VALIDATION OF CALIBRATION TECHNIQUES FOR TEKSCAN PRESSURE SENSORS

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INTRODUCTION

Thin, flexible pressure sensors are often used in orthopaedic biomechanics to measure loads in the knee joint. Prior to using sensors in cadaver and clinical studies, it is important to show that the results they provide are accurate under the proposed testing conditions. Other investigators have previously validated Tekscan I-Scan pressure sensors (Tekscan, Inc., Boston, MA) for accuracy and repeatability of force and force distribution measurements [1]. The current validation study aims to demonstrate that user-defined calibration algorithms provide more accurately calibrated force measurements than the Tekscan built-in calibration routines.

METHODS

Three new, identical I-Scan pressure sensors (model #5051-2500) were loaded using a materials testing machine (Instron 8874, Canton, MA). To simulate the loading in a prosthetic knee joint, each sensor was compressed between a flat disk of UHMWPE (D = 3.82 cm) and a larger aluminum plate. To reduce shear loads at the sensor surfaces, sensors were coated with K-Y lubricant (Johnson & Johnson, Montreal, Canada).

Sensors were conditioned four times at a load of 20.0 kN (120% of the maximum expected pressure). Four different calibration methods were used: a Tekscan linear calibration (performed at two different scales), a Tekscan power calibration, a user-defined 10-point cubic calibration and a user-defined 3-point quadratic calibration. The Tekscan linear calibrations were performed at 20% and 80% of the maximum applied load; the Tekscan power calibration was performed using both of these loads. All Tekscan calibrations pass through (0,0). The user-defined polynomial algorithms used a least squares curve-fitting technique.

Following conditioning and calibration, each sensor was subjected to 3 loading cycles consisting of 10 loads between 0 and 16.7 kN applied in a random order. Throughout conditioning, calibration and loading, forces were ramped up over 10s, held for 5s, and decreased over 10s. Sensors remained unloaded for 120s between load applications. Force data were saved as raw (uncalibrated) values; each calibration algorithm was applied to the same output. Force measurement error was defined as the difference between calibrated Tekscan output and Instron load cell measurements.

RESULTS AND DISCUSSION

Figure 1 shows the typical calibrated output for one sensor using the 5 calibrations. Of the 3 Tekscan calibrations tested, the power calibration was the most accurate (Figure 2); the root mean square (RMS) errors of the measured forces for the 20% linear, 80% linear, and power calibrations were 4.07±0.21 kN, 1.75±0.09 kN, and 0.447±0.16 kN, respectively, corresponding to 24.4%, 10.5% and 2.7% of the tested sensor range. The user-defined polynomial calibrations were markedly more accurate; the quadratic and cubic calibrations had RMS errors of 0.24±0.15 kN (1.5%) and 0.10±0.03 kN (0.6%), respectively. While most studies do not report their calibration procedure, the previous study which used the Tekscan power calibration found a higher, but comparable, RMS error of 6.5±4.4% [1].

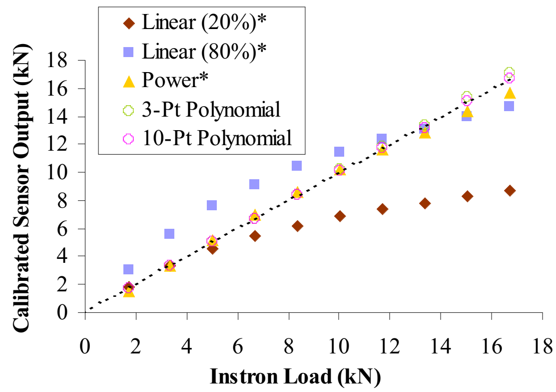

Figure 1: Typical sensor output calibrated using Tekscan (*) and user-defined algorithms.

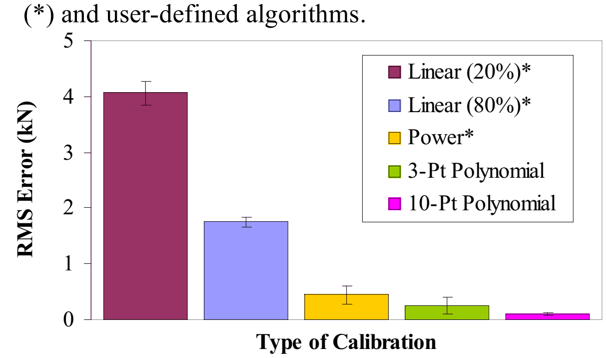

Figure 2: Average RMS errors of Tekscan (*) and user-defined calibration techniques.

CONCLUSIONS

I-Scan force measurements may be accurate to within 0.6% when calibration algorithms use a least squares minimization technique. Although the 10-point cubic polynomial was the most accurate algorithm, the loading process is considerably more time-consuming. The 3-point quadratic calibration requires only one additional calibration load compared to the Tekscan power calibration and decreases the error in force measurement from 2.7% to 1.5%. Since it is straightforward to export sensor output and calibrate data externally, it is recommended that investigators design their own calibration curves. Since output is dependent on experimental protocol (sensor type, interface materials, sensor range in use, etc.), sensor behaviour must be investigated for each application.

REFERENCES

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