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Combining Multiple Technologies to Optimize Surgical Outcome in Total Knee Arthroplasty

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Abstract

Purpose
Innovative technologies such as robotic assistance and intraoperative load sensors for total knee arthroplasty (TKA) aim to reduce outliers, as well as to address patient dissatisfaction. There is currently no information available that assesses the findings of using these technologies together during TKA.

Methods
Intraoperative data on alignment, gap spacing, and quantitative balance was prospectively collected in a cohort of 79 consecutive TKAs performed with robotic assistance. An instrumented trial component was utilized that captured medial and lateral tibio-femoral loads, allowing the quantitative assessment balance.

Results
Of the 79 knees, 58 (73%) had varus alignment and 21 (37%) had valgus. We divided these groups into correctable and fixed deformities**. Correctable varus knees**: At trial reduction 30% of the knees demonstrated quantitative imbalance at trial reduction. **Fixed varus knees**. At trial reduction 55% (of knees were deemed imbalanced. **Correctable valgus knees**: At trial reduction, 35% were imbalanced. **Fixed valgus knees**: Half of the knees (n=2) were imbalanced at trial reduction. The imbalance in all groups was addressed with combinations of bone and soft tissue adjustments so that at final implantation 99% of cases (n=78) were quantitatively balanced

Conclusion
While the robot was both precise and accurate with its cuts to create appropriate gap spaces, only 57% were quantitatively balanced. Ultimately, almost all knees were balanced with final implants, but that state required the use of additional techniques, including soft tissue and bony modifications. More data is needed to determine if these technologies will equate to increased clinical success.

1 Introduction

Innovative technologies such as robotic assistance and intraoperative load sensors for total knee arthroplasty (TKA) aim to reduce the clinical and radiographic outliers, as well as to address patient dissatisfaction. Previous technology such as imageless navigation and patient specific instrumentation failed to meaningfully improve patient outcomes[1-2]. Sensor technology that assists the surgeon in quantitatively achieving a state of balance has

been shown to improve patient outcomes[3]. The current generation of robotic techniques allow patient specific implant placement based on computed tomography images and intraoperative assessment of ligament tension and deformity. Intraoperative load sensors supply the surgeon with real time data regarding loads across the knee joint. There is currently no information in the literature that assesses the findings of using these technologies together during TKA. The authors hypothesized that robotic derived gap symmetry does not alone yield quantitative knee balance.

2 Methods

Intraoperative data on alignment, gap spacing, and quantitative balance was prospectively collected in a cohort of 79 consecutive TKAs performed with robotic assistance. For extension gap construction, the surgeon used variable angle distal femur and proximal tibial resection angles, no greater than 2 degrees per bone from neutral mechanical alignment. The necessity and degree of angular deviation from neutral was based on surgeon assessment of gap symmetry derived from the robotic system. The 2-degree boundary from neutral was surgeon preference. The flexion gap was constructed, using a tensioner and adjusting the femoral rotation and position to achieve a symmetric flexion space equal in size to the extension space. An instrumented trial component was utilized that captured medial and lateral tibio-femoral loads, allowing the quantitative assessment of the state of balance through the range of motion. As previously reported, an absolute mediolateral load differential of less than 15 lbs. was characterized as balanced. Additionally, even if symmetric, loads less than 5lbs were characterized as too loose and loads greater than 40lbs were deemed too tight.

3 Results

Of the 79 knees, 58 (73%) had preoperative varus alignment and 21 (37%) had preoperative valgus. We further divided the groups into correctable and fixed deformities. Correctable deformities were those that, with manual intra-operative stress, corrected to 3 degrees or less to a neutral mechanical axis. Thus, we had 4 groups for analysis: 23 correctable varus knees, 35 fixed varus knees, 17 correctable valgus knees and 4 fixed valgus knees. **Correctable varus knees**: The planned extension and flexion gaps were all planned for symmetry or 1mm asymmetry. Despite this, 30% (n=7) of the knees demonstrated quantitative imbalance at trial reduction. The trial gap data for these knees correlated with sensor data in 2 cases and did not correlate in the remaining 5. Final limb alignment was within 3 degrees of neutral in all these cases. **Fixed varus knees**: The extension gaps were planned for symmetry in 23% of cases, 1mm asymmetry in 43% of cases, and 2mm asymmetry in 34% cases. The flexion gap plan was for symmetry in 55% and 1mm asymmetry in 45% cases. At initial trial reduction 55% (n=19) of knees were deemed imbalanced. In 58% of the unbalanced knees (n=11) the robotic derived gap data noted symmetry or gaps asymmetry opposite of the imbalance. Final limb alignment was within 3 degrees of neutral in 40% of cases, 4-5 degrees off neutral in 43%, and 6 degrees or greater variance in 17%. **Correctable valgus knees**: In these 17 knees, all but one was planned for symmetric or 1mm asymmetric flexion and extension gaps. At trial reduction, 35% (6 knees) were imbalanced. The trial gap data correlated with the imbalance in 1/3 of those but demonstrated symmetry in 2/3 unbalanced cases. Final limb alignment was within 3 degrees of neutral in all cases. **Fixed valgus knees**: There were only 4 knees in this group, with ¾ gaps planned for symmetry or 1mm asymmetry in extension and flexion. Half of the knees (n=2) were imbalanced at trial reduction, with the trial gap data showing symmetry in both of those cases. Final limb alignment was within 3 degrees of neutral in 2 cases and 4 and 5 degrees in the other 2 knees. The imbalance in all groups was addressed with combinations of bone and soft tissue adjustments so that at final implantation 99% of cases (n=78) were quantitatively balanced.

4 Conclusion

Combining multiple technologies in TKA allows the optimization of both patient specific component placement and soft tissue driven adjustments to create precise gap spaces and quantitative balance. A goal of this study was to elucidate the relationship between robotic system established gap spaces and the quantitative data provided by intraoperative load sensors. While the robot was both precise and accurate with its cuts to create appropriate gap spaces, only 43% were quantitatively balanced. Ultimately, almost all knees were quantitatively balanced with final implants, but that balanced state required the use of several additional techniques, including soft tissue balancing and additional bony modifications. The author's focus on achieving balance as a paramount goal in TKA is supported by recent studies. These include a prospective study has demonstrated that a balanced knee has improved patient reported outcomes compared to knees that are imbalanced [4]. Additionally, there is also data to suggest that a surgeon "feel" is a poor predictor of balance[5]. These technologies are powerful adjuncts to TKA but used alone have some limitations. More data is needed to determine if these technologies will ultimately equate to increased clinical success.

References

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