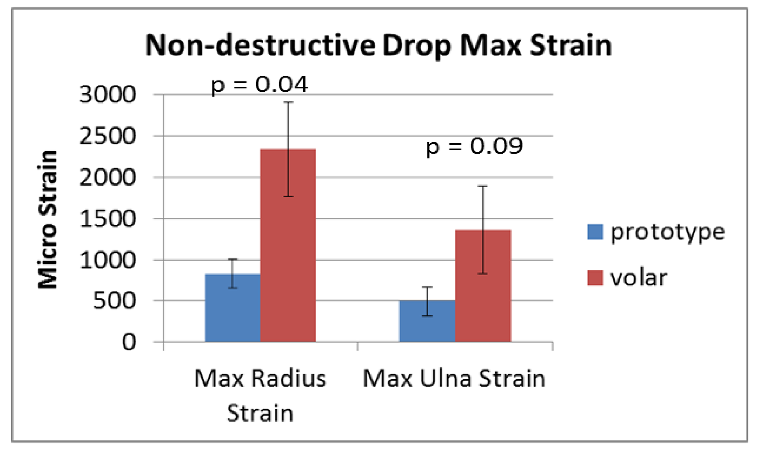

Figure 9: Comparison of maximum principal strain in radius and ulna in non-destructive tests

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

This work was partially supported by the Center for Applied Biomechanics (CAB) at the University of Virginia. The help of Dennis H. Roethlisberger and Sara B. Heltzel in conducting the experiments at CAB is greatly appreciated.

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