

Surgical Planning Education Using a Digital Platform

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Introduction: Formal preoperative planning increases surgical efficiency, helps communication with operating room personnel, and improves patient outcomes. The Bonesetter App (Bonesetter Solutions, Ann Arbor, MI) is a free online educational planning tool for digital images. The purpose of this study is to evaluate learner and educator efficiency with this tool in Association for the Study of Internal fixation AO courses.

Methods: The Bonesetter App was used for digital planning in 8 AO Trauma Advanced Principles courses (>500 participants), 1 AO Trauma Basic Principles course (120 participants), 1 AO Trauma North America Deformity and Nonunion course (178 participants), 2 AO Recon courses (32 participants, 16 participants), and 1 AO Trauma North America Lower Extremity Deformity and Nonunion course (32 participants). Data included saved plans, participant evaluations, and faculty feedback.

Results: In the AO Trauma North America Deformity and Nonunion, 655 entries with 3275 tasks were evaluated with 74% of the exercises performed correctly. Difficulties included understanding retrotorsion/antetorsion of the femur and total deformity calculation. The AO Trauma North America Advanced Principles had difficulty with equipment, faculty discomfort with the application which led to improvements in the equipment, software, and teaching material. Participants of the AO Recon, Deformity and Nonunion courses provided overwhelming positive feedback, but only a 40% completion rate of exercises.

Conclusions: Remote learning platforms and digital planning are new tools for the AO courses. Hurdles develop when implementing new technology, including training faculty, making tools user friendly, and affordable. These tools can show whether participants are performing skills correctly and where educational difficulties are encountered, so teaching strategies can change.

Key Words: remote learning platforms, digital planning, preoperative planning, educator efficiency

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INTRODUCTION

Operative management begins with preoperative planning. Although often viewed as a time-consuming process with little actual benefit, surgeons who neglect the formulation of a surgical tactic often prove true the maxim, “failing to plan is planning to fail.”^{1,2}

The steps of preoperative planning first described by Lambotte³ have been popularized throughout Arbeitsgemeinschaft für Osteosynthesefragen (AO) fracture courses and are part of nearly every orthopaedic resident’s training. The materials required include radiographs of the fractured bone, a radiograph of the contralateral uninjured extremity, templates of implants, tracing paper, and colored pens. The overlay technique¹ begins with making a tracing of the injured and uninjured sides. The intact tracing is placed over the fracture tracing, and the fracture pieces are traced onto the uninjured side creating a template for the position of the fracture pieces once they have been completely reduced. Various aspects of the plan are then considered such as the surgical approach, methods of preliminary fixation, and optimal handling of the soft tissues. Once these factors have been considered, implants are selected, and the order of placement is described and this is termed the “surgical tactic.” Logistics represents the management of resources for an operation, for example, the type of operating room table, patient positioning, use of intraoperative imaging, and required implants. Together, these form a comprehensive surgical preoperative plan.^{1,2,4} However, despite considering preoperative planning to be important, surprisingly few surgeons routinely create a preoperative plan.⁵

There may be several reasons for this disconnect. With the move to digital imaging at most modern centers, it has become cumbersome to obtain a key component required for the creation of the traditional preoperative plan—the printed radiographs of the injured and uninjured extremities. Commercial solutions have been developed in an attempt to compensate for the lack of physical radiographic films. Their cost may be prohibitive, and they may not provide the functionality or implant selection desired by the surgeon.

It was with this preamble that we found ourselves at our US county hospital, with a lack of resources to purchase digital planning software, which also did not address many of our needs. We felt that video games cost about 50 US dollars and

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were much more complex than digital planning software developed by companies that wanted thousands of dollars for very little return. The problems that had to be overcome were a library of implant templates, sizing of radiographs, measuring tools and the ability to cut and paste fracture fragments, osteotomies, or bones for joint replacement. An application (App) was created at our institution with programmers to solve this dilemma. The AO provided a unique environment to develop this tool, test it, and rework it so that the App could be used in multiple educational situations and environments. Regarding this, we have partnered with many AO surgeons, staff, and participated in courses. This has led to a point where the Bonesetter App (Bonesetter Solutions, Ann Arbor, MI), a free online program, has the ability to aid surgeons and orthopaedic residents in their quest to plan their operations. The purpose of this descriptive paper is to detail the capabilities and review the educational experience with the App thus far.

