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RHIZARTHROSIS AND ITS TREATMENT, STRESS AND DEFORMATION ANALYSIS OF THE TOTAL JOINT REPLACEMENT

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Abstract: *The first part of this paper deals with consequences and treatment of trapeziometacarpal joint disease called rhizarthrosis. Rhizarthrosis consists of some different phases. Initial phase can be asymptomatic, but in next phases bad mobility and unpleasant pain can occur. There are many ways how to reduce the pain and improve the mobility caused by rhizarthrosis. However, in serious cases the problem can be solved completely only by the total joint replacement. There have been many surgeries carried out since 2008 in the Czech Republic. Development of such total joint replacement is still current thanks to its optimization. There are some advantages resulting from the development, e.g. longer lifespan of the implant, better biocompatibility etc. Therefore the second part of the paper aims at stress and deformation analysis of simplified model of the joint replacement. An equivalent stress and a contact pressure are investigated.*

Keywords: Rhizarthrosis, Trapeziometacarpal joint, Total joint replacement, Stress and deformation analysis, Finite element method.

1. Introduction

Many people suffer from painful diseases of joints. However, similar diseases affect not only people of an old age and it is necessary to eliminate the problems. Fortunately, a specific scientific branch called biomechanics has been developed for last decades. Biomechanics gathers important knowledge of an engineering mechanics and a medicine applying them on a development of various types of replacements. Treatment of joint diseases includes a lot of methods, but the most efficient are partial and total joint replacements. The similar situation is in the hip joint (Fuis et al., 2001, 2002, 2004, 2009, 2009a, 2011 and 2011a).

2. Rhizarthrosis

Rhizarthrosis is a kind of an arthrosis, i.e. painful degenerative joint disease, namely disease of trapeziometacarpal joint connecting thumb bones with wrist bones. Rhizarthrosis is one of the most frequent arthrosis of hand. Compared to men, there are 80-90% of women over age of 50 suffering from it (Trtik, 2011). Occasionally, it is a result of partial luxation – subluxation. Rarely, a fracture in the joint surrounding can be the reason of disease.

2.1. Consequences of rhizarthrosis

Many studies discovered rhizarthrosis occurs related to disability of neighboring joints. The characteristic feature is a presence of bony projections – osteophytes. Increasing of the osteophytes causes reduction of a joint space, damage of an intermetacarpal ligament and following evolution of a subluxation. Growth of osteophytes can bring a lot of other unpleasant problems.

The first phase of rhizarthrosis is asymptomatic. As time goes by, particularly hard work and movement result in a pain located in the first metacarpus basis. Swellings, immobility and low strength of the thumb are typical symptoms of an advanced stage. For the correct identification of the location of pain origin, medical examination by touching (palpating) an area of the hand have to be done necessarily. Commonly,

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mobility of the thumb in accordance with a flexion, extension, abduction and adduction is medically examined. Generally, evaluation of thumb opposition according to Kapandji is carried out. This simple evaluation consists in pressing the thumb against other fingers. There are many classifications of determination of the joint disability level, e.g. according to Dell, Eaton-Littler, etc. Let's introduce classification according to Dell:

- ***1st stage*** - The joint space is smaller and smaller, but there haven't been any osteophytes and subluxation yet.
- ***2nd stage*** - The first osteophytes and slight subluxation can be noticed.
- ***3rd stage*** - The osteophytes are big and subluxation is extensive. The thumb is irreversibly deflected from initial position.
- ***4th stage*** - The joint line fades away, pain is manifested moderately. On the other hand, mobility of the thumb is nearly impossible.

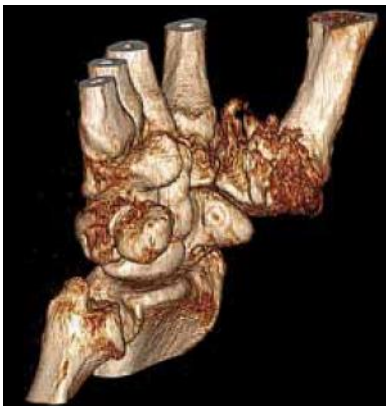

Fig. 1: Advanced stage of rhizarthrosis.

