

Postmortem Studies of High-Energy Lateral Impacts to the Zygomatic Bone

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INTRODUCTION

- Fractures to the zygomatic bones of the face are devastating injuries that may lead to permanent deformation. Zygomatic bones are also crucial in protecting the brain, so preventing their injury can aid in avoiding associated brain injuries. These injuries are commonly due to motor vehicle collisions (MVCs), assault, sports and falls.
- Impact studies have previously been conducted for the frontal and facial regions of the skull in order to develop biomechanical response corridors of the head.¹ These data were used to assess the biofidelity of Anthropomorphic Test Devices (ATDs), such as the Facial and Ocular Countermeasure for Safety (FOCUS) Headform (Figure 1), developed by Virginia Tech. The FOCUS headform has the ability to measure forces applied to various facial and orbital structures¹ (e.g., lateral zygomatic impacts).
- A classification scheme for fracture patterns that result from trauma to the zygomatic bone has previously been developed by Zingg et al². The application of such studies includes the manufacture of protective gear, surgical treatment decisions, and management of clinical complications associated with different fracture patterns.
- The objectives of this study are: 1) establish lateral injury criteria for the FOCUS Headform, 2) to classify zygomatic fracture severity for comparison with peak force and measures of skeletal morphology.

MATERIALS & METHODS

- Heads of 20 fresh male post-mortem human subjects (PMHS) were used in this study. Mean age was 74.4 ± 11.1 yrs.
- Tissue was prepared for testing by removing the scalp overlying the parietal and temporal regions to the non-impact side. Metal screws were inserted into the bone to provide structure for the casting material and each head was mounted to a semi-circular, polycarbonate support using Bondo. All were aligned using the Frankfort plane prior to mounting to provide consistent orientation.
- A free-falling 3.2 kg aluminum cylindrical impactor was used to systematically impact the body of each zygomatic bone from a height of 35 inches. The resulting impact velocity was 4.2 m/s and energy was 27.5 J. An accelerometer mounted on the impactor recorded peak force.
- Post-test computed tomography (CT) images were taken and gross dissection of the impacted regions was performed. Fracture patterns were documented with sketches and photography and classified based on the Zingg et al² classification scheme. 3D reconstructions of CT scans were used to measure zygomatic height (Figure 2), thickness, arch length and width.