METHODS

Development: The Hardware/Access

The App was designed to be web-based so that it can be used on any personal computer, smartphone, or tablet device with internet access. The website is <https://detroitbonesetter.com>. We found that residency programs wanted to plan as groups, so group logins were developed so that radiographs and computed tomography scans could be placed in a folder and multiple users could use them for planning and altering each other's surgical tactics at the same time. The program had to be Health Insurance Portability and Accountability Act compliant so there is a function to remove any words and numbers before entering an image into the program. Sizing is very important and so there are 4 ways to size the images correctly: (1) with radio-opaque markers that are recognized by the program, (2) with a ruler on the radiographs, (3) sizing to images that have been already imported from the same patient, and (4) sizing to a standard template of body parts that are in the program that have been sized to an average from the bones of 100 individuals from our practice.⁶

Internet Access

We discovered that internet access is an issue for many courses because organizers of events are charged per user at hotel venues. Thus, we developed a downloadable version called Learn. detroitbonesetter.com, which can be used to make any teaching module. The teaching module can be downloaded directly to the device you want to use without the need of internet access. For the AO Trauma North America Advanced Fracture Principles course, this was an iPad (Apple Inc, Cupertino, CA).⁷ For the basic course, it was downloaded to a personal computer or Mac computer or used online.

Tools

We added tools for measurement including distance, angle, area, tracing, cut out inverting, grouping, opposite side templates, and a tool to show progression of your case. Specialty tools for deformity planning (right deformity and left deformity) can measure coronal deformity and move with the bones after osteotomy. For arthroplasty, Ranawat angles

and an acetabular anteversion tools were developed. For fracture implants, a plate bending tool and the ability to overlay radiographs were developed, and a tool to enter or make your own templates and store them in your account. A text box was added for the logistical component of the plan.

COVID-19

The pandemic made it necessary for courses to be virtual. The challenge for any course was to evaluate practical skills exercises. When exercises were performed, there had to be a way to check them and give feedback. The use of online video conferencing and web meeting platforms were embraced for virtual meetings and were used for AO Trauma North America courses such as the Basic Principles and Advanced Fracture, Lower Extremity Deformity, and Nonunion courses.⁸ The ability to demonstrate on an online meeting platform, and then put forth exercises on the Bonesetter Learn App provided an opportunity for teaching surgical planning and deformity measurement, assessment, and feedback.

Deployment

The Bonesetter App was used for digital planning on 8 live AO Trauma North America Advanced Fracture Principles courses (>500 participants), 1 AO Trauma Middle East Basic Fracture Principles course (120 participants: Middle East, Assiut, Egypt), a virtual AO Trauma North America Lower Extremity Deformity and Nonunion course (178 participants), 2 AO Recon courses (32 participants, 16 participants), and a blended AO Trauma North America Lower Extremity Deformity and Nonunion course (32 participants). Data included saved preoperative plans from the blended and virtual AO Trauma North America Advanced courses, Lower Extremity Deformity, and Nonunion courses, participant evaluations at the online AO Foundation Recon and deformity courses, and from faculty of the other events.

RESULTS

AONA Advanced Fracture Principles Course Proximal Femoral Osteotomy Module Live Events (2016-Current, https://www.youtube.com/watch?v=_3ocbyjb7S4)

In 8 live AO Trauma North America Advanced courses with approximately 500 participants, the proximal femoral osteotomy module was used for a femoral neck fracture nonunion (2017–2021). Challenges occurred with this lab and the App. Problems included difficulty with Wi-Fi early on leading to the development of the App that was downloaded on iPads. Other hardware improvements included switching from the 100 US dollar iPad pen to 3 US dollar generic styluses that performed better and did not require charging. The faculty had a much harder time learning the App than participants who were more comfortable with modern digital media. Teaching planning on the App was streamlined by teaching the tools online before the course⁷ and then chunking the workflow into 7 parts via a prerecorded video session to minimize challenges with live

demonstrations. These 7 parts included: (1) measurement of the resultant deformity including leg length discrepancy, neck shaft angle, and Pauwels angle; (2) tracing the fractured proximal femur; (3) using the contralateral proximal femur as a template; (4) creating an opening wedge osteotomy; (5) medializing the proximal fragment to get the correct height; (6) placing the 120 degree angled blade plate (Depuy Synthes, Paoli, PA); and (7) applying Kirschner wire markers for reverse planning of the osteotomy on the operative side. In the latest version of the App, this module worked seamlessly (Fig. 1).

