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Innovation in Orthopaedic Surgery Education: Looking Through the Past to the Future

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Summary

From the non-surgical advancements of the 18th century to the surgical revolution of the 20th, orthopedics is a field with great potential for innovation. Fast forward to the 21st century and the rise of the digital age has brought an abundance of technological innovations into the orthopaedic landscape. Due to recent challenges associated with the current pandemic, these innovations, both existing and new, are rapidly transforming the way we educate our orthopaedic trainees.

Insights

- Understanding the context of past orthopaedic innovations helps us to appreciate how different innovations have emerged alongside social and cultural phenomena.
- Recently, the pandemic has presented yet another example of how a public health crisis and resulting social disruptions can impact the orthopaedic community.
- One of the main challenges so far has been addressing the educational gap caused by institutional closures and the suspension of many clinical training experiences.
- To solve this, leaders in the field have drawn upon many new and existing innovative ideas.
- Existing web-based technologies and surgical simulations have allowed orthopaedic training to continue during the pandemic and are being refined at an incredible rate.
- Other innovative ideas such as training “bootcamps” and new objective skill assessment tools are also making their way into orthopaedic surgical education programs around the world.
- These new ideas and technologies are predicted to become standard practice in the future.

The Past to the Present: "Orthopaedic Surgery and Society are Intertwined"

From non-surgical innovations, such as Nicolas Andry's use of splints to treat musculoskeletal deformities in children during the 18th century, to surgical ones, such as the rapid advancement of rods, screws and metal plates to treat bone injuries at the onset of World War I, the field of orthopedics has experienced no shortage of innovation (1). Throughout the remainder of the 20th century, knowledge gained during the war inspired a new focus on trauma, eventually leading to the development of new materials and techniques for bone and joint replacement surgeries (1). The rapid advancement of materials and technologies continued into the 21st century, allowing greater focus to be placed on refining surgical techniques to be less invasive and promote faster healing (1). Without a doubt, the orthopaedic field has an inspiring history of innovation that is deeply connected to social and cultural phenomena. Exemplifying the importance of understanding the social context of past innovations, Hernigou et al. (2013) explain that "history shows how orthopaedic surgery and society are intertwined" and that "the history of orthopaedic surgery is also valuable as a "how-story" of science. That is, it allows us to appreciate how concepts emerge." (2)

This rich history of innovation extends to the education of orthopaedic trainees, which has also historically experienced great periods of change. Throughout the 19th century, the apprenticeship model was largely considered the standard for surgical education where students mainly learned surgical techniques through the direct observation and imitation of a skilled mentor (3). However, the length, age at starting, and content of surgical education curriculums varied greatly. Direct patient contact was also largely considered a skill that was beyond surgical trainees (3). It was not until the end of the 19th century that surgical education became more structured and formal, and learning became more patient-centred. This was done with the help of Drs. William Osler, who saw great value in learning directly from patients, and William Halsted, father of the Halstedian model, who suggested students be given advancing patient responsibilities with each year of training (3).

Fast forward to the 21st century and, despite the many changes to the surgical curriculum and subspecialty training pathways, the Halstedian model still forms the basis of modern surgical education (3). Surgical education still relies on face-to-face teaching, direct observation and participation in surgical cases, and travel for academic in-person meetings (5). However, over the past 10 years, a rise in new, computer-based technologies has been slowly changing this. There is now more emphasis being placed on web-based technologies that increase the efficiency of the learning process (5). Simulation-based skills training and assessment is also becoming a new feature in surgical education, creating a more objective measurement of skills performance and ensuring competency-based advancement through surgical training (3).

"Overall, this era of surgical education is characterized by rapid and dynamic changes in knowledge, understanding of surgical disease, new procedures, and technologies. Furthermore, public demand for greater accountability and patient safety, with greater scrutiny in institutions where training occurs and heightened requirements for oversight in training programs, is increasing. Novel educational and training paradigms will be necessary to navigate the current waters, meet the challenges of the 21st century, and ensure the production of professional, capable, competent, and versatile surgeons." (3)

Polavarapu et al. (2013)

Most recently, the COVID-19 pandemic has brought about yet another wave of change. Academic institution closures, the suspension of clinical training and the redirection of trainees to other areas has meant that surgical education overall has been greatly affected and trainees can no longer benefit from the direct observation and assessment of skills in a supervised clinical learning environment (4)(5). The overall educational experience for orthopedic trainees has been additionally limited by the postponement of elective surgeries (4). Once again, the orthopaedic community is faced with the challenge of transforming societal obstacles into opportunities for broader innovation.

