Development of surgical algorithms for ligament balancing using an orthosensor instrumented tibial trial in total knee surgery

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Obtaining accurate bone cuts based on mechanical axes, and ligament balancing, are considered necessary for a successful total knee procedure. Most total knee surgeries carried out today use measured resection followed by ligament balancing using spacer blocks to equalize flexion and extension gaps. However this is a limited criterion for balancing and is not quantitative. The Orthosensor Tibial Trial displays the magnitude and location of the lateral and medial contact forces, allowing the surgeon to perform several tests. From this information, more accurate balancing could be achieved. To achieve that, testing methods need to be defined and algorithms developed for utilizing the data.

The goal of this study was to develop the algorithms to inform the surgeon which bone cuts or soft tissue releases were necessary to achieve balancing. This was an in vitro study using 10 lower limbs. A special rig was designed which fitted on the operating table. This allowed various tests to be performed as follows: Sag Test, leg supported at the foot; Dynamic Heel Push test, flexing to 120 degrees along a rail; Varus-Valgus test; AP Drawer test; Internal-External Rotation test. All input forces were measured with an instrumented applicator. The bone cuts were made using a Navigation system, to match the Triathlon PCL retaining knee. To determine the initial thickness of the tibial trial, the sag test was performed to reach 0 deg flexion. The Heel Push Test was then performed to check the AP position of the lateral and medial contacts, from which the rotational position of the tibial tray was determined. Pins were used to reproduce this position during the experiments.

A set of Surgical Variables was then defined, which would influence the balancing: LCL Stiffness, MCL Stiffness, Distal Femoral Cut Level, Tibial Sagittal Slope, Tibial Varus or Valgus, and AP Femoral Component Length. Balancing was defined as equal lateral and medial forces due to soft tissue tensions throughout the flexion range, equal varus and valgus stiffnesses, and no contacts closer than 10mm to component edges in AP. All of the tests were then performed and the data studied. If there was a
consistent overload on either the lateral or medial sides, a collateral ligament release was performed. The tests were repeated. The process then was to introduce a Surgical Variable by the use of wedges/spacers, or by bone cuts. The tests were repeated. The differences in data before and after represented the ‘Signature’ of that Variable. Several other Surgical Variables were performed and the data obtained in order to obtain the differences in the data for each Surgical Variable. This process was repeated for all 10 knees.

On average, each Surgical Variable had data from 6 knees. In general each test was carried out relative to a starting point of a reasonably balanced knee, to avoid extreme loading conditions. Graphs were plotted of the mean differences for each variable. In the sagittal plane, a 2 deg reduction of tibial slope caused a 100N extra total (lat+med) contact force. A femoral component size increase increased total contact force by 100N after 60 deg flexion; a size decrease reduced forces 200N throughout flexion. In the frontal plane, lateral or medial stuffing by 2mm (2 deg) led to forces increases of 40-70N in early or late flexion. Varus-valgus effects showed balancing when the lift-off moments in varus and valgus were equal. The experiments showed that the Orthosensor tibial trial was able to provide quantitative data during well defined tests, from which a choice of different Corrective Procedures (Surgical Variables) was predicted in order to achieve balancing. The method allowed for the primary Correction to be carried out first, followed by a secondary Correction.