AO Middle East Basic Fracture Principles Course, Assiut, Egypt (March 2018)

There were 120 participants. The Bonesetter App was introduced as an alternative to planning for the forearm fracture bone model on paper. The internet connection was unreliable so a USB drive with the program was distributed to all the participants. Participants attempted to complete both tasks. The problem for the course was that many participants only had a cell phone available as their device (about 30% of participants had PCs and could use the App well). Others with android phones and pencil type styluses were also able to complete the task. Those without styluses or those with iPhones were not able to complete the task at all because using one's finger was not an accurate method of the manipulating the tools. For courses where the internet connection may not be reliable, the downloadable version of the exercise is mandatory.

AO Trauma North America Lower Extremity Deformity and Nonunion Course (Virtual, https://www.youtube.com/playlist?list=PLK_-TIY7xyD45C4upDXXY5xK28_3P4k6t)

During the virtual AO Trauma North America Lower Extremity Deformity and Nonunion course, 178 participants learned how to measure coronal, sagittal, and axial alignment through lectures and tutorials. There were 8 modules (4 on coronal alignment and 4 on axial alignment). There were 655 participant entries with 3275 tasks that were saved and evaluated.⁸

In 238 entries encompassing 1190 measurements for 4 cases measuring axial alignment, the success rate for completing the task correctly 5/5 points was 158/238 (66%). It improved from 56.25% for case 1 to ~80% for the last 2 cases. We discovered that the SD of these angular measurements for all measurements was ± 4.29 degrees. It was found that participants easily found a measurement for the posterior condylar axis of the femur (SD ± 1.6 degrees), but the landmarks of the femoral neck (SD ± 4.5 degrees) and bimalleolar axes (SD ± 4.2 degrees) were more difficult for them to reproduce ($P < 0.001$). Participants had trouble with adding and subtracting numbers when retrotorsion of the femur was an issue that led to 8% calculating errors versus 2% when there was normal anteversion. Direct measurements of the angles versus measuring to horizontal lines and then adding or subtracting lead to less variation and errors (participants who used the horizontal line method were

more likely to measure outside of 1 SD than the direct method, $P < 0.025$) (Fig. 2).

The number of measurements from each method outside 1 SD was totaled for right and left tibial torsion in all 4 cases and ranked from low to high in a Mann–Whitney U test. The direct method ($R = 169.5$) produced less measurements outside of 1 SD than compared with the horizontal line method ($R = 358.5$); the test statistic for the directional measurement was used, $U_{0.01,16,16} = 169.5$, $p < 0.025$. Participants who used the horizontal line method were more likely to measure outside of 1 SD, then the direct method ($P < 0.025$).

Case 1: <https://www.youtube.com/watch?v=HL8wq8mUL7o>.

Case 2: https://www.youtube.com/watch?v=4y_OYq7RZIQ.

Case 3: <https://www.youtube.com/watch?v=5RJNvpJ5R00>.

In 417 entries, we evaluated the completion of 2085 tasks for coronal alignment. Each exercise had 5 components: the leg length or leg length discrepancy, total deformity, femoral deformity, joint line deformity, and tibial deformity. To complete the task correctly, all 5 tasks had to be correct for each exercise. There was a 76% success rate for the 4 tasks. Thirty four percent of the participants attempted the exercise more than once (best completed exercise was chosen). The most errors during the trials were made when measuring the total deformity (12%) and joint deformity (9%). Instructors should repeat how to do these measurements during the tutorial several times because once you have failed at the total deformity measurement, the rest of the tasks follow along (Fig. 3). The average SD of length measurements across the exercises was ± 0.29 cm (417 measurements) and for angular measurements it was $+0.71$ degrees (1668 measurements) between participants. This was calculated from participants who correctly completed the tasks. It shows the accuracy of multiple individuals being able to get the same answer with this digital planning tool. The measurement of coronal deformity using the hip center tool and easily identifiable lines such as the distal femur and tibial plateau was much better than that of axial measurements ($P < 0.001$).