2.2. Treatment of rhizarthrosis

There are many ways how to reduce or entirely eliminate symptoms of rhizarthrosis. Basically, conservative and surgical medical treatments of the disease are distinguished. Conservative treatment is carried out in case of less serious problems when doctors strive for reduction of a pain manifestation. Usually, pain stage has persisted for 2-3 years, sometimes longer. Conservative treatment requires use of orthoses and medicaments, for instance analgesics (non-steroidal anti-inflammatory drugs etc.).

2.2.1. Trapeziectomy and arthrodesis

Surgical solution includes three different ways of treatment, namely trapeziectomy, arthrodesis and trapezium prosthesis. Trapeziectomy is a surgery to remove the trapezium bone. Arthrodesis is the artificial induction of joint ossification between two bones. The joints are immobilized at the level of fusion. This surgery is done to relieve pain at the expense of mobility. The plaster fixation has been required for three months at most. Among others, there is a problem of loss of the thumb dexterity.

2.2.2. Partial and total trapezium replacements

If there is the only partial arthrosis of the joint, the partial prosthesis of the first metacarpus basis suffices. In the present these replacements are made of pyrolytic carbon. Well-known types are Asword-Blatt and Kessler. The total trapezium replacement replaces all the trapezium bone, but the metacarpus bone remains. The most famous is Swanson's silastic implant.

2.2.3. Total trapeziometacarpal replacements

On the development of replacements Jacques Duparc and Jean-Yves de La Caffinière have participated since 1970s. The goal was an anatomic adaptation, acceptable mobility, sufficient stability and high service life. Whereas the first generation was disappointing, the contemporary second generation is much more successful. Some names of the second generation models are Elektra, Roseland, Arpe, Carat, Maïa, Rubis2, Ivory etc. Improvement of the replacements was caused by the progress of mechanical engineering and medicine. In the technical sphere, anchoring into a bone and surface finishing of matter was improved. In the medical science the process of surgery became better.

In the Czech Republic are frequently used these types of total joint replacements – Maïa and Rubis2. Individual types differ in a use of material and center of rotation mainly. The metal stem of Maïa type is pressed in the polyethylene cup and the center of thumb rotation is in trapezium. On the other hand, both the stem and the cup of Rubis2 type are metal and the center of rotation is in the first metacarpus basis.

There are advantages of the second generation replacements like preserving anatomy and mainly invariability of the physiological center of rotation. In contrast, disadvantages are luxation (6-8% of patients) and release of a connection between prosthesis and bone (10% of patients).

Fig. 2: Total replacement Maïa.

Fig. 3: Total replacement Rubis2.

3. Stress and Deformation Analysis

Thanks to need of development of partial and total joint replacements, experimental and computational modelings are done. For this particular prosthesis, stress and deformational analysis was carried out by numerical computational modeling by finite element method software (ANSYS).

The simplified model of geometry corresponding approximately with real used implants was made. Diameters of contact surfaces of the cup and the stem are 7 and 7.05 mm. For both parts of model the only material was chosen, namely frequently used Cr-Co-Mo alloy with Young's modulus 208 GPa and Poisson's ratio 0.3. Axial symmetry loading by pressing the stem to the cup by force of maximum magnitude of 1200 N was preferred.

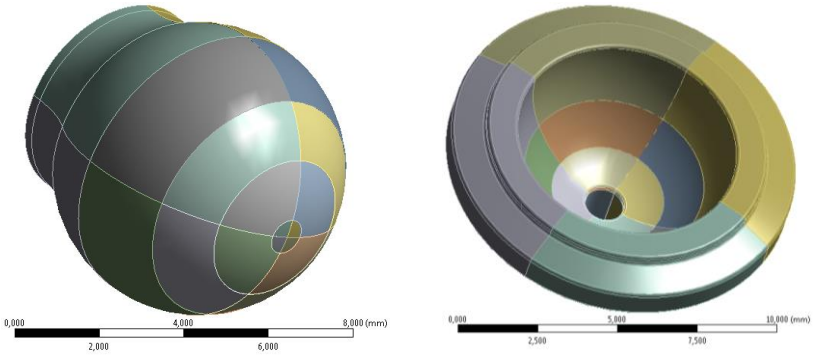

Fig. 4: Simplified model of geometry of joint replacement.

