NUMERICAL SIMULATION OF STAPLES FOR EPIPHYSIODESIS

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Introduction

1. Epiphyseal stapling is a method used for bone growth control and correction.
2. Used mainly for correcting angular deformities.

   (Genu varum and genu valgum)
3. Growth of children's bones is provided mainly by physis – which

   is a cartilage structure near joints.
4. The physis' growth is restrained using bone staples.

Fig. 1: Long radiogram of preoperative genu valgum and consecutive correction with staple

Introduction

5. Unlike the permanent epiphysiodesis, the hemiepiphysiodesis does not damage or destroy the physis.
6. After the optimal correction is achieved, the growth can be restored.
7. Altough new technique using plates and screws is slowly becoming preferable option, the stapling method is still an effective mean to treat growth deformities.

Staple implantation

1. Operational procedure includes short longitudal incision through tissues over physis.
2. Under radiographic control the staples are implatned using special instrument.

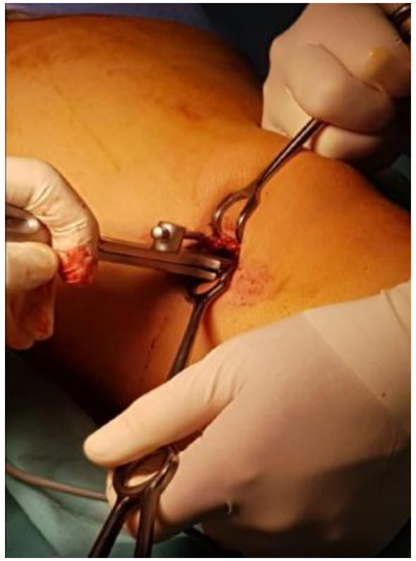

Fig. 2: Implantation of staple

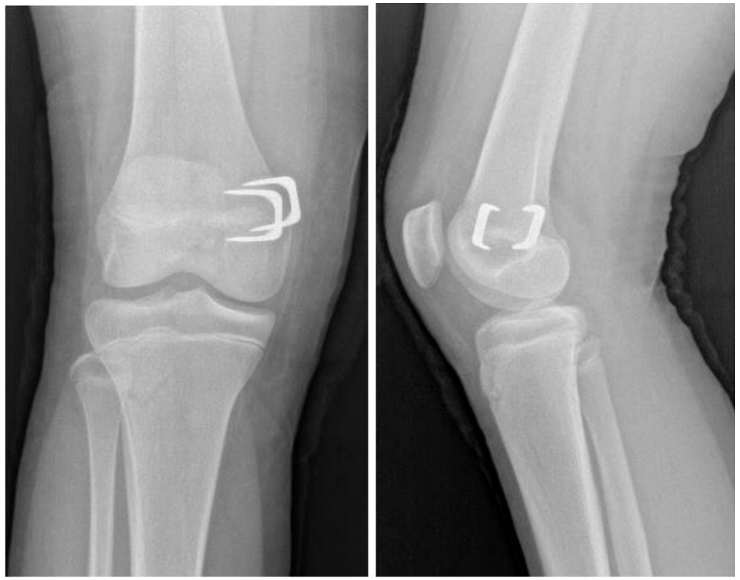

Fig. 3: Position of staples bridging the physis

Possible complications

1. The staples must bridge the physis not damaging it.
2. The staples should not restrict the physis for period longer than 2 years – to prevent permanent growth cessation.
3. As other complication we can count imprecise implantation, mechanical failure of staple (bending, rarely break) or staple migration.

Computational Model of Staples in Tibia

1. To determine the behavior of bone staples used during treatment of Epiphysiodesis, a computer model of proximal part of tibia was created.
2. This model was then split in the place of epiphyseal disk for further simulation of bone growth.
3. For this determination a set of two bone staples was chosen.
4. For more realistic approach (simulating staple migration), the contacts between bone staples and bone were set as frictional, with friction coefficient 0.2 acquired via educated guess.