In addition to the course, the recorded teaching sessions and exercises are available on the AONA YouTube (San Bruno, CA) channel: https://www.youtube.com/results?search_query=aona+north+america+youtube+channel.

To date, 127 more participants have completed the coronal exercises on their own and 52 more have completed the axial exercises.

Case 2: https://www.youtube.com/watch?v=t7c7GBUeu7o&list=PLK_-TIY7xyD45C4upDXXY5xK28_3P4k6t&index=55.

Case 3: https://www.youtube.com/watch?v=1n-XH3_oFaI&list=PLK_-TIY7xyD45C4upDXXY5xK28_3P4k6t&index=51.

AO Recon Principles and Complex Hip/ Blended AO Trauma North America Lower Extremity Deformity and Nonunion Courses

The Bonesetter App was used for an AO Recon pilot course (32 participants), AO Recon Complex Hip course

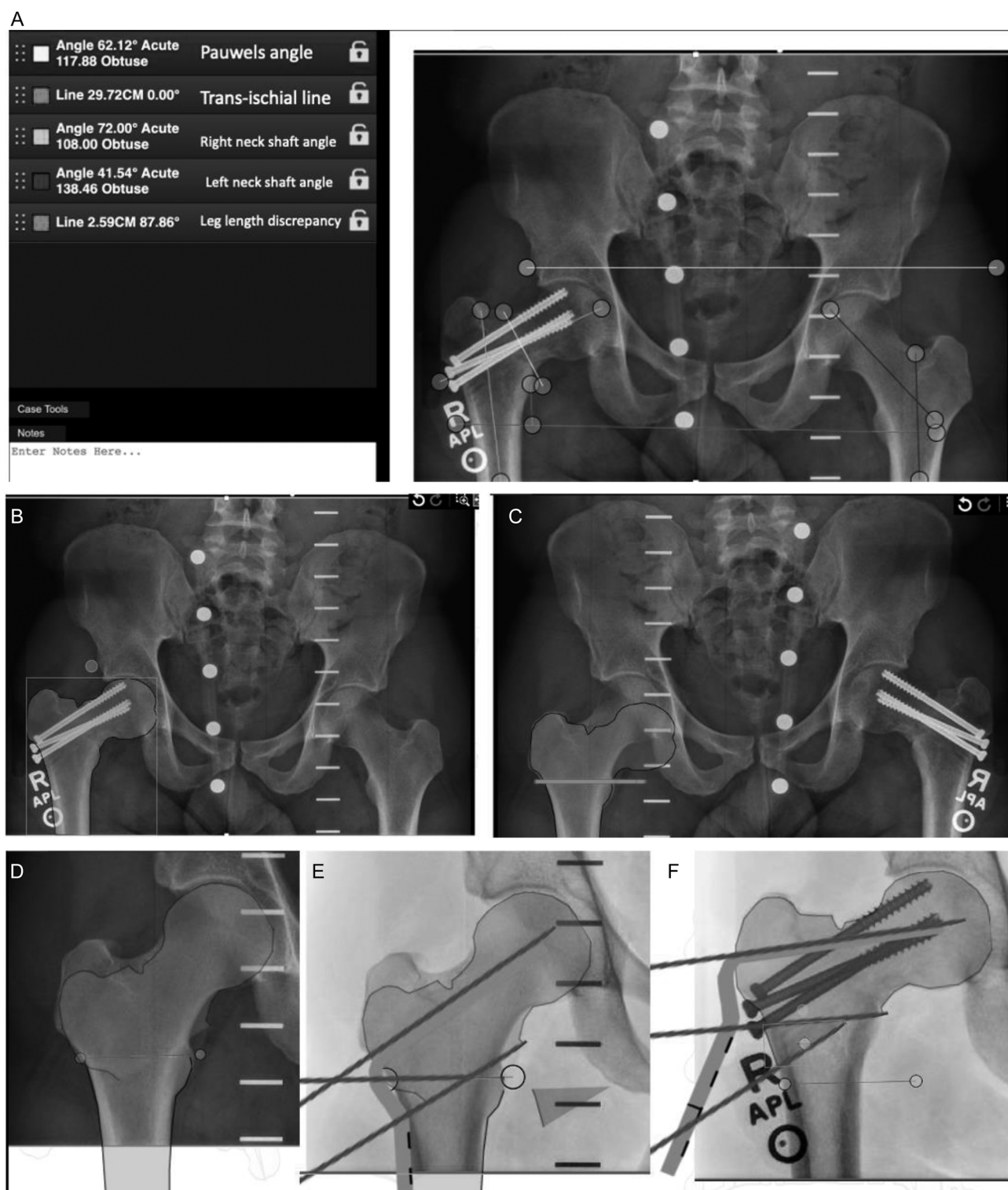


FIGURE 1. Nonunion of a femoral neck fracture with varus collapse for osteotomy. A, The first step is to measure the neck shaft angle on both sides, leg length discrepancy, and Pauwels angle. B, The trace tool is used to