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COMPARISON OF MECHANICAL ASPECTS OF DIFFERENT TREATMENT METHODS OF HUMAN FINGER TENDON CONTRACTURES

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Summary: *The article reports on an analysis of conservative treatment methods of finger flexor contractures (splinting and external fixation). The treatment simulation is based on numerical Finite Element Method. The stress states of bones and soft tissues are evaluated and compared for different values of the flexion angle. Suggestions for optimal treatment progress are derived from the stress state analysis.*

1. Introduction

The contractures of finger tendons are a serious therapeutic problem in orthopedics and reconstructive surgery of the hand. The etiology of contractures is quite complex. There is a wide range of possible causes, some examples are:

- burns
- wounds
- post inflammatory
- Dupuytren's disease
- congenital.

Although the treatment is in most cases surgical the conservative methods (splinting and external fixation) still play an important role. In some cases surgical treatment cannot be used because of the risk for the patient. Splinting is also widely used as a method of post-operative rehabilitation.

A general clinical experience with conservative treatment methods is positive. Both methods (splinting and external fixation) lead to flexor extension in a time period of several weeks. A

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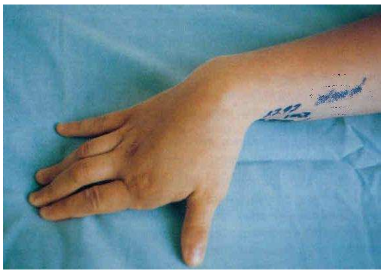
(a) Dupuytren's disease



(b) congenital

Figure 1: View of contracted hands (Smrčka & Dylevský, 1999)

big advantage of the splinting method is very simple application of the splint and bandage while an external device screwed to the phalanges is required for the other method. On the contrary the surgeons occasionally observe edema and painful reaction to the splinting treatment method. There is an assumption that one possible reason of the reaction could be mechanical overloading (by compression stress) of the soft tissues of the Proximal interphalangeal (PIP) joint. The task of the biomechanical analysis is to analyze the stress state of the PIP joint for both treatment methods.

2. Methods

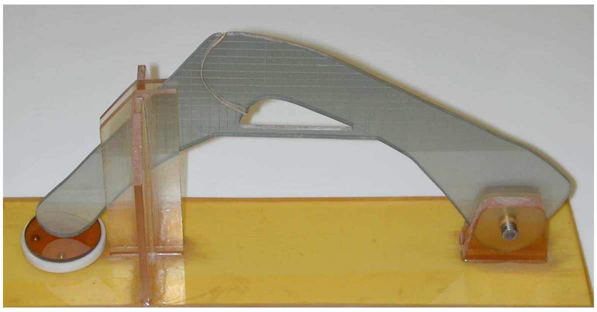
Different models were used to analyze the treatment progress – Finite Element (FE) model (3D and 2D) and also 2D photoelastic model.

The 3D geometry of the phalangeal bones was reconstructed from Computer tomography data (Jiroušek, 2000). The reconstructed geometrical model was simplified for faster solution convergence. Our attention was primarily aimed at the stress state of the cartilage therefore the simplification of bone geometry was quite significant. Also the bone material was considered to be simply linear elastic and isotropic. The tendons were modeled as bilinear bars and the cartilages as a flexible contact pair of two viscoelastic materials.

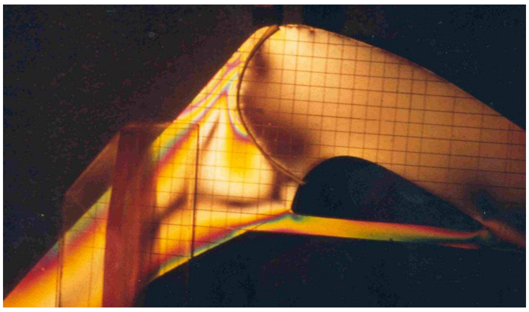
Table 1: Material properties used in the model (An & Draughn, 2000)

property name	cancellous bone	cortical bone	tendon
Young's modulus [MPa]	600	17 000	100
Poisson's ratio	0.25	0.25	0.40

The 2D Finite Element model was used for testing and development purposes. One was also built for the purpose of comparison with the photoelastic model. In this case the material is linear elastic; geometry, boundary conditions and loads copy the photoelastic model.



(a) experimental set-up



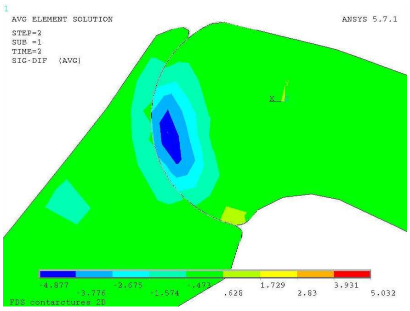
(b) isochromatic lines

Figure 2: The 2D photoelastic model

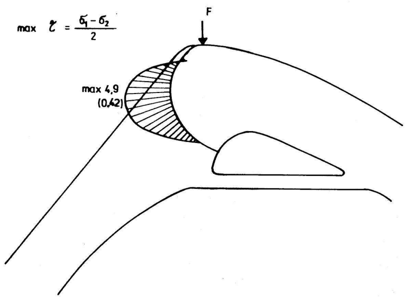
The reflex photoelastic model (see Fig. 2) has the shape of a planar cross-section of proximal and middle phalanges obtained from an X-ray image. Two hinges (one fixed and one sliding) and a vertical force (pointing downward) simulate the splinting treatment method.

3. Results

Two different 2D models (FE and photoelastic) provide us a possibility to compare and check the results. The comparison (see Fig. 3) shows very good correspondence of calculated principal stresses.



(a) 2D FE model



(b) Photoelastic model

Figure 3: Comparison of principal stress differences

The contact stresses in the PIP joint were evaluated for different treatment methods and for different values of the angle between flexed proximal and middle phalanx using the 3D FE model. For better possibility of treatment methods comparison the condition of (approximately) equal axial stress in the extended tendons was used because the axial stress is what makes the the tendon to extend. The values of contact stress were scaled and relative values (where 100 % is the highest calculated value of all cases) are shown in Fig. 4.

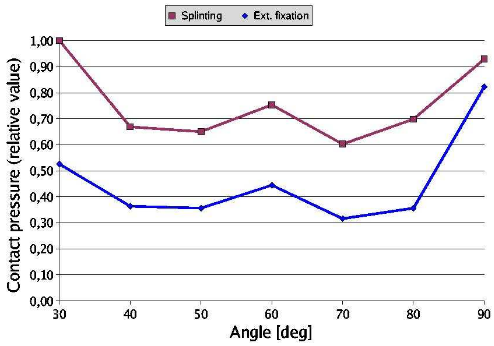


Figure 4: Maximal contact stresses

4. Conclusions

The comparison of treatment methods shows that the contact pressure is significantly higher for the splinting method for all investigated angles between flexed phalanges. The big advantage of splinting (simple application) is balanced by higher stresses during treatment. We could suggest the orthopedists to use splinting method if possible and remember that higher stresses can bring edematic reaction.
Next studies could help to reduce joint stresses by splint shape optimization.

5. Acknowledgment

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6. References

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