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AAO Foundation Final Report Form
(a/o 2/9/2021)

Type of Award: Orthodontic Faculty Development Fellowship Award (OFDFA)

Name of Principal Investigator: Kyungsup Shin, D.M.D., Ph.D.

Institution: University of Iowa

Title of Project: Fracture Energy Assessment Using CBCT: a pilot study for predicting risk of Post-Traumatic Craniofacial deformities

Period of AAOF Support: 07-01-2019 to 6-30-2022 (with NCEs)

Amount of Funding: $20,000

Summary/Abstract:

Introduction: Trauma to the mandible with fractures has been implicated as one of the main etiologic factors of post-traumatic osteoarthritis (PTOA) on temporomandibular joint (TMJ). Due to its multifactorial etiology, the incidence of PTOA on the TMJ related to trauma to the mandible is difficult to determine. Recently, fracture energy has been utilized as an objective method for assessing fracture severity and predicting PTOA risk in the lower extremities, but not yet in the craniofacial bones. Thus, there is a critical need to develop a methodology to predict patients under high risk for developing PTOA in TMJ after traumatic injury on the mandible.

Objectives: This study aims to validate that Cone-beam CT (CBCT) data can be used to compute an objective fracture energy and characterize that energy over different anatomical regions of the mandible. Furthermore, since medical CT scans have previously been used to assess fracture energy on long bones, there is a specific need to determine that CBCT can be reliably utilized for fractures of the mandible.

Materials and Methods: A full application of the IRB (Institutional Review Board) was approved for this study prior to initiation of the study.

Aim #1: Validate the objective fracture energy scores computed from CBCT data in comparison to Medical CT data. Prior assessments of fracture energy have relied upon a Medical CT scan, with their calibrated Hounsfield Unit (HU) values, to estimate location-specific bone density. Most fractures in the TMJ regions at our institution are scanned instead of utilizing a Cone Beam CT (CBCT) system. CBCT systems acquire scans in a fundamentally different manner and do not obtain the same uniform image reconstructions. This aim will test the working hypothesis that fracture energy scores that have been assessed on long bones from standard medical CT, can also be reliably utilized for fractures in the mandible using CBCT. Intact mandibles of five cadaver heads were purchased from the AGR (Anatomy Gifts Registry, www.anatomygifts.org) and fractures on mandible were created. Then both CBCT and CT scans were obtained respectively.

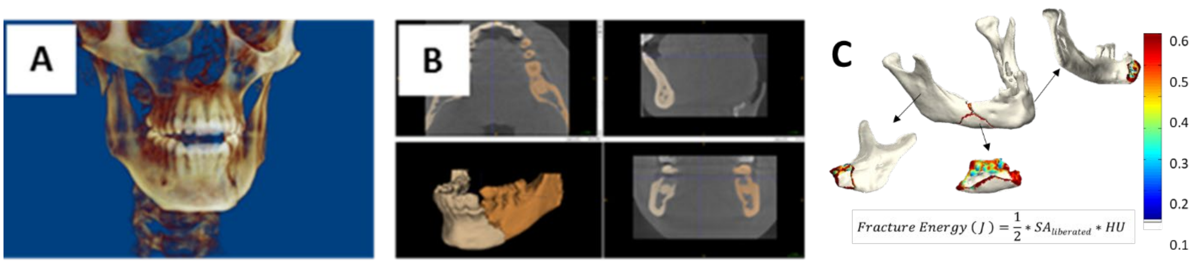

Figure 1. Pre-operative CBCT 3D image (A), Segmentation (B), Computed fracture energy (C).

Aim #2: Determine the association between fracture energy and anatomical regions of the mandible. This aim tested the working hypothesis that the level of fracture energy scores is associated with the anatomical regions of the mandible such as condyle, coronoid, body, symphysis and ramus of the mandible. The CBCT scans from 37 anonymized patients' mandibles were collected. Fracture energies were computed for all the scans. All fractures were grouped by six anatomical regions of the mandible: condyle, coronoid, boy of the mandible, symphysis, angle, and ramus. Fracture energies were computed for all the scans, and the fracture energy values were then compared between cases for which standard and CBCT scans were acquired.