draw the fractured proximal femur. C, The pelvis radiograph is flipped over and used as a template for the osteotomy of the right hip, which is made just at the level of the lesser trochanter. D, A 30-degree valgus osteotomy is made with the proximal femur moved to mimic the length of the opposite side. E, The 120-degree blade plate is applied and k-wires are used to mark its location and the osteotomy. F, The image is then templated again on the fractured side to mark the k-wires for blade plate insertion and the osteotomy cuts.

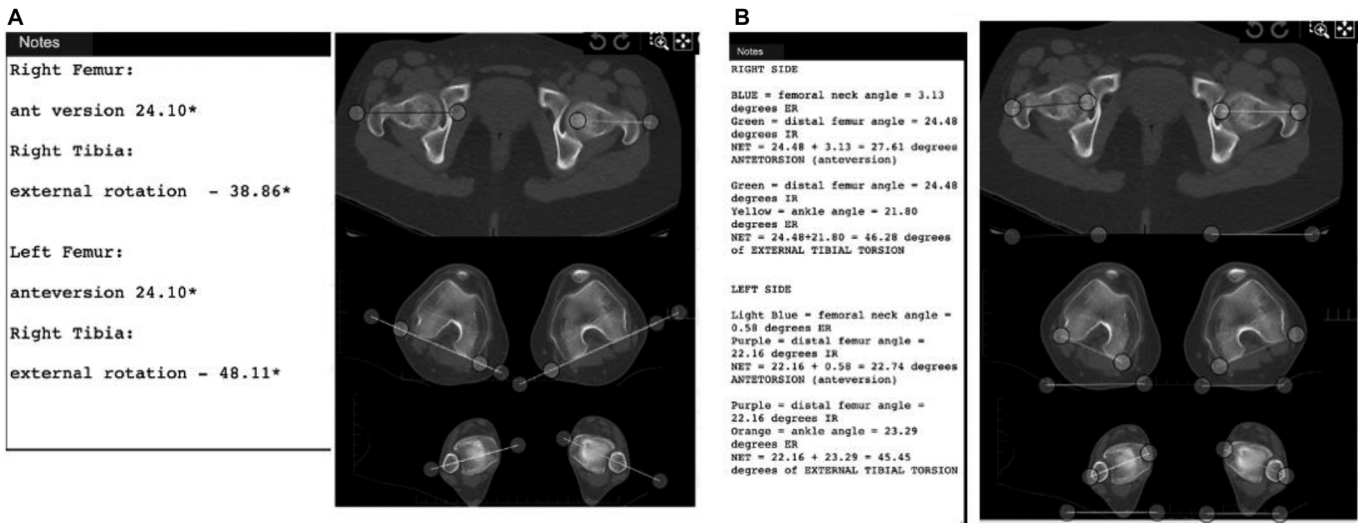


FIGURE 2. Measuring axial alignment—AONA osteotomy course. A, Measuring axial alignment using single angles between the proximal femur and distal femur and the distal femur and the ankle axis. B, Using horizontal lines to measure each location the proximal femur, distal femur, and ankle axis. The distal femoral axis was easiest to reproduce with the proximal femur and distal ankle axis measurements had more variability because there are poorer landmarks.

