Reproducibility of in vivo constitutive parameter identification based on 4D ultrasound strain imaging

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Introduction

Time-resolved three-dimensional ultrasound combined with speckle tracking algorithms (4D ultrasound) is a non-invasive medical imaging technique that provides full field displacement and strain data of aortic and aneurysmal wall motion in vivo. In an in vitro validation study by our group, the 95% confidence interval of local strain measurement for tissue segments with a size of about 1.5 x 1.5 mm was determined to be ± 2.1%.

Methods

In a numerical experiment, we have examined the reproducibility and uniqueness of the results of the inverse identification of the nonlinear and anisotropic constitutive behavior of aortic walls by use of a previously developed Finite Element Model Updating (FEMU) approach that is applicable to in vivo 4D ultrasound data and non-invasively measured diastolic and systolic blood pressure. In a further numerical experiment, we have tested the effect of the uncertainty of 4D ultrasound strain measurement on the inverse identification of the constitutive behavior.

Results

The repeated identification of the constitutive behaviour based on strain data that were not corrupted by measurement uncertainty indicates that the solution of the inverse problem is unique with regard to the identified stretch-Cauchy stress curves at finite deformations, and the load-free configuration, but non-unique with regard to the parameters of the chosen constitutive equation. These results were confirmed by the parameter identification based on strain field data with overlaid error.

Conclusion

The performed numerical verification experiment shows that it is feasible to identify the non-linear and orthotropic constitutive behaviour of the geometrically irregular aortic wall based on the observation of just two load-cases if heterogeneous fields of all components of the in-plane strain tensor are available.

Comparison of a standardised and advanced four-point bending test of an osteosynthetic system in static and dynamic load scenarios

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Introduction

Current test standards of osteosynthetic implants examine the bone plate and screw separately leading to unrealistic load scenarios and unknown performance of the system as a whole. Furthermore, the individual components are not tested in realistic boundary conditions, which prevents the identification of characteristic failures in clinical use. Today's standards need to be re-examined and compared to new approaches that test the whole osteosynthetic system.

Methods

A standardised static and dynamic four-point bending test (ASTM F382) was performed on a bone plate. Based on that standard, an advanced Implant-System-Test (IST) was designed and performed to test a mechanical construct consisting of a bone plate, screws and an artificial bone substitute out of Polyoxymethylene with a simplified anatomic geometry. The test object was an osteosynthetic system to treat fractured ulna bones. Both results of the conventional and advanced test methods were analysed and compared to each other.

Results

Static results of the IST differ highly with respect to the conventional test. Still, the bone plate's yield point is reached at the same resultant bending moment in both test scenarios. Dynamic results show a bilinear behaviour for both test methods with a significant difference in the second linear phase. This phase can be defined as a constantly increasing plastic deflection quantified by its slope in mm per one million cycles, leading to a ten times higher slope for the IST than the conventional test.

Conclusion

A more realistic test scenario has an high impact on the test results and the resultant interpretation of the mechanical behaviour of the osteosynthetic system. A constantly increasing plastic deflection might lead to non-linear contacts and small plastic deformations within the screw head-bone plate interaction, causing fatigue failures. The development of new standardisations referring to the whole system within reasonable boundary conditions of individual biomedical applications are crucial for high quality mechanical analysis.

A modular bioreactor perfusion system for in vitro stimulation of native and bioartificial vessels under physiologic and pathologic conditions

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Introduction

In the human body, blood vessels are exposed to numerous mechanical stimuli including intraluminal blood pressure, cyclic stretch and shear stress. These forces do not only depend on the position of the vessel in the vascular system, but are also highly variable between patients with different cardiovascular pathologies.
In vitro mechanical stimulation has been proven to be of pivotal importance in cardiovascular tissue engineering approaches. Additionally, the option to simulate specific pathologic flow- and pressure patterns could allow the development of in vitro models to study cardiovascular diseases. Both approaches require a variable bioreactor perfusion system (BPS), which facilitates accurate simulation of both physiologic and pathologic flow- and pressure patterns in different parts of the vascular system.

Methods

We here present a modular BPS, which can be easily adapted to simulate physiologic and pathologic flow and pressure patterns of different components of the human vascular system. The BPS combines a pump facilitating pulsatile and static flow, a variable compliance chamber mimicking the aortic Windkessel-effect and different interchangeable bioreactors.

Results

Possible pathologies that can be simulated with characteristic pressure curves include hyper- and hypotension, tachy- and bradycardia, arterial stiffness, low cardiac output syndrome and aortic valve insufficiency. The system facilitates creating typical pressure patterns for different vessels like the aorta, proximal and distal arteries, veins and the microvascular system. Moreover, the BPS has been used previously to condition cellularized fibrin-based vascular grafts using pulsatile perfusion in a low-pressure environment.