Results:

Aim #1: Mean fracture energy of the cadaver CT data was 5.77 J, with a standard deviation of 1.8 J [range: 3.29 – 7.99 J]. The mean fracture energy of the cadaver CBCT was 4.27 J, with a standard deviation of 1.6 J [range: 2.27 – 6.26 J]. The mean difference in fracture energy between the CT and CBCT was 1.50 J; linear R^2 between the computed fracture energies was 0.994.

Figure 2. Captured 2-D images of cadaver specimen with mandibular fractures created

Table 1. Comparison between fracture energy measured in Medical CT and CBCT

Cadaver	Medical CT (J)	CBCT (J)	Difference
1	7.99	6.26	1.73
2	6.74	5.20	1.54
3	4.97	3.05	1.92
4	5.86	4.55	1.32
5	3.29	2.27	1.02
Average	5.77	4.27	1.50

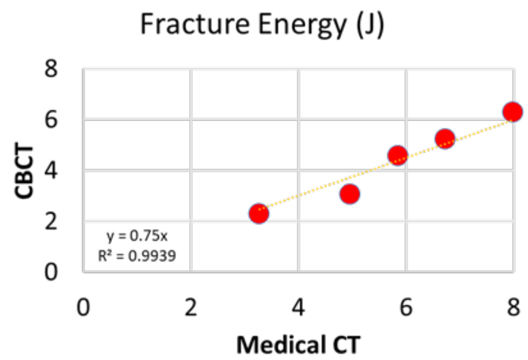

Figure 3. Relationship of fracture energies measured in Medical CT and CBCT

Aim #2: The 37 subjects with 53 fractures were characterized as follows: 17 fractures of the condylar process, 3 fractures of the coronoid process, 12 fractures of the angle, 14 fractures of the body, and 7 fractures of the symphysis. The average fracture energy of all the fractures was 2.1 Joules (J) with the standard deviation of 1.66 J. Maximum fracture energy was 7.7 and the minimum was 0.3 J. A comparison between the 5 regions of the mandible was made by the Wilcoxon rank sum test.