online (16 participants), and a blended AO Trauma North America Lower Extremity Deformity and Nonunion course (32 participants). There were 2 modules in the AO Recon Principles pilot course, 5 modules in the AO Recon Complex, and 5 in the AO Trauma North America Lower Extremity Deformity and Nonunion pilot course. Participants had a

positive opinion of the exercises and 46% of the participants completed the cases (Fig. 4). In these courses, we did not evaluate the data except to see whether the plans were performed reasonably and in 72% of cases, a reasonable rendition of a plan was completed and in 28%, a plan was started but not completed.

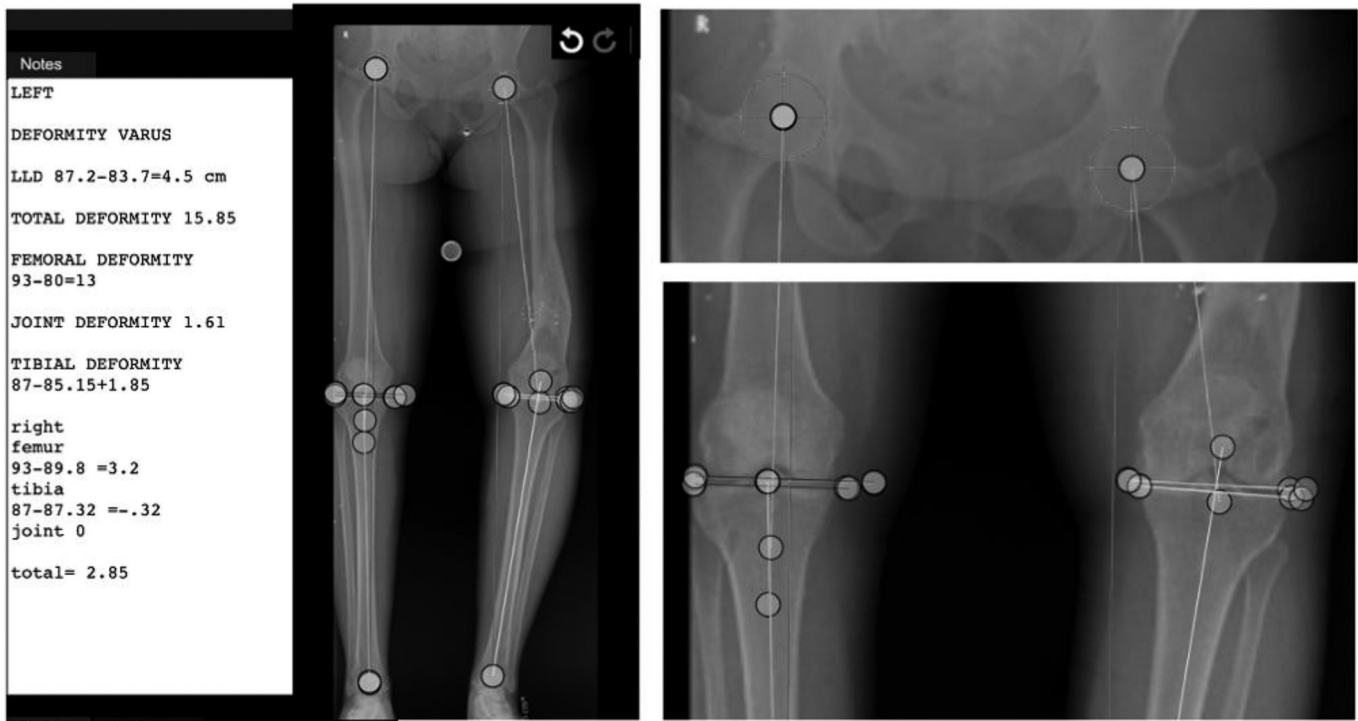


FIGURE 3. Measuring coronal alignment—AONA osteotomy course. Measuring the total deformity, femoral deformity, tibial deformity, and joint deformity to then assess which location the deformity is in.