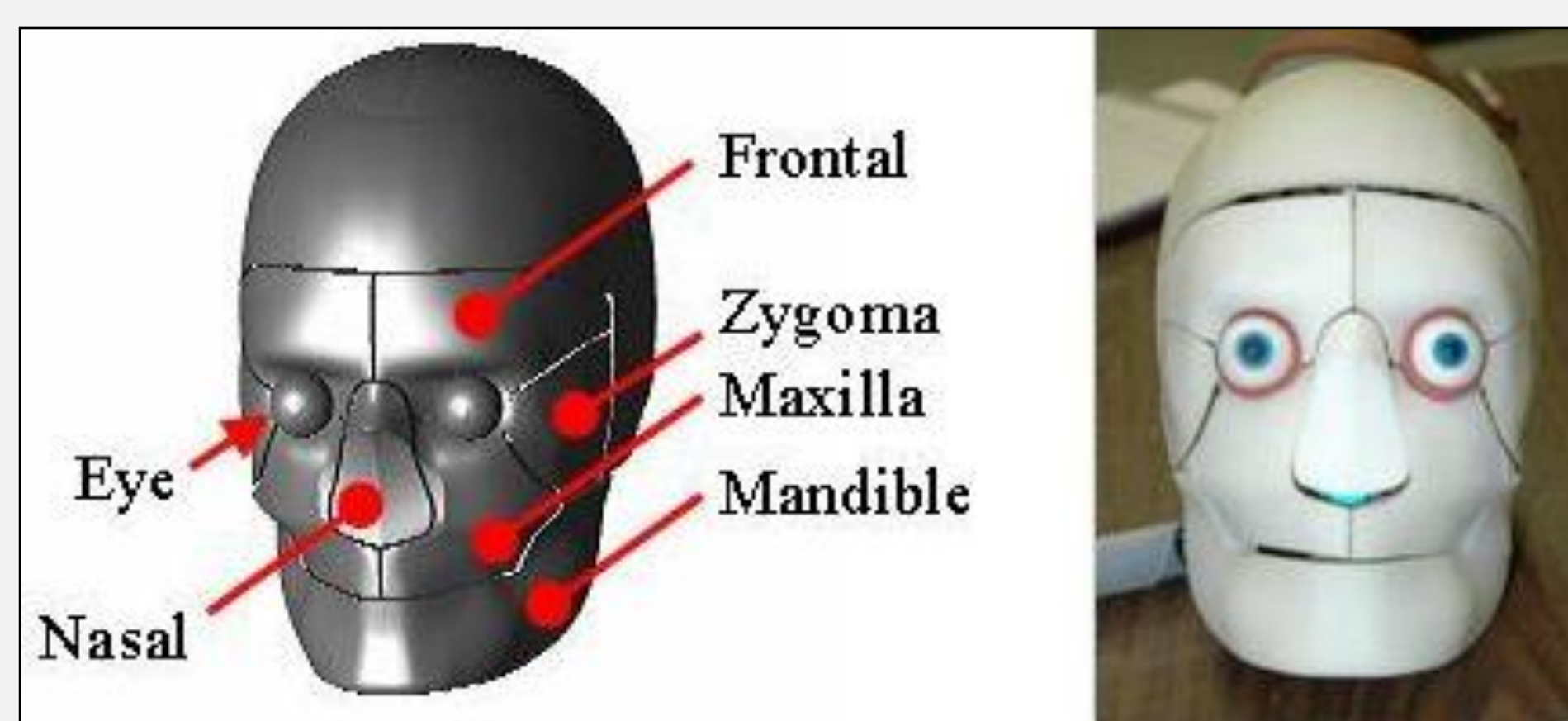


Figure 1. FOCUS headform



Figure 2. 3D CT reconstruction with zygomatic height measurement method

RESULTS & DISCUSSION

- All zygomatic fractures were consistent with types described by Zingg et al². Table 1 provides a summary of all relevant data. Data were not recorded for one impact (Test ID 46) because of a testing error.
- Two Type A fractures were recorded (type 1 and 3). Type A, low energy, fractures are isolated to one location of the zygoma, and are differentiated into types 1 (zygomatic arch), 2 (lateral orbital wall), and 3 (infraorbital rim) based on individual fracture location. Figure 3 provides an example.
- Ten Type B fractures were recorded. Type B, middle energy, fractures include disruption of all four articulations of the zygoma with the frontal, maxillary, temporal and greater wing of the sphenoid. Figure 4 provides an example.
- Seven Type C fractures were recorded. Type C, high energy, fractures are type B with comminution and additional fragmentation of the zygomatic bone. Figure 5 provides an example.
- It was expected that fracture severity ($A < B < C$) would increase with peak force, however this trend is not supported (Figure 6).
- It was expected that zygomatic measurements from CT would be associated with peak forces. This trend is not supported for any measurements. Figure 7 displays this relationship with zygomatic height.