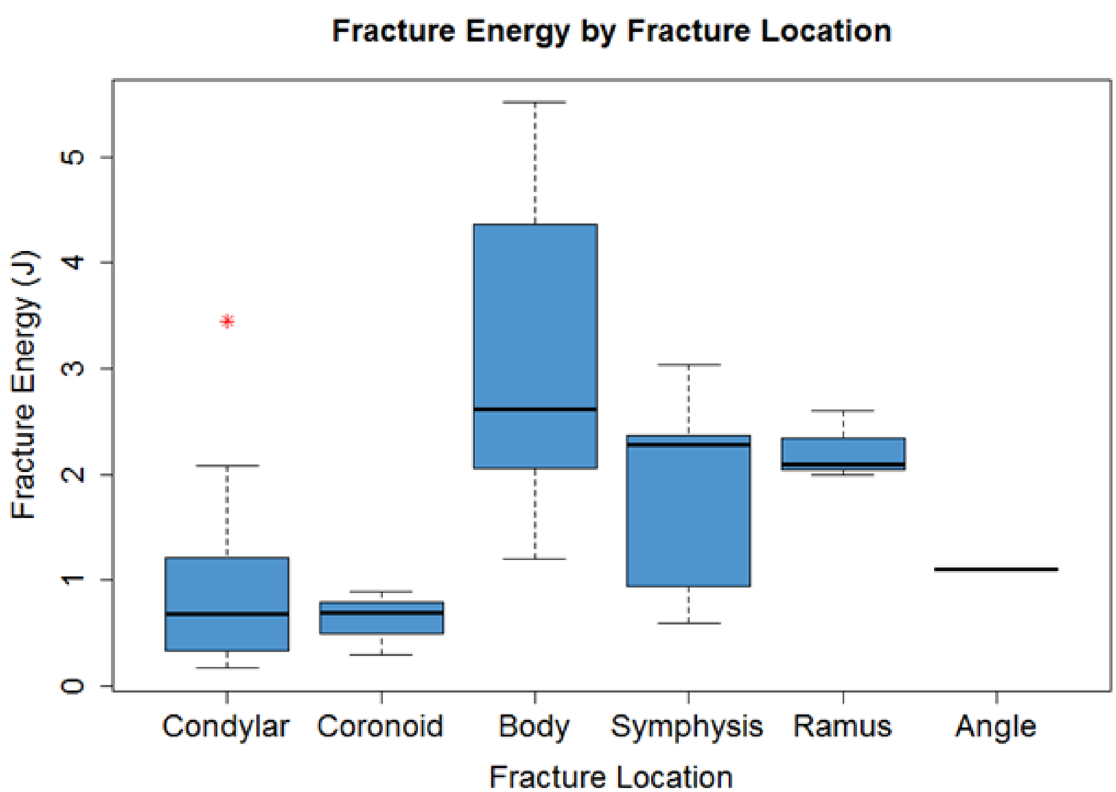

Figure 4. Boxplots of Fracture Energy by Fracture Location. The fracture energy for the body location has the highest variance and the highest center.

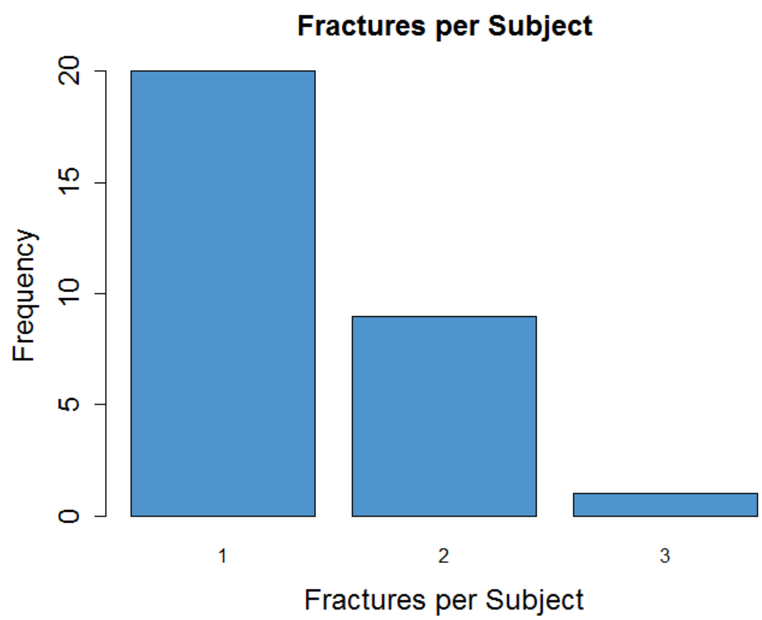

Figure 5. Number of Fractures per Subject. Most subjects only have one fracture and only one has 3 fractures.

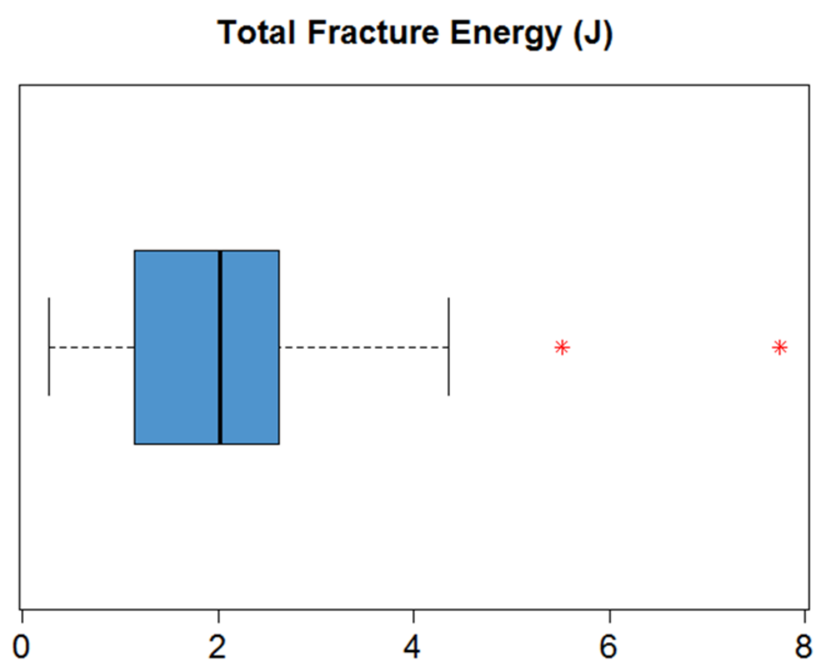

Figure 6. Total Fracture Energy. The total fracture energy appears to be skewed upwards, with most values being around 2 J. There are two outliers (> 5 J).

