Improvement of Human Body Damage Evaluation Method by Computer Simulation
- Verification of Infant Bone Properties Compared with Actual Experiment -

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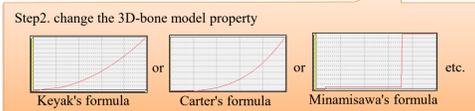## I. Introduction and using Analysis Software

Abstract

- In this study, we conducted a comparison between experiment and analysis, in order to verification of infant bone properties compared with actual experiment. newborn porcine bones as infant bone was used for the experiment. Furthermore, we changed the physical properties of the bone in the analysis and made a developmental comparison.

- As the result, in fracture risk evaluation using FEA, sufficient simulation accuracy could be confirmed even with infant bones. And, in order to further improve the accuracy, it is necessary to review the conventional properties of analysis.

Introduction

- To estimate the intention of murder in case of injuries such as child abuse and to prove negligence, reproduce infant bone in simulation is effective. Also, it is necessary to verify infant bone properties compared with actual experiment and improve the accuracy.

Child abuse

Compression part / Sample material / Actual experiment

Step1. compare

Bone model / FE analysis
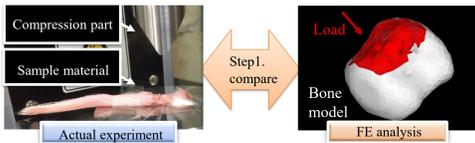
Step1. Accuracy verification (Keyak's formula)

Step2. For high accuracy (Keyak's, Carter's, Minamisawa's, Keller's formula)

Step2. change the 3D-bone model property

Keyak's formula   or   Carter's formula   or   Minamisawa's formula   etc.

Finite Element Analysis for Fracture

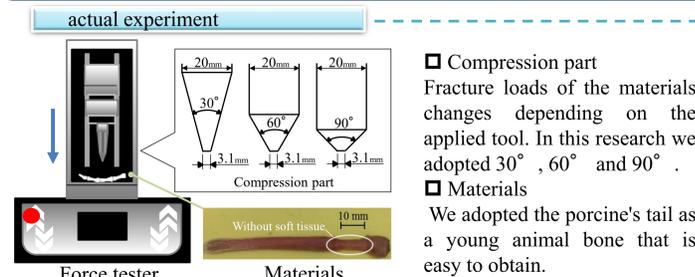Software: MECHANICAL FINDER ver. 10.0 Extended Edition
- It is an integrated system of (1)-(3).
  (1)Reading DICOM data obtained by CT imaging to model creation
  (2)analysis execution (3)result display function
- 3D-model based on DICOM data, it is possible to reflect the bone shape and bone density of each analysis object.

3D model creation flow using MECHANICAL FINDER

Micro-CT HA Phantom / Analysis object / CT-image / 3D-model

Dimensional X-ray CT

Automatically calculation dynamics parameter from CT data.
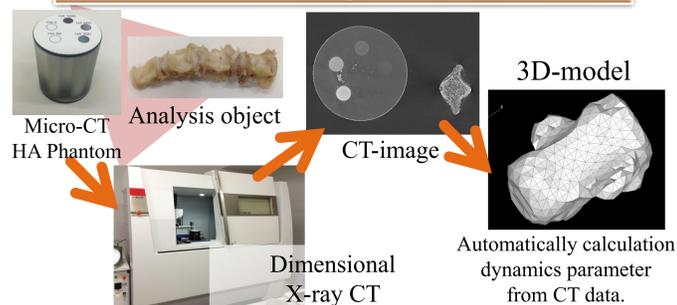
II. Basic comparison between experiment and analysis

Materials & Conditions

actual experiment

20mm 30° 3.1mm   20mm 60° 3.1mm   20mm 90° 3.1mm
Compression part

Force tester   Materials

Without soft tissue   10 mm

□ Compression part
Fracture loads of the materials changes depending on the applied tool. In this research we adopted 30°, 60° and 90°.
□ Materials
We adopted the porcine's tail as a young animal bone that is easy to obtain.