Computational model of Staples in Tibia

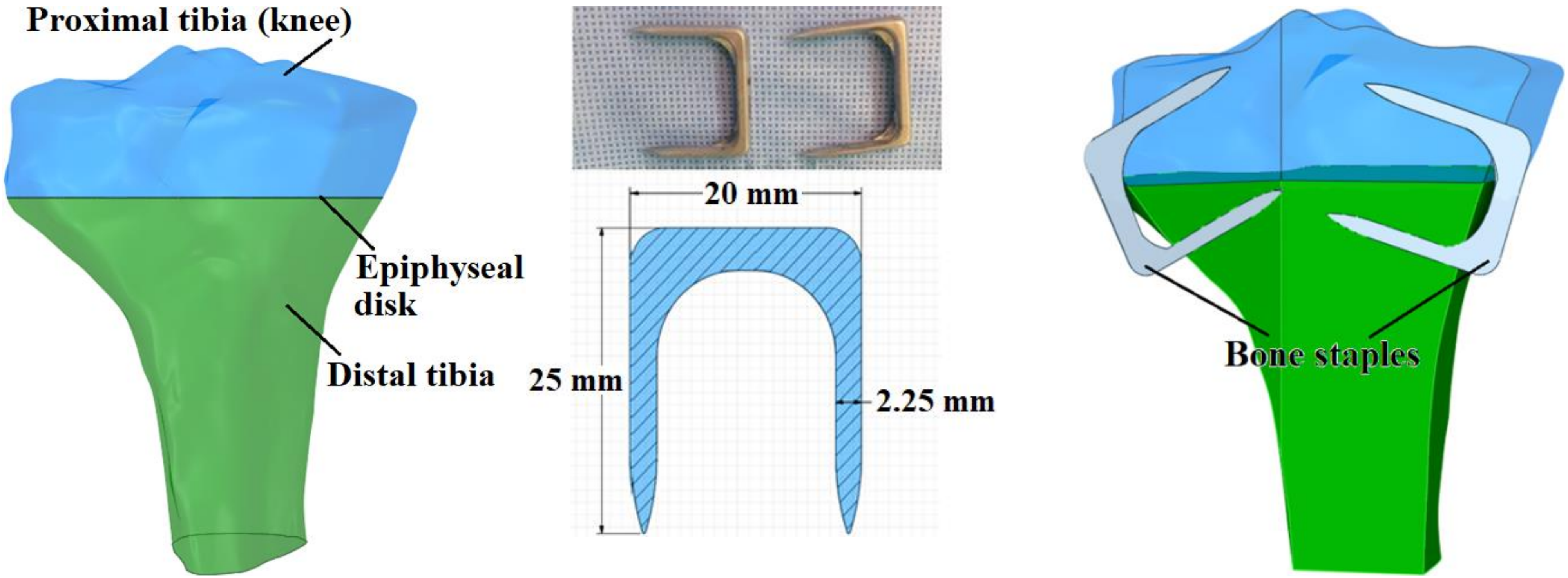

Figure 4: (a) Model of split tibia (b) Bone staples (c) Final model of split tibia with staples

Material models of Staples and Tibia

1. Material models of both bone and steel are assumed homogenous and isotropic.
2. The emphasis is put on bone staples. Hence, there is no need to divide tibia into cortical and spongiosal part (i.e. simplification).

Material	Young’s modulus [GPa]	Poisson’s ration [1]	Yield stress [MPa]
Cortical Bone	0.161	0.3	–
Stainless steel 1.4441	183	0.33	690

Stress–Deformation Analysis

1. Anatomical CAD model of tibia was acquired by 3D CT scan.
2. This model with staples was then imported into Ansys Workbench 2019 R3
3. Bone model was meshed with quadratic tetra elements (avg. size 5 mm)
4. Staples were meshed with average element size of 1 mm.
5. In places with stress concentration the size of elements was locally reduced to 0.5 mm.

Stress–Deformation Analysis

1. The bone growth is simulated by internal tensile stress.
2. Used boundary conditions two forces “B” and “C” of value 980.7 N $\approx$ 100 kg.
3. Displacement “A” acts as a weak simulation of a knee (for stabilization of numerical solution).
4. Fixed support “D” acts as a definition of position of bone in space.

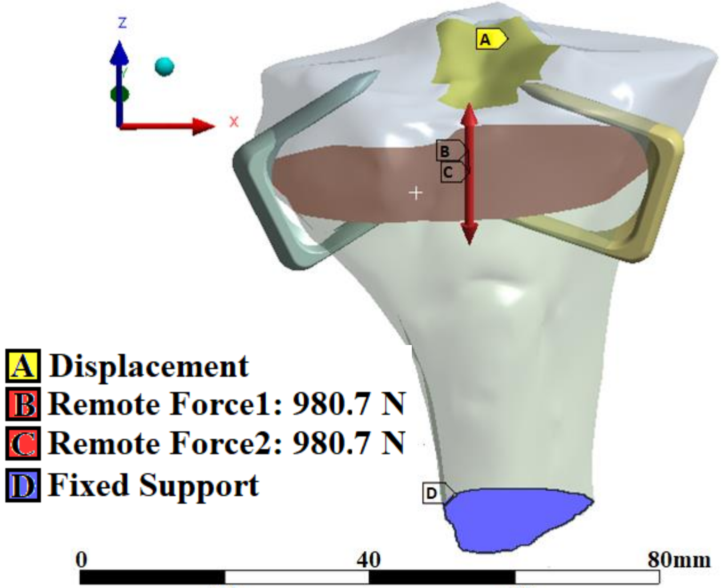

Figure 5: Boundary conditions

Results

1. Maximum stress occurs in sections of staples with radius and narrowed cross section.
2. Maximum displacement occurs on parts of bone staples which are located inside proximal part of tibia, due to growth of bone, which pushes this part upwards.
3. Bone was also found sufficiently safe, because the bone tissue is practically intact around the bone staples.

