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Short communication

Experimental modal analysis on fresh-frozen human hemipelvic bones employing a 3D laser vibrometer for the purpose of modal parameter identification

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ABSTRACT

To provide a close-to-reality simulation model, such as for improved surgery planning, this model has to be experimentally verified. The present article describes the use of a 3D laser vibrometer for determining modal parameters of human pelvic bones that can be used for verifying a finite elements model. Compared to previously used sensors, such as acceleration sensors or strain gauges, the laser vibrometric procedure used here is a non-contact and non-interacting measuring method that allows a high density of measuring points and measurement in a global coordinate system. Relevant modal parameters were extracted from the measured data and provided for verifying the model. The use of the 3D laser vibrometer allowed the establishment of a process chain for experimental examination of the pelvic bones that was optimized with respect to time and effort involved. The transfer functions determined feature good signal quality. Furthermore, a comparison of the results obtained from pairs of pelvic bones showed that repeatable measurements can be obtained with the method used.

1. Introduction

Computer models of the implant–bone interface are considered helpful for examining orthopedic issues such as the selection of suitable implants or their resulting range of motion (Bader et al., 2008). Verification by experiment is required for close-to-reality finite elements models. Comparing the static or the dynamic response of the real structure and the numerical model are common procedures to evaluate how well the material parameters of the model represent the stiffness distribution of the real structure (Hobatho et al., 1991;(Taylor et al., 2002). Strain gauges or acceleration sensors are frequently used for this purpose (Anderson et al., 2005; Conza and Rixen, 2006; Taddei et al., 2007; Kluess et al., 2009); however these instruments are limited in use by the limited number of measuring points they permit. Furthermore, interaction of the attached sensor is difficult to estimate and its exact positioning is particularly difficult on curved surfaces.

Conza and Rixen (2006) have used a 1D laser vibrometer as detector. Due to the complex geometry of pelvic bone, it takes a great effort and is time-consuming to obtain measurements precisely perpendicular to the surface and to transfer the measuring points to a global coordinate system (Werner et al., 2009).

The objective of the present study was to experimentally determine modal parameters of the first five normal mode shapes of fresh preparations of human pelvic bones.

2. Materials and methods

2.1. Donor preparations

Ten human pelvic bones (specimen SP01–SP10) were taken from donor bodies. The deceased had given their consent during their lives to donate their bodies for science and research. The sacrum and all soft tissues were removed from pelvic bones. Eight markers were attached to anatomically distinctive points for the later exact alignment of coordinate systems. These points are described in the anatomical literature (Tillmann, 2010; Fick, 1904). They can be easily identified during attachment, are well distributed in all spatial directions, and can be reached by the lasers from various views. The coordinates of the markers were read out from predefined μCT records. Some key data of body donations are listed in Table 1.

2.2. Test setup

The measuring setup consisted of a PSV-400-3D laser measuring system (Polytech GmbH, Waldbronn, Germany), the associated controller, an amplifier, and a test rig.

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