Simulation of Fracture Healing due to Intramedulary Nailing

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Introduction

unreamed Intramedullary Nailing

high interfragmentary movements (IFM)

critical for healing outcome*

*Claes et al., J Orth Res 1997
*Augat et al., J Orth Res 2003
*Larsen et al., J Orth Res 2004

Aim: Simulation of fracture healing process to analyze the influence of fracture type and interface distance on the healing outcome
simulation of fracture healing process

- flexibility behaviour of BIC (FE contact model)
- internal loads (muskuloskeletal model)
- fract. geometry

Initial condition

FEA
Calculation of local mechanical stimuli

Fuzzy-Logic-Controller
Revascularisation and tissue conversion

FE-Preprozessor
Change of element stiffnesses

\( c_{\text{bone}}(t), \text{IFM}(t) \)
Prediction of healing outcome

next time step
flexibility behaviour of BIC
(FE contact model)

reconstruction of an in vitro tested bone implant complex (BIC)
determination of flexibility behaviour

due to idealized fractures

boundary conditions
applied on rigid
beam elements
direction dependent contact

\[ U_i \]

\[ \varphi = 10^\circ \cdot i \]

\[ F_{\text{shear}} = \]

specific map of shear flexibility behaviour
modification of musculoskeletal model „gait 3D“ from AnyBody repository 6
Internal load case with AnyBody

modification of musculoskeletal model „gait 3D“ from AnyBody repository 6
transverse fract.    oblique fract.                  bending wedge fract.
simulation of fracture healing process

flexibility behaviour of BIC
(Fe contact model)

internal loads
(muskuloskeletal model)

fract. geometry

Initial condition

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Calculation of local mechanical stimuli

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Revascularisation and tissue conversion

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Change of element stiffnesses

$c_{bone}(t)$, $IFM(t)$
Prediction of healing outcome

next time step
results of healing simulation

time course of bone concentration in the callus region
Influence of nail diameter (interface distance)

time course of IFM, transverse fracture

Influence of nail diameter (interface distance)

time course of IFM, transverse fracture

IFM_shear ant/post

iterative step

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bone concentration (red = 100%)

d_nail = 11 mm 10 mm 9 mm
Influence of nail diameter (interface distance)

time course of IFM, transverse fracture

Bone concentration (red = 100%)
Influence of nail diameter (interface distance)

time course of IFM, transverse fracture

- d_nail = 11 mm
- d_nail = 10 mm
- d_nail = 9 mm

Bone concentration (red = 100%)
Influence of fracture type

![Graph showing the influence of fracture type with different nail diameters.](image)
limitations

- Influence of cancellous bone and soft tissue on the BIC flexibility behaviour was neglected
- Internal loads for stimulus were taken out of normal gait of a healthy human
- Only idealized fracture geometries were investigated
- Beside valcularity, no biological factors were simulated
discussion

• Influence of the mechanical behaviour of the BIC with regard to healing time can be analyzed

• Thin intramedullary unreamed nails (large interface distance)

and

• transverse osteotomies are critical for fracture healing process any might prolong the healing time

• method will be used for optimizing current osteosynthesis implants in terms of minimizing the healing time
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