Results

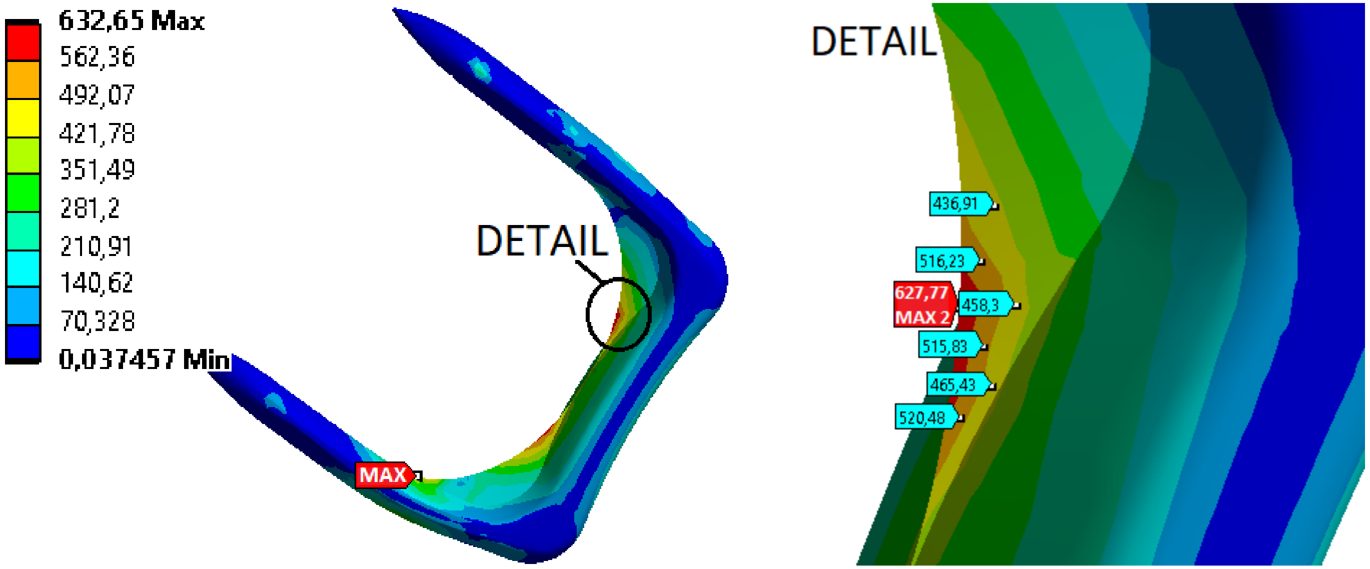

Figure 6: Equivalent von Mises stress distribution and maximum stress in staple [MPa] (remote tensile forces 980.7 N)

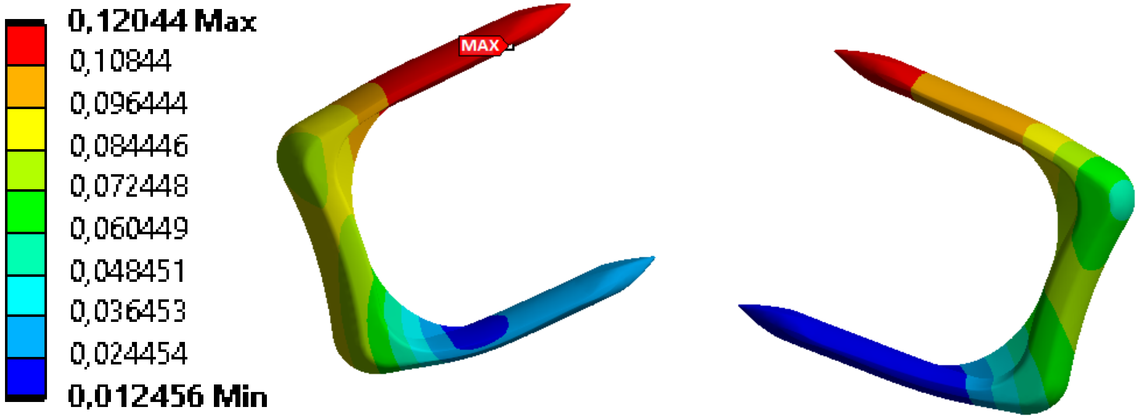

Figure 7: Total displacement of bone staples [mm] (remote tensile forces 980.7 N)

Conclusions

1. Staples are made from medical grade stainless steel 1.4441. Minimum yield strength of this steel is 690 MPa. The calculated maximum equivalent von Mises stress in staple is 627.77 MPa (632.65 in the point of singularity).
2. Calculations were done for overloaded staples, hence applications are safe and suitable for use.
3. Results may differ from person to person. Also different positioning of staple has a huge impact.
4. For future endeavors a heterogenous material could be used and for verification of results experiment should be made.

Acknowledgement

1. This work has been elaborated in the framework of projects FV40306 “Development of New Implants for Correction of Angular Pediatric Deformities in Sterile Design”, CZ.02.1.01/0.0/0.0/17_049/0008441, CZ.02.1.01/0.0/0.0/17_049/0008407 and SP2020/23 “Numerical and Experimental Modeling to Support Solutions to Technical and Biomedical Problems”

Thank you for your attention

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