



3D Visualization and Prediction of Spine Fractures

Progress Report #2

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Background



- **Client:**
 - Professor Elise Morgan
- **Focus:**
 - Study on failure of human vertebra
- **Prior studies:**
 - Numerical simulations to provide predictions
- **Their achievement:**
 - Method of measuring the deformations throughout a human vertebra during compression to failure
- **Their Goal:**
 - Perform assessment on simulations by comparing them to measurement.



Background

Factors:

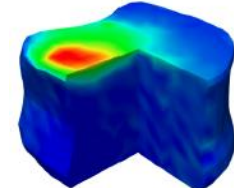
■ Types:

1. Crushable Foam
2. von Mises

■ Methods:

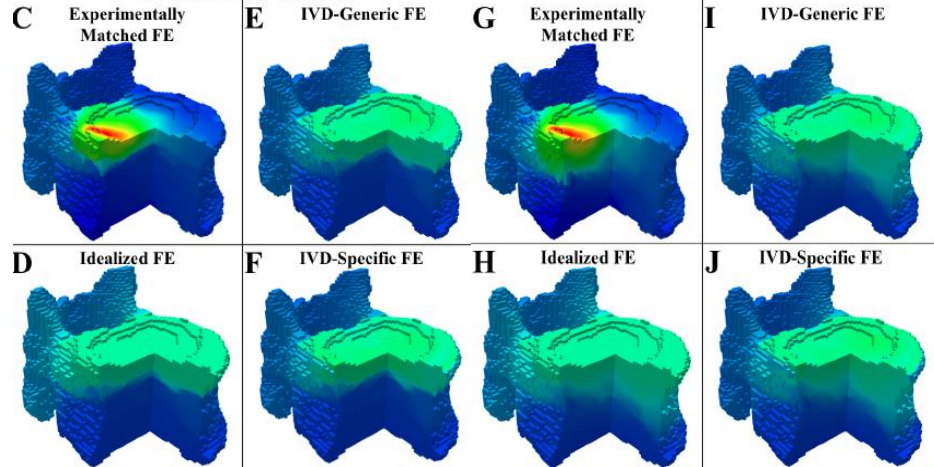
1. Experimentally Matched FE
2. Idealized FE
3. IVD-Generic FE
4. IVD-Specific FE

B Experimental



Crushable Foam

von Mises



+ What are the questions?



- How similar is each of simulation results to experimental results?
- Are some of the eight simulations more similar than others to the experimental measurement?



Datasets



Two different types of compression:

- Union (14 specimens)
 - Only compression
- Flexion (14 specimens)
 - Combination of flexion and compression



Datasets

Blue -- Grid point number (ID)

Pink -- Experimental data

Purple -- Simulation data

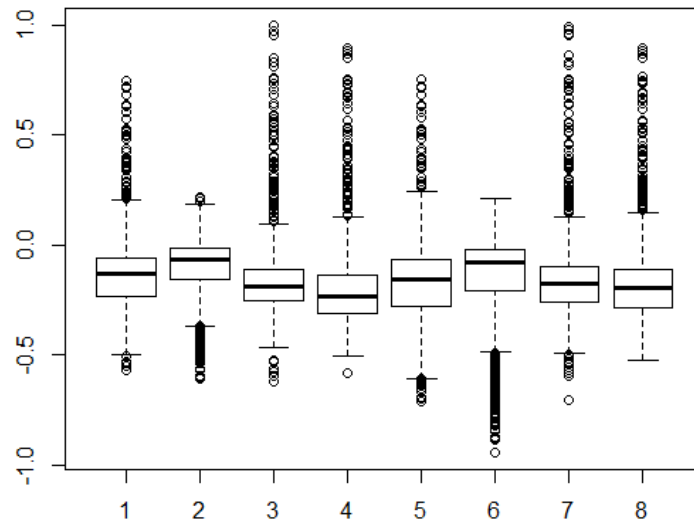
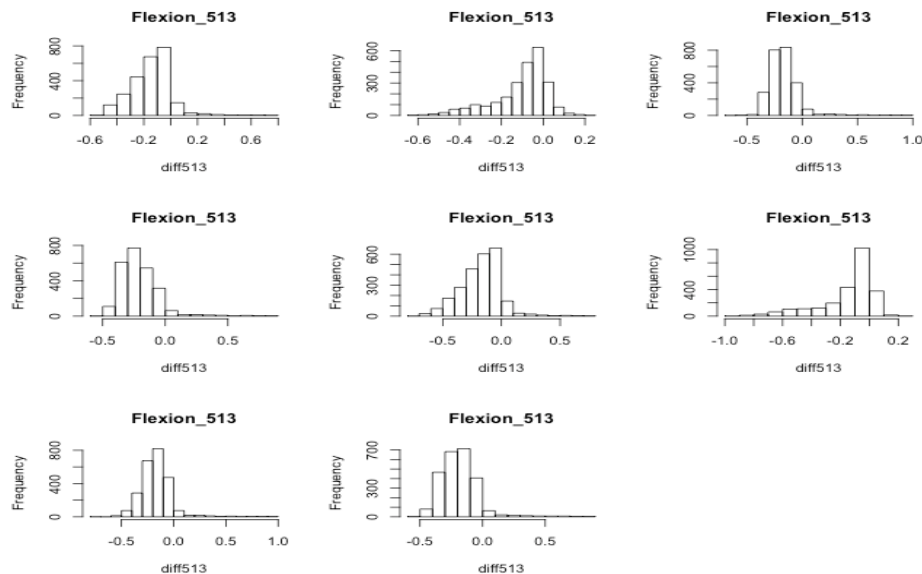
Volume: 2 x 14 x 8 x 3