DISCUSSION

The AO has been a champion of preoperative planning in its courses, publications, and online resources. A preoperative plan enables the surgeon and the operating room personnel to ensure the required instruments and implants are prepared in the operating room before beginning the case. Radiology can be prepared with intraoperative fluoroscopic equipment setup and ready to go in the desired position, and the anesthesia team can follow the anticipated flow of the case to ensure smooth and timely emergence from anesthesia. A well-formulated preoperative plan leads to smoother cases with less stress, and operating room personnel are more likely to have a positive view of the surgeon as competent and dependable. Better outcomes and increased safety typically result from solid preparation and are a direct benefit to the patient.^{1,2,4} In addition, a detailed preoperative plan can be discussed with the patient and included in the medical record, providing and documenting a thorough discussion of the risks and benefits of surgery.

The Bonesetter App was developed as a digital planning tool for the tactics and logistics that are required for an effective preoperative plan. The move to digital imaging was an opportunity to develop digital planning tools that are portable, accurate, and sharable for collective planning and education. Through courses, interaction with AO faculty and users, the online planning tool has morphed into a tool that can be used for various orthopaedic surgical specialties: trauma, total joints and deformity, and for educational courses.

The App was used for preoperative planning an osteotomy of the proximal femur in the AONA Advanced Principles course. It replaced a paper and pencil exercise, which is rarely possible because of digital imaging. Through several courses, glitches in the software, hardware, and education format lead to a lab that could be accomplished by all participants, and used to plan real proximal femoral osteotomies. For the Basic course, the AO felt that at least 1 paper and pencil exercise should be completed by residents in their career and for now the digital exercise is on the back burner. During the online AONA osteotomy course, we were able to assess each individual's ability to learn and preform the skills of deformity measurement, give real-time feedback, and discover where difficulties exist in teaching these skills. At the course, instructors need to explain retrotorsion and antetorsion and internal and external rotation with greater care, because this was a common mistake within the data. Thus, the next time this course is taught, focus can be on reinforcing the total deformity measurement in the coronal exercises and understanding anteversion and torsion and retroversion and torsion of the femur to develop better methods of measuring the femoral neck and distal tibial measurements.

The Covid-19 pandemic was an opportunity to shift to online and remote learning. Despite engaging participants online for virtual AO Foundation courses, there is still a disconnect that occurs. In several courses, less than half of the participants actually completed or even attempted the exercises unlike in the live events where there is approximately 100% engagement and effort to complete the tasks. This is likely true for other assignments besides just digital planning. At live