FE analysis

3D-models property

Mesh size [mm]	1
Number of solids	41951, 22814, 13631, 34248, 20731, 29341
ROI volume ratio [%]	100.0
Young's module [MPa]	$33900\rho^{2.20} (\rho \leq 0.27 \text{g/cm}^3)$ $5307\rho^{2.20}+469$ $(0.27 < \rho < 0.6 \text{g/cm}^3)$ $10200\rho^{2.01} (0.6\text{g/cm}^3 \leq \rho)$
Poisson ratio	0.4
Critical stress [N]	$\sigma = 0.8\varepsilon$
Yield criterion	Drucker - Prager
Crushing strain[μ]	10000

□ Fracture definition
A point at which the broken number of solids rapidly increases is defined as a fracture load.

Load / Bone model
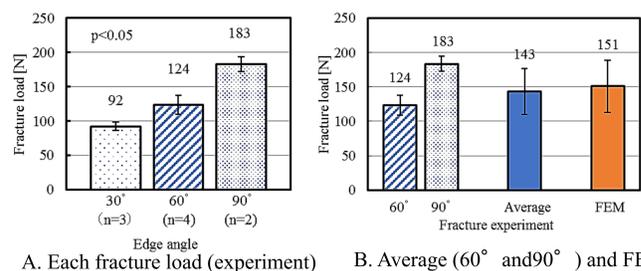
3D-model   Fracture definition
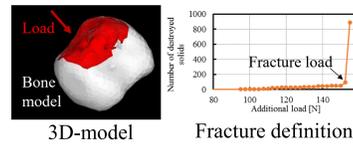
Fracture load

Results & Discussion

✓ Results
Figure A showed experiment results for each tool. Angle30° : 92 N (n = 3), angle60° : 124 N (n=4), angle90° : 183 N (n = 2). In the 4 trials, the results of observing the fracture load clearly were summarized. The result by FE is 151 N. In addition, the average of the result of angle60° and the result of angle90° is 143 N.

✓ Discussion
Except for angle30° when sharp fractures occurred, the results of experiments and FEs are almost match (figure B). However, Even if we include angle30° different fracture forms, we have to make it more accurate. In order to be highly accurate in various cases, it is necessary to change material properties of bone. Although Keyak's formula was used in the analysis, it is attempted to verify Carter's formula, Minamisawa's formula and Keller's formula which have been devised so far.

A. Each fracture load (experiment)
30° (n=3): 92, 60° (n=4): 124, 90° (n=2): 183, p<0.05
Edge angle

B. Average (60° and 90°) and FE
60°: 124, 90°: 183, Average: 143, FEM: 151
Fracture experiment

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III. Developmental comparison between experiment and analysis