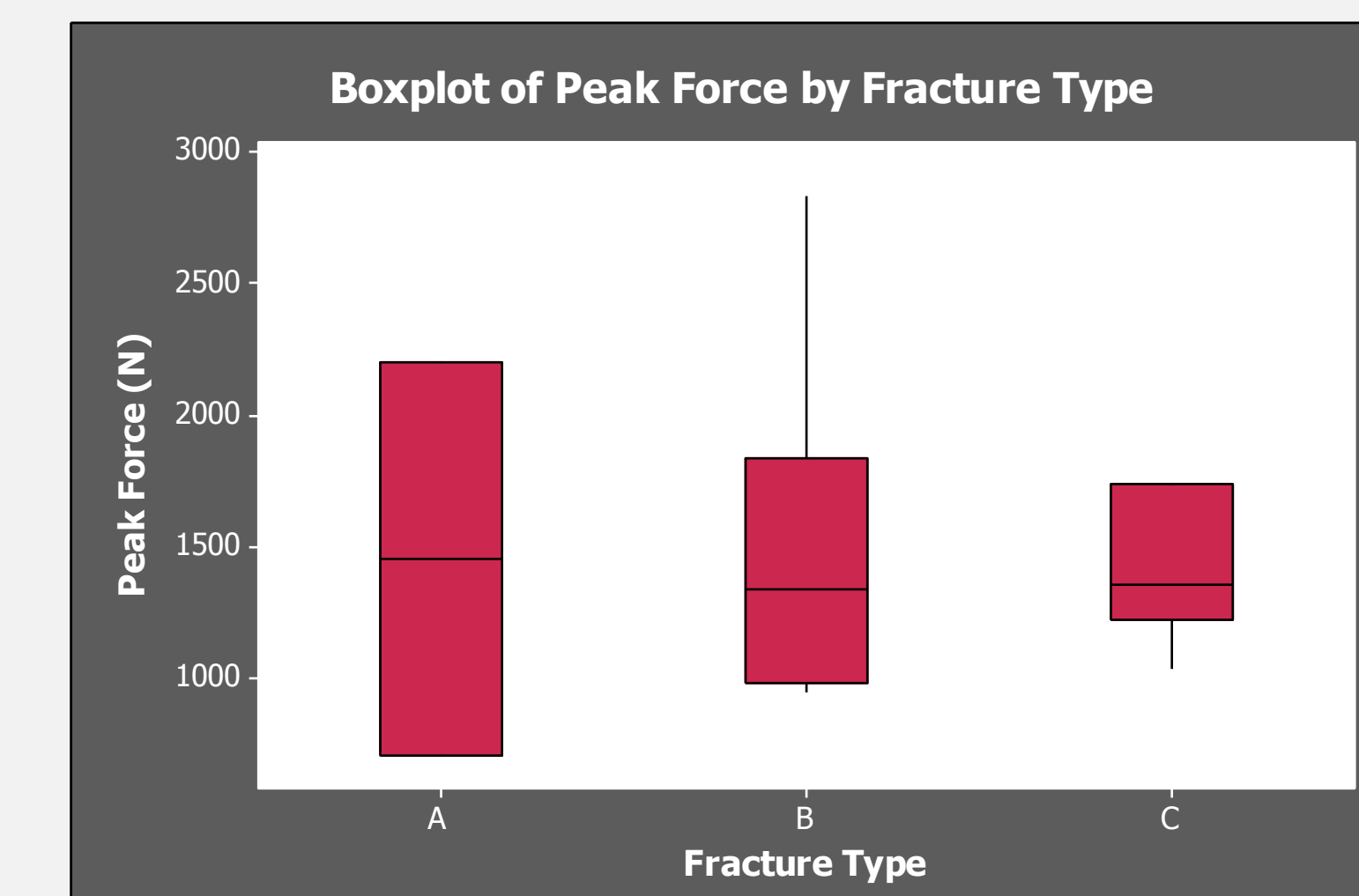


Figure 6. Boxplot illustrating variation in peak force by fracture type

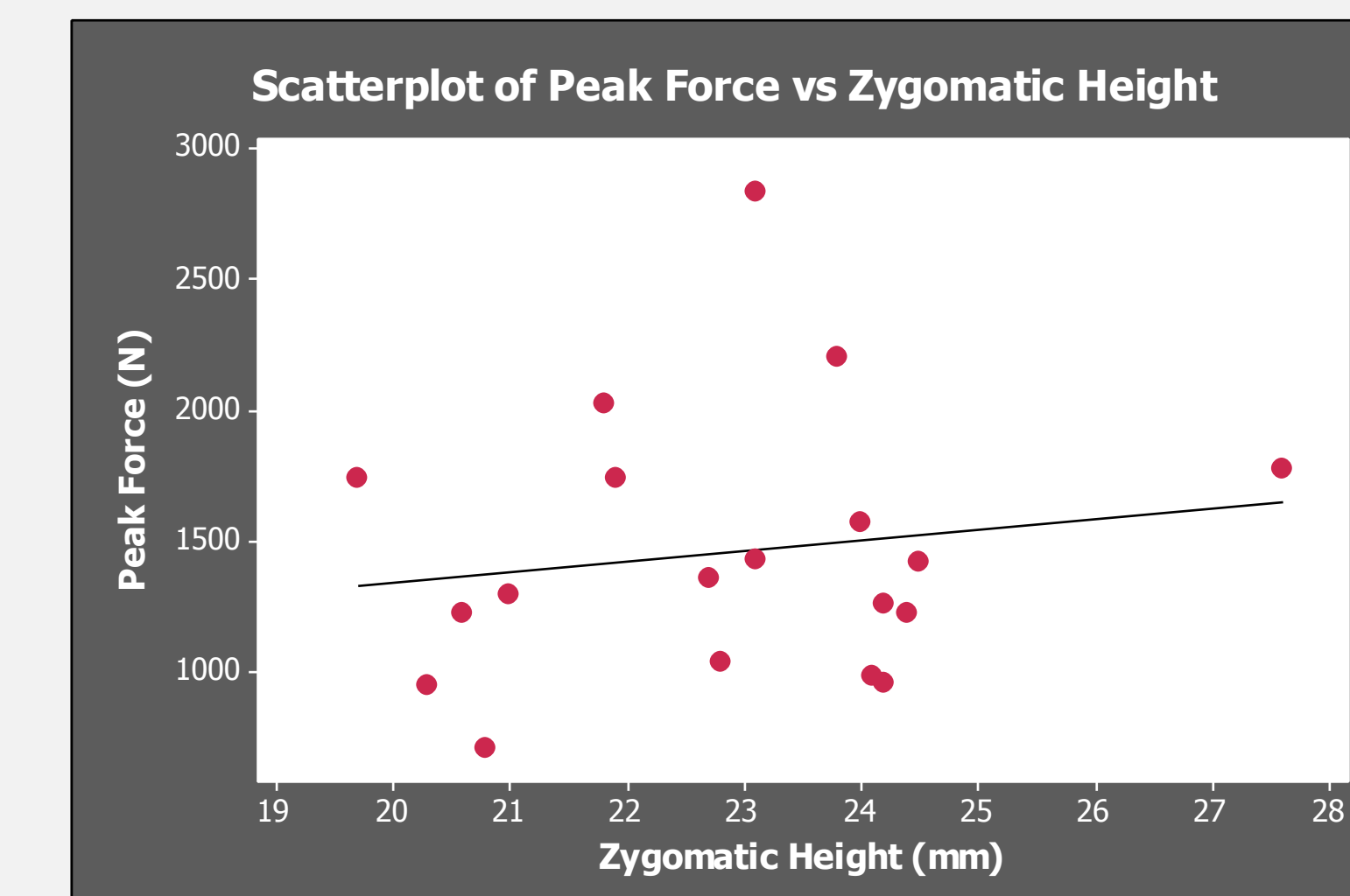


Figure 7. Scatterplot illustrating relationship between zygomatic height and peak force

Table 1. Summary of results

Test ID	Age	Fx Type	Peak Force (N)
38	83	B	1259
39	82	C	1033
40	87	C	1296
41	79	C	1741
42	62	B	1222
43	54	C	1743
44	53	B	2023
45	82	A	2205
46	76	*	734
47	71	A	708
48	79	B	1777
49	63	B	947
50	76	C	1355
51	90	B	1417
52	89	C	1572
53	74	B	954
54	76	B	1425
55	70	B	2836
56	59	B	986
57	83	C	1224