	A	B	C	D	E	F	G
1	513						
2	CFisoKop_Flex			CFisoKop_Step			G
3	2	0.3973	0.8273	2	0.3973	0.5762	2
4	3	0.4058	0.8322	3	0.4058	0.5504	3
5	6	0.5779	0.7852	6	0.5779	0.6516	6
6	7	0.5399	0.7719	7	0.5399	0.6465	7
7	9	0.2495	0.5297	9	0.2495	0.5853	9
8	10	0.2818	0.4894	10	0.2818	0.5514	10
9	11	0.2776	0.6317	11	0.2776	0.6049	11
10	12	0.1264	0.6982	12	0.1264	0.6134	12
11	13	0.0022	0.4779	13	0.0022	0.5626	13
12	14	0.0627	0.4244	14	0.0627	0.523	14
13	15	0.0799	0.5188	15	0.0799	0.5412	15
14	16	0.1082	0.4091	16	0.1082	0.439	16
15	17	-0.0247	0.4511	17	-0.0247	0.5403	17



Visualization (Flexion)

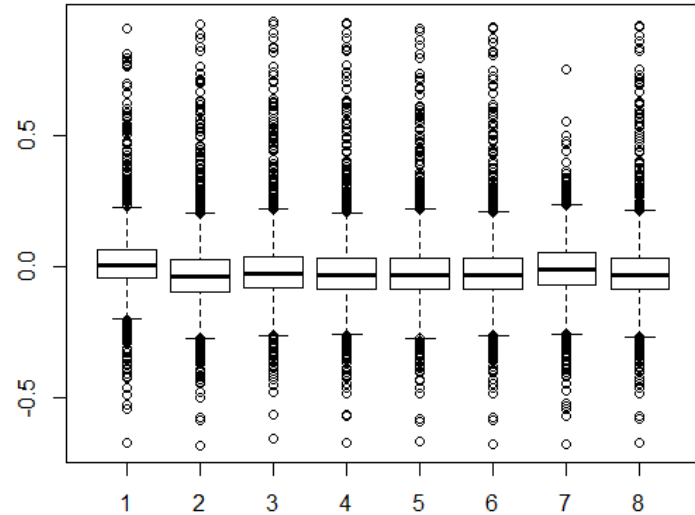
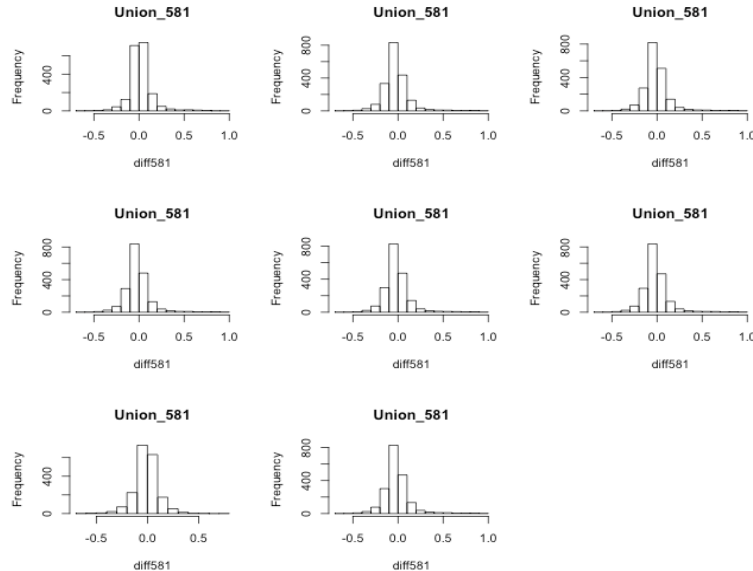
- Histogram & Boxplot: Difference between Experimental and Simulated
- For Flexion group:





Visualization (Union)

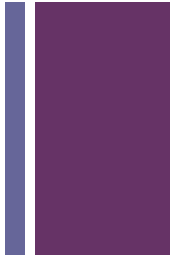
- Histogram & Boxplot: Difference between Experimental and Simulated
- For Union group:





Two-Way ANOVA

- Purpose: Examine the influence of type and method on mean difference and MSE between the experimental and simulation results.
- Group: Flexion, Union
- 14 specimens
- Type: Crushable Foam, von Mises
- Method: Experimentally Matched FE, IVD-Generic FE, Idealized FE, IVD-Specific FE
- Mean difference:
- Mean standard error $\frac{1}{n} * \sum (Experimental - Simulation)$
- Assess the main effect of type $\sum (Experimental - Simulation)^2$ ions.