- The following graphs show fracture loads by analysis. Two samples that can accurately compare experimental values and FE values in the same model were used. One sample is shown below. In this study, we observed not only numerical values but also the appearance of 3D - model.
- Also, fracture loads are 86 N and 191 N, which is 139 N on average in actual experiment. This value is compared with the below.
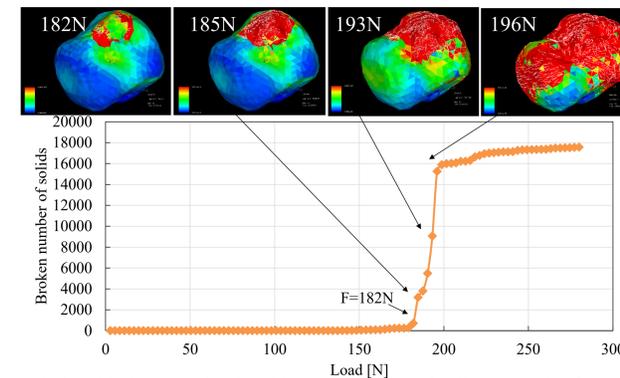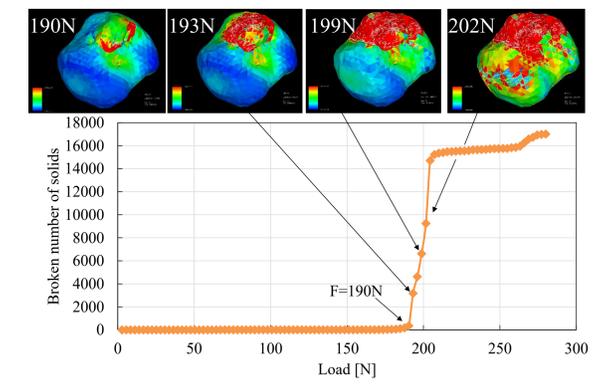
182N 185N 193N 196N
F=182N
Relationship between load and broken number of solids (Keyak's formula)
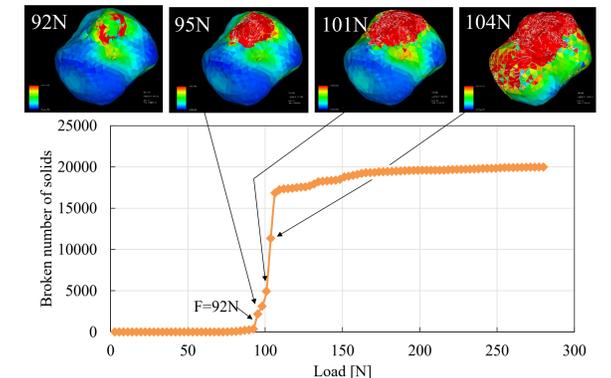
92N 95N 101N 104N
F=92N
Relationship between load and broken number of solids (Carter's formula)
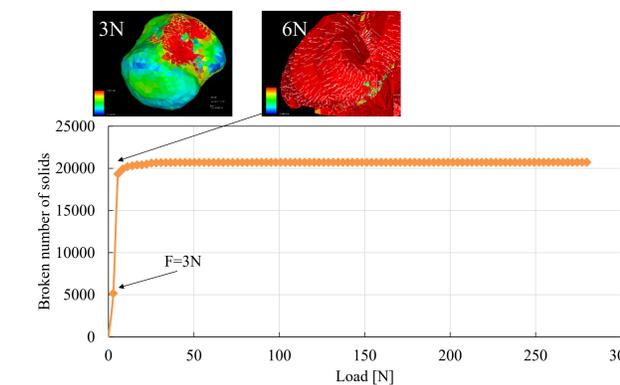
3N 6N
F=3N
Relationship between load and broken number of solids (Minamisawa's formula)

190N 193N 199N 202N
F=190N
Relationship between load and broken number of solids (Keller's formula)

✓ Results
The above figure show the fracture load (F : fracture load). The average fracture load in Keyak's formula is 190 N (182N, 198N), in Carter's formula is 97 N (92N, 102N), in Minamisawa's formula is 3N (3N, 2N), in Keller's formula is 190N. To be accurate, a fracture load is a starting fracture load. In this analysis, accurate the starting fracture load was investigated by observing the appearance of stress distribution with broken number of solids. Also, the number of data is one in Keller's formula.

✓ Discussion
Taking into account the behavior of various bone fractures, there were no formula that could accurately simulate young bone. However, the formula of Carter was the most similar to the young bone in this study. The fracture load is 97N in Carter's formula and it is 139N in the experiment, so there is a difference of about 40N. Since there is a difference between the experimental value and the analytical value, we have to attempt bring it closer. Therefore, in order to accurately simulate the young bone, it is necessary to (1) use another formula, (2) develop a formula that fits the experiment value, (3) increase the number of analyzes, and so on.

Conclusions

- The formula of Carter was the most similar to the young bone in this study. The fracture load is 97N in Carter's formula and it is 139N in the experiment.
- It is necessary to develop a formula that fits the experiment value.

Acknowledgments

References

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