Table 2. Results of Wilcoxon Sum Rank Tests

Location 1	Location 2	Location 1 N	Location 2 N	P-Value
Condylar	Coronoid	17	0	--
Condylar	Body	17	6	0.0013*
Condylar	Symphysis	18	3	0.1534
Condylar	Ramus	20	3	0.0181
Condylar	Angle	19	0	--
Coronoid	Body	3	9	0.0091
Coronoid	Symphysis	3	5	0.1429
Coronoid	Ramus	3	3	0.1000
Coronoid	Angle	2	0	--
Body	Symphysis	7	3	0.3833
Body	Ramus	9	3	0.4818
Body	Angle	9	1	0.2000
Symphysis	Ramus	5	3	1
Symphysis	Angle	5	1	1
Ramus	Angle	3	1	0.5000

P-values less than 0.003 were considered significant. Thus, there is a statistically significant difference between the condylar and body locations (p-value = 0.0013). There are no statistically significant differences between the mean fracture energies for any other pair of locations.

Table 3. Summary Statistics – Condylar vs. Body

Location	N	Mean	SD	Median	Min	Max
Condylar	17	0.996	0.862	0.670	0.172	3.448
Body	6	3.248	1.827	3.260	1.200	5.510

There is a statistically significant location shift in the distributions of fracture energy for the condylar and body locations (p-value = 0.0013). This means that there is evidence that these two locations have different fracture energy.

Conclusions: Fracture energy can be computed for mandibular fractures using CBCT. There is a possible scaling factor to transform CBCT fracture energy to Medical CT fracture energy. An objective scale can be possibly implemented to objectively scale fracture severity of mandibular fractures. Analysis by location of fracture demonstrated a significant difference between the mean fracture energies for fractures in condyles vs fractures in the bodies of the mandibles. No other locations showed statistically significant differences in mean fracture energies. With the results of this study, further investigation will take place to find a potential association between PTOA and fracture energy level in the temporomandibular joint.

<u>Respond to the following questions</u>:

1. Were the original, specific aims of the proposal realized? Yes

2. Were the results published? The manuscript of these outcomes is currently in preparation to be submitted to the journal, *Orthodontics and Craniofacial Research*.

3. Have the results of this proposal been presented?

a. If so, list titles, author or co-authors of these presentation/s, year and locations

i) Mooneyham R, Jasek I, Dibbern K, Andrew M, Welhaven A, Allareddy V, Anderson D, **Shin K**, "Fracture Energy Assessment Of The Mandible Computed Using CBCT," Iowa Section of the AADR, poster presentation, College of Dentistry, University of Iowa, February 12, 2019

ii) Mooneyham R, Jasek I, Dibbern K, Andrew M, Welhaven A, Allareddy V, Anderson D, **Shin K**, "Fracture Energy Assessment Of The Mandible Computed Using CBCT," IADR/AADR/CADR General Session, Poster, Vancouver, Canada, June 19-22, 2019

iii) Smith H, Dibbern K, Andrew M, Welhaven Anne, Allareddy V, Anderson D, **Shin K**. "Validation of Fracture Energy Assessment from Cone Beam CT," Iowa Section of the AADOCR, on-line presentation, College of Dentistry, University of Iowa, February 15, 2022

b. Was AAOF support acknowledged? Yes, I acknowledged the AAOF's support in all the presentations of these outcomes with the AAOF logo on the presentation materials.

c. If not, are there plans to do so? If not, why not? We have acknowledged AAOF's supports on all the presentations we had. In addition, the support of AAOF will be acknowledged for a future publication.

4. To what extent have you used, or how do you intend to use, AAOF funding to further your career? This AAOF funding also allowed me to generate preliminary data. I present our works at the research meetings. The outcomes from this AAOF-funded study can be utilized to apply for the federal funding programs such as the Department of Defense research support.

<u>Accounting for Project</u>; No leftover fund.