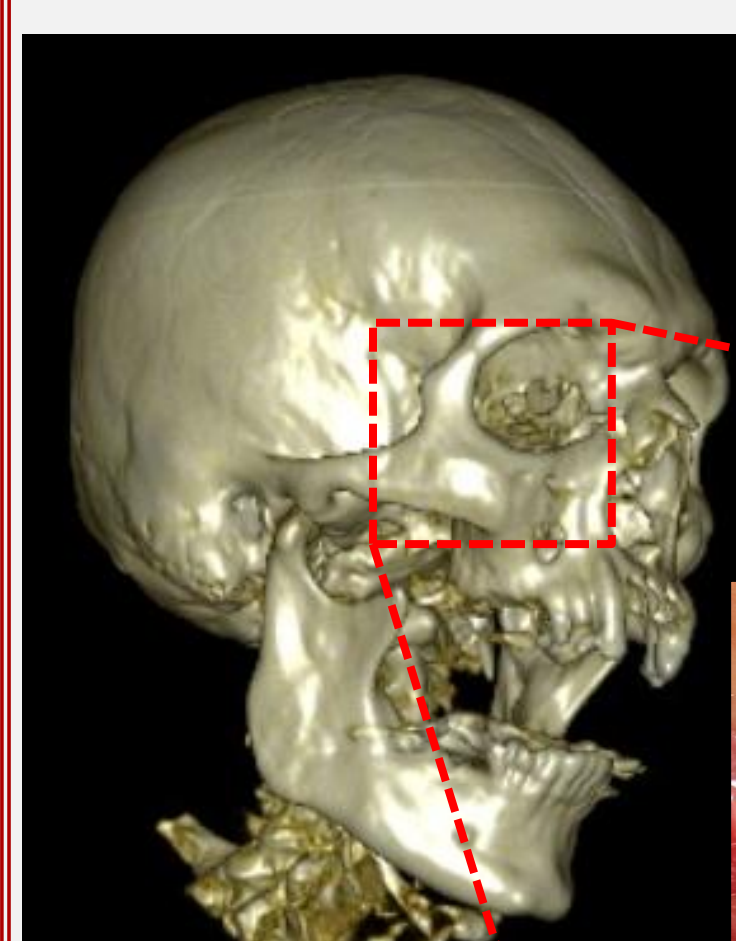


Figure 3. Type A Fracture

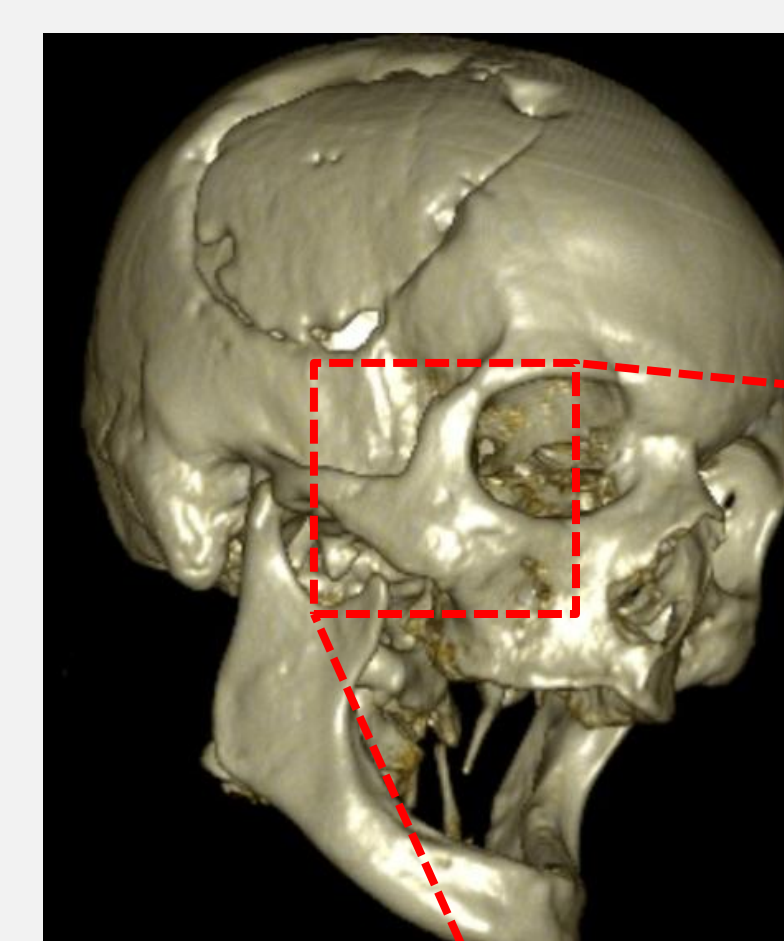


Figure 4. Type B Fracture

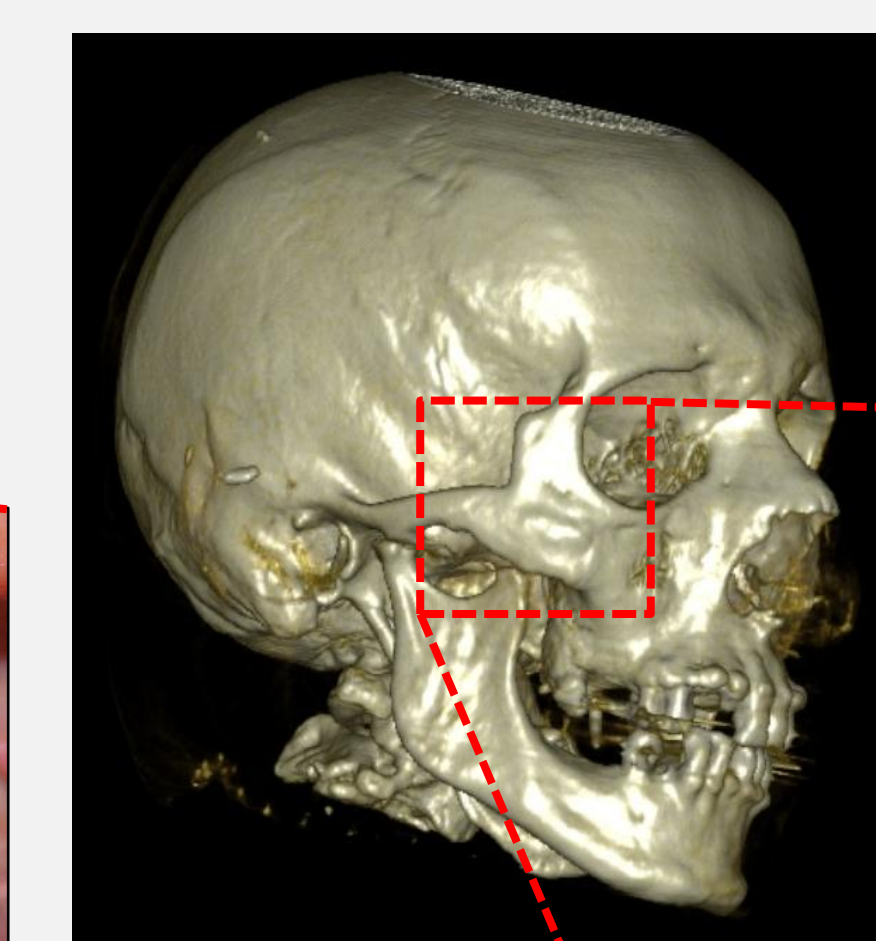


Figure 5. Type C Fracture

CONCLUSIONS

- Limitations in this study include: 1) the inability to ensure test repeatability, because alignment of the impactor was slightly subjective, and 2) the force used to ensure failure was excessive, making it difficult to assess relationships between peak force, bone measurements, and severity of fracture.
- Future work will focus on calculating force at time of failure to compare with zygomatic measurements and fracture severity.

References

1. Cormier J, Bisplinghoff J, Manoogian S, Rowson S, Santiago A, McNally C, Duma S, Bolte J. 2010. Biomechanical Response of the Human Face and Corresponding Biofidelity of the FOCUS Headform. *SAE International* 119-SP-2268. 2. Zingg M, Laedrach K, Chen J, Chowdhury K, Vuillemin T, Sutter F, Ravet J. 1992. Classification and treatment of zygomatic fractures. *Journal of Oral and Maxillofacial Surgery* 50: 778-790.

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