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Introduction: An emerging consensus in the surgical specialties is that skill acquisition should have a greater emphasis during surgical training.1 In order to enhance the ability to correctly execute a surgical skill, training should focus on both the technical and the cognitive aspects of surgical methods, giving surgeons tools to properly judge the correctness of an action2 while maintaining the overall goal of proficiently using a system or technique in the intense environment of the operating room. This study was an attempt to evaluate the effects of repetitive practices using an image-free computer-assisted orthopedic surgery (CAOS) guidance system (ExactechGPS, Blue-Ortho, Grenoble, FR) on both technical and cognitive skills.

Methods: We used a commercially available artificial leg (MITA trainer leg M-00058, Medical Models, Bristol, UK) compatible with modular, synthetic knee models simulating the proximal tibia and distal femur. We randomly and sequentially used simulated knees from a pool of varus-deformed (n=12), neutral (n=12), and valgus-deformed (n=4) models (MITA knee insert M-00566, M-00598, M-00567; respectively, Medical Models, Bristol, UK). A senior knee replacement surgeon with limited previous experience using the CAOS system performed the simulated surgery, including the following key steps: (1) define resection parameters for the proximal tibial and distal femoral cuts (2) attach the system trackers to bone, (3) acquire landmarks,(4) adjust the cutting blocks, (5) perform cuts, (6) and check the cuts. In order to assess the effects repetitive practice has on technical skills, we evaluated two indexes:
- Error index: A unitless indication of overall error magnitude obtained by averaging the absolute values of all linear and angular measurement differences between steps 1 and 6.
- Time index: An indication of the time required to acquire landmarks (i.e., step 3), adjust the custom blocks (i.e., step 4), and make cuts (i.e., step 5).

In order to assess the effect repetitive practice has on cognitive skills, we evaluated the number of times the surgeon elected to deviate from pre-surgical planning or re-acquire landmarks.

Results: On one hand, from Group A to Group C, the variability of surgical errors (reflected by standard deviations) remained at the same level. The error index failed to reach significance along the course of the practice and ranged between 0.45 to 0.71 for all three groups.

On the other hand, the variability of surgical time at key steps reduced substantially from Group A to Group C. Statistical improvements in terms of surgical time were also detected on several comparisons throughout the course of the practice.
Finally, the surgeon elected to re-perform the landmarks acquisitions on the femoral side 8 times, 4 times, and none for the Group A, B, and C respectively.

**Discussion:** The authors attempted to delineate the effects of repetitive practices on skills using a CAOS system. The overall perception was the number of sequential practice surgeries had no significant effect on surgical accuracy. Regardless of the number of operations, the surgeon consistently performed tibial and femoral cuts associated with a low error index, meaning the continuous guidance offered by CAOS system provided an opportunity to correct any discrepancies from the plan during the surgery. The significant decrease in the time index during the course of the practice surgeries is in line with recent studies regarding the learning curve associated with navigation for knee arthroplasty. In our case, the combined mean duration for acquisition, adjustment, and cut was reduced by more than 43% from Group A to Group C, which correlates with the outcomes from Karia et al. who report procedure time decreased by more than 36%. As another important observation, the variability of surgical time at key steps also decreased substantially from Group A to Group C, reflecting a more consistent and proficient operation along the course of the practice.

Last, the addition of continuous feedback from the CAOS system was deemed important in helping the surgeon detect potential errors and then act. Compared to the initial planning, the only modifications in surgical steps were related to re-acquiring femoral landmarks.

As with any image-free system, the present CAOS system relies on precise landmark acquisition. To achieve this goal, the system under consideration presents an interactive software enabling landmark visualization (Figure 1).

**Figure 1:** Image of the CAOS system display unit rendering femoral landmark acquisitions.
This feedback loop was perceived to be essential, as it allowed the surgeon (1) to quickly check landmark acquisition before advancing to the next step and (2) learn from previous experiences in order to perfect his version of the overall technique.

**Significance:** Direct feedback loop as provided by CAOS guidance system was perceived to be essential, as it allows surgeons to properly judge the correctness of an action, and then learn from previous experiences in order to perfect his surgical skills.

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