Conclusion

Due to its modular composition, the BPS enables physiologic stimulation of bioartificial vessels for tissue engineering approaches as well as simulating different pathologic mechanical patterns in native vessels for etiopathogenetic investigations of cardiovascular pathologies. Thus, it can be adapted to fit patient-specific conditions and represents a first step towards integrating the principles of Personalized Medicine into in vitro bioreactor technology.

Cross-sectional analysis of tubular polymer semi-finished products using ultrasound in comparison with other measuring methods

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Introduction

Tubes, cannulae, catheters, as well as tubular implants made of polymers are of great importance in modern medicine. Regardless of whether they are invasive or non-invasive, tubular medical devices contribute to life-saving measures. Safety related evaluation of these products also includes cross-sectional analysis. The ultrasonic measuring method is to be evaluated as an alternative to micro computed tomography and scanning electron microscopy for the analysis of polymer microtubes.

Methods

In this work, different extruded tubular stent semi-finished products made of biodegradable polymer PLLA were measured with micro computed tomography (µ-CT), ultrasonic measuring (US) and scanning electron microscopy (SEM) methods. The methods were compared regarding their feasibility and accuracy.

Results

It is to be noted that, with a few exceptions, the three investigated methods deliver very reliable results. In particular, µ-CT and US are providing similar results, while both methods are non-destructive. The US method is less time-consuming.
As all investigated methods appear mutually supplemental, no single preferred method was derived from this series of measurements.

Conclusion

In summary, characterization of tubular polymeric specimens by means of the presented ultrasonic method represents a low-cost and promising alternative for precise and high throughput quality control of tubular semi-finished products.

Water uptake of various electrospun nonwovens

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Introduction

In recent years, nanofiber based materials have emerged as especially interesting for several biomedical applications, regarding their high surface to volume ratio. Due to the superficial nano- and microstructuring and the different wettability, water absorption is an important parameter with respect to the degradation stability, thermomechanic properties and drug release properties, depending on the type of polymer.

Methods

The thermoplastic silicone polycarbonate elastomer (PCU-co-Si), the thermoplastic polyester elastomer (TPC-ET), and the polyamides PA 6 and PA 6.12 were used as sample materials. An electrospining process was performed using a commercial electrospinning device (Contipro 4Spin C4S LAB2). The nanofibers were modified via O_2-Plasma. Water absorption of the modified and non-modified nanofibers was tested after 24 h, based on the DIN EN ISO 62 and analysed via Karl-Fischer titration. Furthermore, the different nanofiber nonwovens were characterized regarding their morphology, contact angle and fiber diameter.

Results

PCU-co-Si and TPC-ET show similar properties, as well as PA 6 and PA 6.12, respectively. The water absorption for all nanofiber nonwovens was higher for the modified compared to the non-modified ones. Except for TPC-ET with 0.1%, the water absorption of the non-modified polymer samples is between 6.5 and 8% after 24 h wetting. The water absorption for all modified polymers was higher compared to non-modified nanofiber nonwovens. Moreover, the water apsorption of the alternative polymers TPC-ET and PA 6.12 were lower compared to PCU-Si and PA 6, respectively.

Conclusion

Within this study alternative promising polymer candidates were investigated in view of their water absorption. TPC-ET and PA 6.12 have shown relatively similar properties compared to PCU-co-Si and PA 6, repectively. The ability to alter water absorption of implants may enable new applications.

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Investigations of flow alteration of commissural misalignment of TAVR using Particle Image Velocimetry

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Introduction

Due to the raising number of TAVR implantations (transcatheter aortic valve replacement), tests for durability and prevention of associated diseases are becoming increasingly important. Not only the anatomy but also the positioning of the TAVR is decisive for its clinical performance. A misalignment in the circumferential direction can influence the flow in the sinus and thus inhibit the blood supply of the coronary arteries and influence the thrombosis potential. Therefore, the modification of the flow field is investigated in this study.

Methods

For the characterization of the flow fields the measuring method of digital particle image velocimetry is used. A hydraulic circulation model is used to generate physiological flow and pressure conditions. Additionally, an aortic root model with Sinus Valsalvae, which represents the implantation environment, was developed. A prototype of a TAVR was implanted aligned to the commissure lines of the native valve leaflets on the one hand, and misaligned by 60 degree to the commissure of the native valves on the other hand.

Results

By determining the velocity vector fields, it could be shown that implantation of the TAVR with a commissureal misalignment influences the flow around the leaflets. A comparison of the flow fields shows that different recirculation areas occur. This is also indicated by a comparison of the mean velocities in the sinus and the observed shear rates.

Conclusion

The influence of the altered flow field on the thrombosis and hemolysis potential should be investigated in future studies.