Retractors with rounded profile preserve soft tissues from excessive loading during surgical exposure

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Introduction

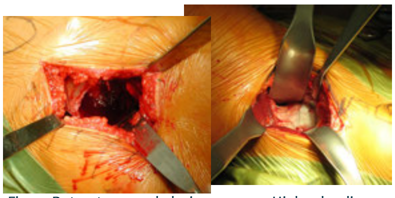

Fig. 1: Retractors used during surgery: Higher loading and local stress to the tissue with classic retractors (left) compared to rounded retractors (right; Subtilis ®).

Retractors displace muscles during orthopaedic surgeries (see Fig. 1) and eventually damage the tissue irreversibly. Classic retractor designs have flat rectangular or elliptic profiles with sharp edges, which are the potential origin of stress concentrations. Such loads are thought to damage tissues. Recently alternative designs having rounded profiles (as realized with Subtilis® retractors) are supposed to substantially reduce the muscle loading.

Goal: **Assessing the less tissue damaging retractor design based on a stress concentration criteria**

Methods

- A section of a retractor deforming soft material (Fig. 2) is used as a basis for the development of a conceptual finite element analysis (Fig. 3)
- Boundary Conditions: The lower edge of the tissue is fixed while the edge on the symmetry axis is a frictionless support. Retractor indentation is simulated through a 11mm displacement corresponding to roughly 1kg load.
- The plane stress assumption is used to simplify the 3D geometry into a 2D model
- Large deformation assumption are needed to render the important indentation
- The system is regarded as static structural system

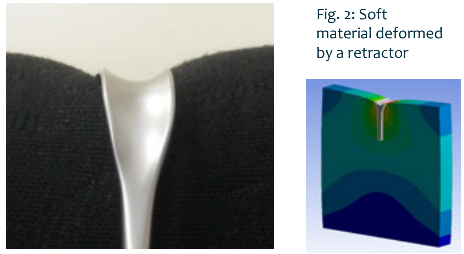

Fig. 2: Soft material deformed by a retractor

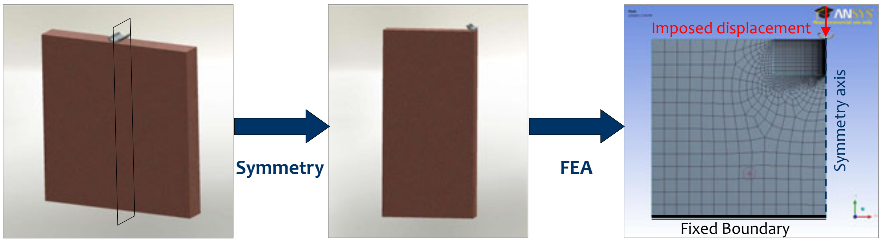

Fig. 3: Highlight of the simplification process to obtain the 2D model

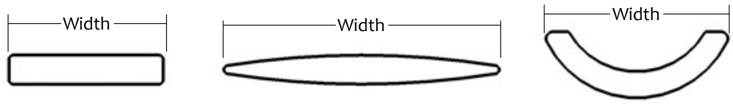

Fig. 4: The three different retractor profiles used in the analysis: flat, elliptic and rounded (from left to right)

- Materials:
  - Retractors: Metallic (Rigid Body)
  - Muscles: Neo-Hookean hyperelasticity (Initial shear modulus: 33kPa, Incompressibility factor: 0.12MPa-1)
- Compared profiles: Flat, elliptic and rounded with 5 different widths (Fig. 4)
- Comparison criteria: The influence of the retractor shape shall be evaluated by comparing the maximal 3D stress states (von Mises stresses)

Results

- Stresses induced by the rounded instrument are transferred through a large area located in the middle of the profile contact line, whereas elliptic and flat designs show stress concentrations at the penetrating edge of the instruments (Fig. 5)

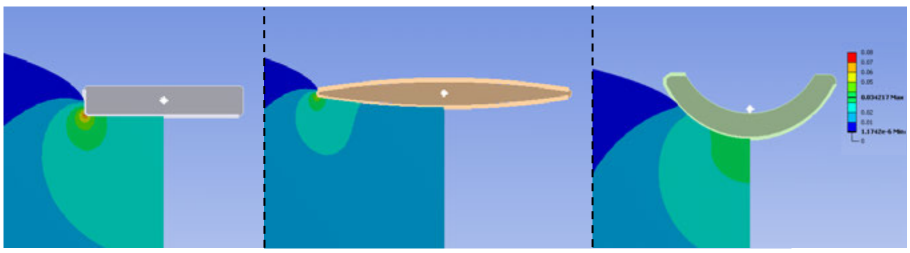

Fig. 5: von Mises stress distributions generated by the three different retractor designs

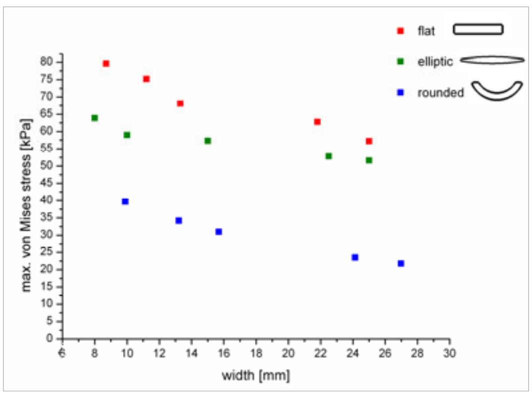

Fig. 6: Maximal von Mises stresses in function of the retractor width for all three simulated profiles

- Maximal von Mises stresses induced by the rounded instrument are 50% lower than by the flat one for all calculated widths: 68kPa compared to 34kPa for a width of 13mm (see Fig. 6 for calculated stresses relative to the width)
- Stresses produced by the elliptic profile are roughly 150% of the ones induced by the rounded design for all widths
- Elliptic retractor generates less stress than the flat profile but the values are quite similar for broader width: 57kPa (flat) vs. 52kPa (elliptic) for a width of 25mm

Discussion

The presented 2D numerical model enables the comparison of the different retractor designs. 3D should allow assessing the effect of the retractor angle against the applied load, which is a potential further key aspect inducing damage in tissue. Nevertheless, the following aspects were successfully determined in the present study: the retractor with the rounded profile induces roughly only half as much stress in the muscle as the flat or the elliptic design for all considered widths. Furthermore, the generated stresses of each instruments decrease for a wider size. As long lasting soft tissue loading during surgery is crucial regarding the damage due to tears or compression, rounded retractors are less likely to harm the tissue during surgery.

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