Computer Assisted Total Knee Arthroplasty

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Introduction

Several prosthetic designs have been introduced since 1970, and those of a semi-constrained type are the most widely used in the world.

Whatever the prosthetic design, it is necessary to achieve clean cuts of the distal end of the femur and of the proximal part of the tibia for cemented or uncemented prostheses. The difficulty is to achieve cuts perfectly perpendicular to the mechanical axes of the femur and the tibia. Indeed, these mechanical axes should be aligned according to an angle of 180°, or as close as possible to 180°.

"Most failures can be attributed to incorrect ligament balance or incorrect alignment. Ideally, the limb should be aligned so that the two compartments of the arthroplasty are equally loaded, a goal that is probably unobtainable" wrote Insall in 1984. Moreover, studies by Insall [10, 11, 12], Goodfellow [7, 8], Ranawat [18], Feng [3], Stulberg [3], show that most total knee arthroplasty loosening comes from bad positioning. Ecker [1] wrote: "There was a highly significant correlation between the Roentgen score and the post-operative score, indicating that the more accurately inserted prosthesis have a better chance of obtaining a superior clinical result." Laskin [16], Ritter [19], show a less favorable longevity for malaligned TKA as compared to well aligned prostheses. Jeffery [14] notes at failure rate of 24% for malaligned TKA against 3% for TKA in neutral positioning. Thus TKA longevity is largely related to its per-operative positioning.

The aim of the project was to propose an efficient and original positioning method derived from the utilization of computer assisted orthopedic surgery (CAOS).

Surgical and methodological restrictions were first defined. The system was to be simple, to follow usual sterile requirements, to be shorter or equal to the length of regular surgery, and to offer the patient and surgeon optimal safety. It was also to be ergonomic, accurate, reliable, and cheap. A minimum of pre-operative imagery was to be used, and access to a classical ancillary was to be available in case of system failure.

Initially, the method was validated on an anatomical basis (Leitner, Picard [17]) and allowed to position the tibial and femoro-tibial according to a 180°
axis (90° for the femur and 90° for the tibia). We will describe the preliminary results and the advantages and drawbacks of this new concept.

**Anatomical, Biomechanical, Mathematical Concepts**

**Material**

The computer assisted platform used:
- a 3D Polaris Localiser using 2 cameras for localization of infrared light emitting diodes within the surgical field.
- A PC (Windows NT) performing the operative protocol by using a graphical interface and a double foot pedal.

All components were mounted on a trolley to provide flexibility for the intra-operative set-up. Rigid bodies (RB) made up of at least six infrared light emitting diodes were secured to the ancillary instruments for localization purposes. They were mounted on a frame and provided spatial reference coordinated. Rigid bodies can be fastened on any object for which measurement of movement, position, or orientation is desired.

The probe was made up of a rigid body fixed to a stem. After lower limb calibration procedure, coordinates of the probe tip were acquired. This acquisition allows to measure the spatial position with high accuracy and precision.

Special bicortical screws were used to attach RB to a bone. These bicortical screws allowed for a secure anchoring of the RB. A subset of the Aesculap ancillary for total gliding knee prosthesis was used. It was specifically redesigned in order to provide fastening interfaces for RB.

**Method**

**Leg Calibration**

- The mechanical axis of the leg is defined by three points. The center of the femur head (F), the center of the knee (K), and the center of the ankle (A). In the femoral frame of reference, this axis is defined by (FK) line. (KA) line defines it in the tibial frame of reference. Calibrating the patient's leg consists in finding these three points. A particularly of these points is that they are kinematical points. They are found by appropriately moving the patient's leg.

- The center of the femur head: The hip joint can be correctly modelled by a ball- and socket joint and the method to find its center of rotation as follows. Movement of the femur has one fixed point which is the center of the femur head. Let P be a point on the femur. Recorded positions of P during femur movement will generate a set of points belonging to the same spherical surface. A least squares algorithm calculates its center F.