+ Two-Way ANOVA Results

	Flexion			Union		
	Type	Method	Interaction	Type	Method	Interaction
Mean Difference	Significant	Significant	Non-significant	Non-significant	Non-significant	Non-significant
MSE	Significant	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant

```
##### Flexion: mean of Exp & Sim
fit1 <- aov(flexion.m ~ type.flexion*method.flexion)
summary(fit1)
#Df Sum Sq Mean Sq F value Pr(>F)
#type.flexion      1  0.0639 0.06391  10.684 0.00147 **
# method.flexion    3  0.0573 0.01912   3.196 0.02657 *
# type.flexion:method.flexion 3  0.0067 0.00223   0.373 0.77284
#Residuals          104  0.6221 0.00598
```

```
##### Flexion: MSE of Exp & Sim
fit12 <- aov(flexion.mse ~ type.flexion*method.flexion)
summary(fit12)
#Df Sum Sq Mean Sq F value Pr(>F)
#type.flexion      1  75975  75975  5.108 0.0259 *
# method.flexion    3  18659  6220   0.418 0.7403
# type.flexion:method.flexion 3  11397  3799  0.255 0.8573
#Residuals          104 1546770 14873
```

```
##### Uni: mean of Exp & Sim
fit2 <- aov(uni.m ~ type.uni*method.uni)
summary(fit2)
#Df Sum Sq Mean Sq F value Pr(>F)
#type.uni          1  0.003 0.00306  0.094 0.760
#method.uni        3  0.015 0.00505  0.156 0.926
#type.uni:method.uni 3  0.023 0.00779  0.240 0.868
#Residuals         104  3.378 0.03248
```

```
##### Uni: MSE of Exp & Sim
fit22 <- aov(uni.mse ~ type.uni*method.uni)
summary(fit22)
#Df Sum Sq Mean Sq F value Pr(>F)
#type.uni          1  9964  9964  0.263 0.609
#method.uni        3 141505  47168  1.243 0.298
#type.uni:method.uni 3 159942  53314  1.405 0.245
#Residuals         104 3945671 37939
```



Tukey HSD Test



- ANOVA's post-hoc pairwise test.
- Purpose: Determine which type/methods in the group differ.
- Question: Which method in Flexion group differ significantly?
- Group: Flexion
- Object: 4 methods - Experimentally Matched FE, IVD-Generic FE, Idealized FE, IVD-Specific FE.

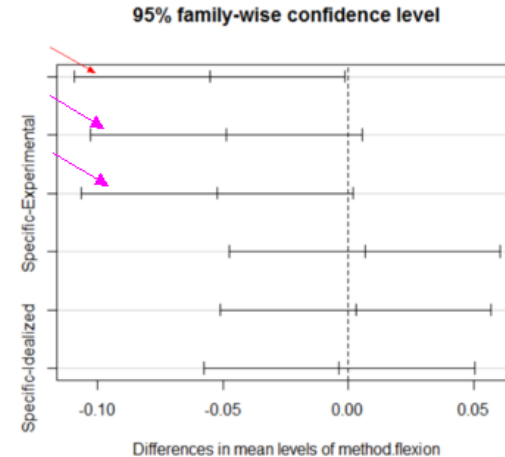
+ Tukey HSD Test Results

■ For methods, significant results are:

1. The mean difference of Experimental has higher value than the mean difference of other three methods.
2. No significant results show up for MSE.

■ Conclusion: Generic/Idealized/Specific simulation methods are closer to experiment results than Experimental simulation method.

\$method.flexion	diff	lwr	upr	p adj
Generic-Experimental	-0.055162356	-0.10913295	-0.001191766	0.0431667
Idealized-Experimental	-0.048569144	-0.10253973	0.005401445	0.0935717
Specific-Experimental	-0.052206779	-0.10617737	0.001763811	0.0617960
Idealized-Generic	0.006593212	-0.04737738	0.060563801	0.9887094
Specific-Generic	0.002955577	-0.05101501	0.056926167	0.9989507
Specific-Idealized	-0.003637634	-0.05760822	0.050332955	0.9980516





Reflection



- Because the grids are highly dependent and correlated to each other, we conduct analyses using mean difference and MSE, instead of the whole dataset.
- We compare the differences between simulations, but not yet give a firm conclusion about which is the best.
- Our current analyses are ignoring the 3-D structures, and spatial comparison may be the next step.

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QUESTIONS?

