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Development of a universal instrument system for locking intramedullary nails

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Summary:
In large animals, fractures of the upper long tubular bones such as forearm and humerus as well as lower and upper leg, continue to represent a major surgical challenge. Fixing these fractures with implanted nails has proven to be difficult and requires a high level of X-ray monitoring. Therefore, a camera-marker system was developed without the need for X-ray monitoring during drilling. The results showed that 8 of 10 implants could be securely fixed. However, the described method has great potential in both veterinary and human medicine and does not require X-ray exposure.

Keywords: Camera-marker system, Intramedullary nail, Femur, Implant locking, Osteosynthesis

Motivation

The horse population has grown significantly in the recent years, not only in Germany but worldwide. According to projections by the Federal Statistical Office, approximately 1.1 million horses and ponies are kept in Germany, which corresponds to a fourfold increase in the population over the past 40 years [1]. Not only the increase in absolute numbers of horses, but also tendential changes in the way horses are kept, lead to an increase of impact injuries and thus of fractures [2,3]. Therefore, an implant and a corresponding surgical procedure for intramedullary osteosynthesis in fractures of the long bones of large animals were developed [4]. Thereby, the fixation of the implanted nail - which is essential for rotational stability - is performed with the aid of an insertion guide and under X-ray monitoring. This causes a high radiation exposure for surgeon and patient. However, in human medicine, it was shown that it is difficult to securely fix the distal drill holes of the nail with the aid of the insertion guide [5]. Therefore, these abstract aims to present a newly developed screen-guided navigation system without the need for X-ray monitoring during drilling, consisting of two mutually sighting camera-marker modules, for the safe locking of nails during intramedullary osteosynthesis in large animals.

Methods

The development of the camera-marker system (CMS) is divided into three phases. The first phase includes the design of hard- and software. The second phase deals with the development of the algorithm for calculating the position data. In the third phase, the system was tested on equine femora. The locking of the intramedullary nail was evaluated according to the number of successful fixations of the distal drill holes. Secure locking was defined as all distal drill holes being fixed.

Camera-Marker System

The CMS utilizes two cameras which face each other, with one camera attached to the insertion guide of the nail and the other attached to the drilling machine. Figure 1 shows the experimental setup consisting of the two devices with attached CMS and the intramedullary nail.

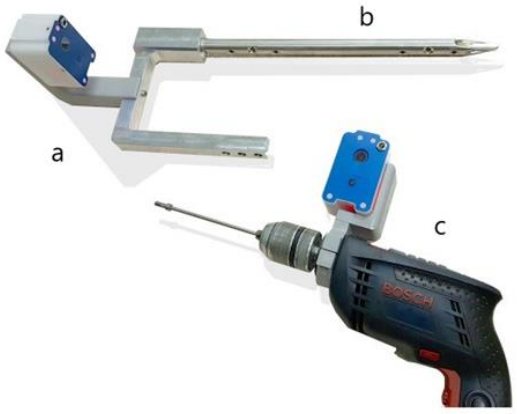

Fig. 1. Experimental setup: a.) insertion guide with CMS, b.) intramedullary nail and c.) drilling machine with CMS.

Four LED marker points on each camera surface emit infrared light, which allows the cameras to determine their relative positions to each other in

real-time through software with complex algorithms. The calculation of coordinates refers to determining the location of a point in each space based on its position relative to other known points (see Fig. 2). In order to calculate coordinates, a variety of factors must be considered, including the angles and distances between the known points, as well as any distortions or deviations in the measurements [4,5].

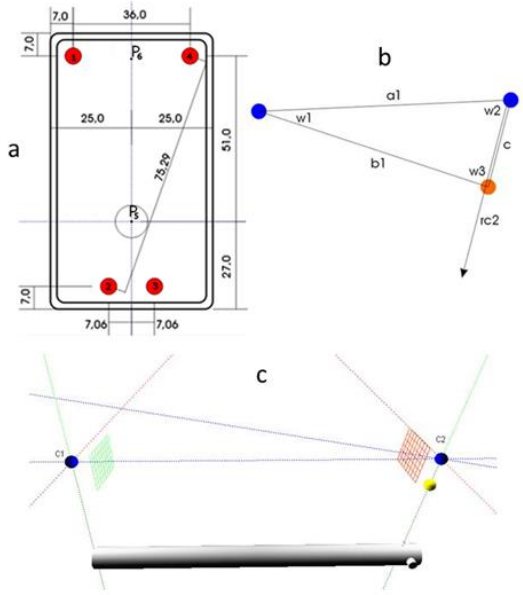

Fig. 2. Sketches about the calculation of the position data: a) CMS surface with dimensions (top left), b) vector calculation (top right) and c) relative angle determination (bottom).

The locking holes in the nail are calibrated to the system using a calibration pin according to the desired nail length. The challenge was to adapt the camera to the insertion guide, which required analyzing the anatomical features of horses and determining the ideal arrangement of the camera-marker modules in terms of opening angle and working distance. As a result of this adaptation, an extension arm was developed which can be mounted on the specific insertion guide in two different positions, covering the working range of the proximal and distal locking holes of intramedullary nails [4,5].

Experimental Setup

Ten femora from slaughtered horses (age 8 - 14 years) were collected from a local horse butchery for testing the CMS. The experimental procedure for testing the CMS can be divided into four steps: 1. preparation of the bone specimens, 2. mounting the CMS on the intramedullary nail and calibrating the system with the calibration pin, 3. nail insertion and proximal locking, 4. drilling and distal locking [4].

Results

The method developed here is suitable for locking intramedullary nails in large animals. The camera-marker system fits well into the surgical procedure and provides a high degree of accuracy. Likewise, the X-ray exposure for surgeon and animal can be reduced to a minimum. X-rays are only required for final locking control [4,5]. With sufficient training and practice, the surgeon can hit the distal locking holes with ease. The very first attempts already showed a hit rate of 80 % with fast improvement with increasing practice. Because of the very good results, the system could also bring great benefits in human medicine.

Outlook

Further work is planned to significantly improve handling and to develop a training concept for surgeons. The system will continue to be tested and iteratively improved in the future.

Author Statement

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