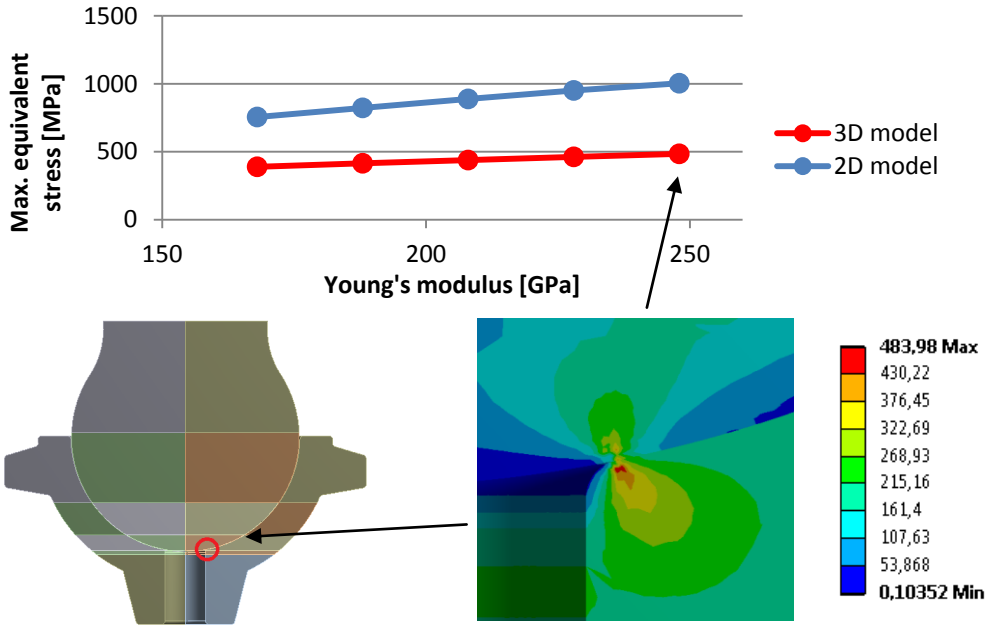

Fig. 5: Dependence between maximal Tresca equivalent stress and Young's modulus.

Contact between the stem and the cup was defined with frictional coefficient 0.3. Just because of the frictional contact, analysis is nonlinear and therefore much more complicated. Discretization of the model

was created with use of axial symmetry. Whereas in the contact area very small elements were created, farther, the elements remained bigger in order to efficient calculation. It is very important to know that quality of mesh determines exactness of results. For comparison, three dimensional and two dimensional axial symmetrical analyses were performed. A use of an axial symmetrical analysis is limited but very useful if possible. Although the results of two and three dimensional models are different, trend situation is evident.

Whereas an influence of frictional coefficient (not mentioned here) is relatively negligible, in contrast, Young's modulus influences studied quantities substantially. It is evident that increasing Young's modulus causes increasing of maximal Tresca equivalent stress as well as maximal contact pressure. In conformity with contact pressure, contact area decreases (Svojanovský, 2013).

4. Conclusions

The overview of treatment of rhizarthrosis tries to highlight an importance of biomechanics. Development of biomechanics is caused thanks to very significant progress of medicine and engineering mechanics in last decades. In the engineering mechanics finite element method is one of the most important computational methods. Nevertheless, it is suitable to combine this method with experiments and essential knowledge of an engineer to achieve credible results.

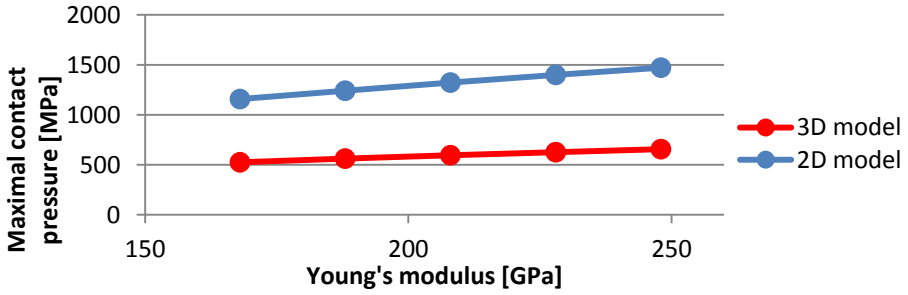

Fig. 6: Dependence between maximal contact pressure and Young's modulus.

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