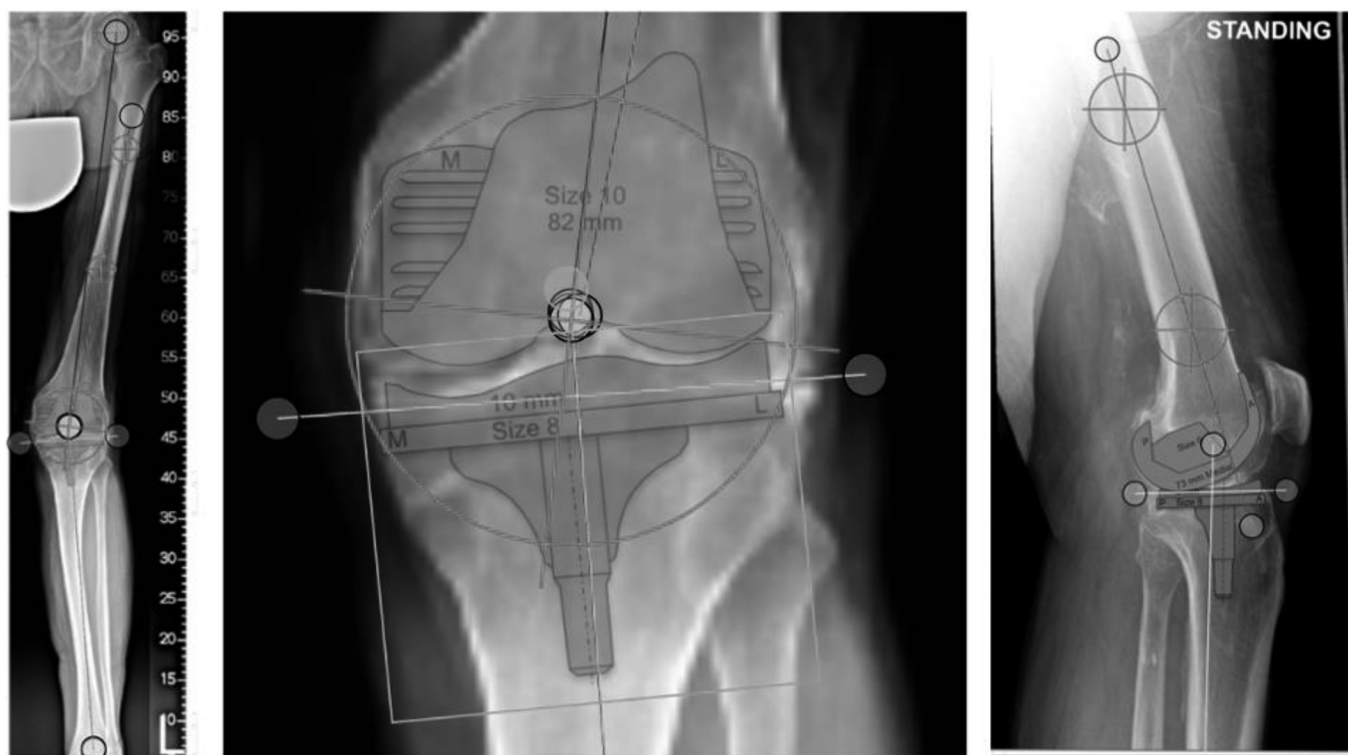


FIGURE 4. The AO Recon knee course. Measuring alignment and then placing the implants in the correct location.

events, participants are engaged and separated from other work and life issues, and can focus on learning. This is a real challenge with online learning. With online courses, lecture videos, exercises, and skills modules can be left online without expiration. Participants can access the information indefinitely.

The main shortcomings of the Bonesetter App were its reliance on the internet and difficulty with use on a smartphone. However, the reliance on the internet was resolved with downloadable modules. The difficulty of using the App with a phone device still exists. This may not be solvable because of the resolution, size of the screen, and manipulation controls available.

Other challenges with the process included faculty engagement and use during courses, and established surgeon participant incorporation into their practice. Having faculty who are unfamiliar with the app and its functionality make it challenging for faculty to teach using the App. Up until now, there has been a paucity of AO faculty who are comfortable teaching the App, but there are approximately 10,000 participant users worldwide who use the App routinely. To meet the needs of the learners, perhaps better videos or a course on digital planning would be appropriate. Alternatively, exclusively using faculty who are comfortable with digital planning to teach the planning component of the courses could prove successful.

Currently, several digital planning platforms are available. The barriers that exist for a lot of surgeons worldwide including platform cost and the need to work with individual picture archiving communication systems. Most of this software validation was performed for arthroplasty sizing and not fracture or deformity, where preoperative planning may be more critical. Many digital platforms also lack the same capability to manipulate radiographs or use in an educational environment.^{9–13} However, with the Bonesetter App, access is free, radiographs may be uploaded via screenshot, exported from picture archiving communication systems, or simply a photo. Validation of the software has been performed with arthroplasty, deformity, and fracture cases.

CONCLUSION

Through virtual and blended educational events, participants were introduced to digital templating; they were

taught the tenets of the surgical tactic, logistics, and how to formulate a preoperative plan. Many participants were able to correctly measure deformity and plan surgery, which could be evaluated directly by the faculty. Errors could be observed and corrected by faculty. Online material was developed that learners and faculty could practice repeatedly using YouTube videos with answers to reinforce knowledge and exercises that are freely available. Remote learning platforms and digital planning are new tools for the AO in courses and for participants. There are many hurdles to implementing new technology, including training faculty and making tools user-friendly, helpful, and affordable.

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