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COMPUTATIONAL MODELING OF A SINGLE-INCISION SLING IN FEMALE STRESS URINARY INCONTINENCE SURGERY

Hypothesis / aims of study

The single-incision sling (SIS) gained great popularity for treatment of stress urinary incontinence (SUI) because of its minimal invasiveness. However, varying success rates have been reported and the long-term outcome is far from satisfying. To achieve a higher success rate, it is important to understand how the sling interacts with surrounding organs/tissues. The objective of this study is to use a computational model to simulate the sling procedure for SUI treatment.

Study design, materials and methods

A computational model was developed following a previous study (Figure 1a) where the high-resolution MR images of the pelvis were acquired from a healthy 21-year old female subject. Image segmentations were performed for over 40 anatomical parts inside the pelvis and 3D closed surfaces were reconstructed for each part. After surface smoothing, all parts were imported into ABAQUS 6.12 (SIMULIA, Providence, RI) and meshed into tetrahedral elements. Material properties of soft tissues were taken from literature. The single-incision sling was modelled according to the specifications of the MiniArc® (American Medical Systems, Minnetonka, MN). Three Valsalva simulations were performed. Test 1 served as the asymptotic test without the presence of urethral hypermobility (UH). In test 2, the levator ani muscle (LAM) was weakened by reducing its stiffness to simulate the presence of UH. Test 3 was built based on test 2 but with the sling implanted at the mid-distal posterior urethra (Figure 1b and 1c). To quantify the degree of UH, the urethral excursion angle (UEA) from rest to the final state with an intra-abdominal pressure (IAP) of 100cmH_2O was monitored.

Results

Test 1 generated a UEA of 24.4°, while test 2 generated a UEA of 36.6°, which is above the critical UH line of 30°. In test 3, the UEA was lowered down to 23.8° after sling intervention. Figure 2 shows pelvic floor deformations in the mid-sagittal view at IAP of 100cmH_2O.

Interpretation of results

In test 1, the urethra received sufficient support as the UEA is less than the commonly accepted urethral hypermobility line of 30°. When the levator ani was weakened (test 2), the urethral support system was malfunctioning, demonstrated by an increased UEA of 36.6°. The sling intervention showed successful correction to urethral hypermobility as the UEA was brought down to 23.8° in test 3 in which the SIS was implanted.

Concluding message

Improper sling positioning could lead to sling surgery failure. In this study we showed the competence of the computational modelling and simulation approach in simulating the biomechanical process inside the female pelvis. This methodology could be employed by medical device manufacturers in sling design or by surgeons as a pre-clinical analysis tool in treatment plan optimization or to study sling surgery failures.

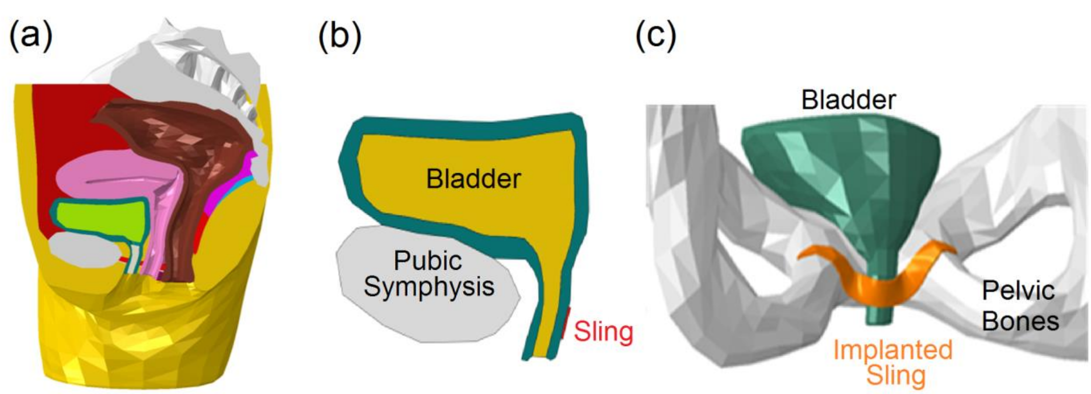

Figure 1 (a) Mid-sagittal view of the pelvic model, (b) Implanted sling in the mid-sagittal view and (c) Implanted sling from the posterior view.

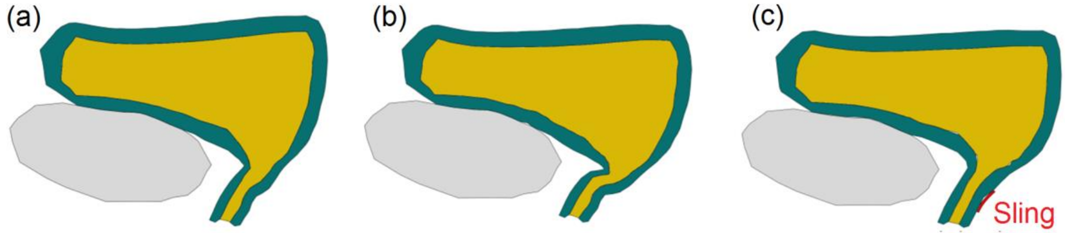

Figure 2 Pelvic floor deformations at the IAP of $100 cmH_2O$ in the mid-sagittal view for (a) test 1 asymptomatic test (b) test 2 with simulated urethral hypermobility and (c) test 3 with simulated urethral hypermobility plus sling intervention.

Disclosures
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