"As the scale of the coronavirus pandemic continues to grow, so does the amount of uncertainty. This virus has upended life as we know it. And we, as surgeons, are not particularly good at dealing with uncertainty...But this crisis also presents value-maximizing opportunities for innovation in the delivery of healthcare, with orthopedic surgery as a particular segment presenting opportunity for value creation…The current period of turbulence and fear may be a learning experience for providers, industry, and patients. It may promote collaboration and creative thinking that could spur changes in behavior." (6)

The Codman Shoulder Society (2020)

The Future: "Long-lagging Ideas Will Become the Norm"

The COVID-19 pandemic has underlined our need for certain technological innovations. However, we cannot forget that leading up to COVID-19, this shift had already begun - although, the use of many technological innovations was considered optional and therefore they were much less widely used. Now, necessity has caused many of these new ideas to become standard features in orthopaedic surgery education. While nothing can ever fully replace the in-person educational experiences, many believe that the convenience and efficiency that these long-lagging technologies offer will cause them to become the norm in the future. Exhibit 1 outlines a few of the most recent innovations in orthopedic surgery education that will be explored.

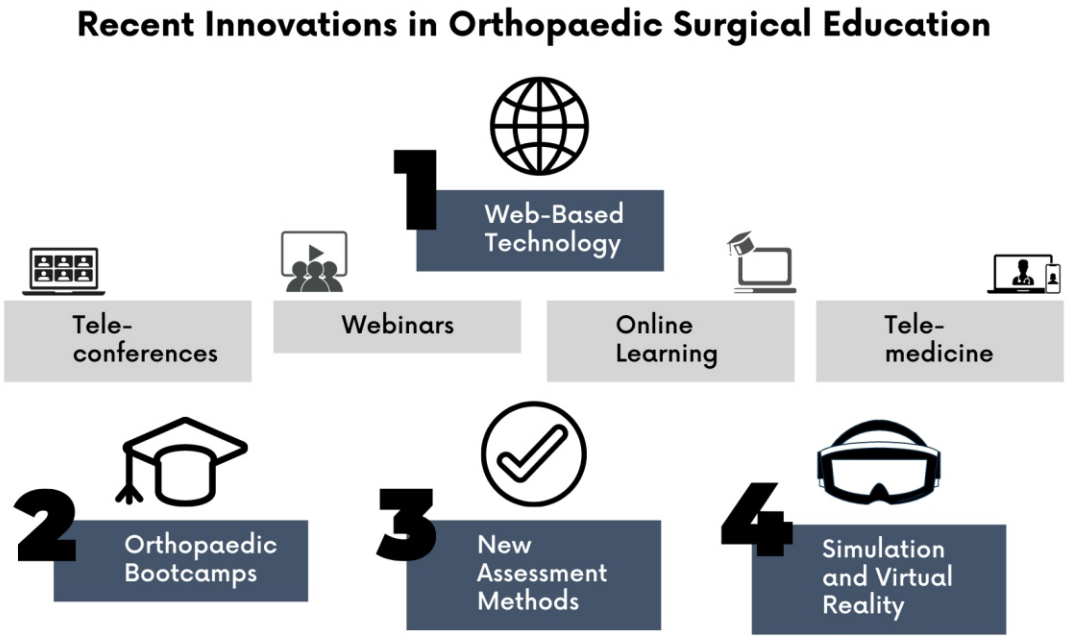

Exhibit 1. Recent innovations in orthopaedic surgical education.

1. Web-Based Technology: Teleconferences, Webinars, Online Learning and Telemedicine

Although many web-based technology platforms existed before the pandemic began, they have experienced a sharp increase in their utilization. (6) These platforms have allowed professional and educational organizations to overcome one of the biggest obstacles, social distancing, and keep at least some health care and education services running as usual.

Virtual platforms such as Skype, Zoom and GotoMeeting for example, have made collaboration easier between orthopedic teams around the world. However, it was not until recently that the use of virtual meeting technology became so commonplace. (4) Orthopaedic training programs can now host visiting experts virtually, meaning that no matter where residents and fellows choose to study, they will have access to the same leaders in the field. (5) Large industry sponsored technology halls and orthopaedic organization meetings have also transitioned to holding regular meetings, conferences or events virtually. (5) This makes attending these events and attending more sessions within each event, even easier. The virtual presentation of information in this context also allows for the use of novel teaching technologies to present information and make sharing important resources more efficient. (5)

> "These platforms allow participants to share documents, photos, and videos to enhance learning. Of course, the question begs, at what cost. Medicine is a field dependent on human interactions. As a profession, we must critically evaluate whether virtual meetings are the best way to learn and whether or not these methods of learning are a detriment to surgical training? Human networking is a key component of these meetings and would certainly suffer in a virtual world if not implemented with this in mind." (5)
>
> **Stambough et al. (2020)**

The use of online learning platforms was also popular prior to COVID-19 and provided asynchronous access to lessons and other educational resources. (4) Now more than ever, medical programs have relied on these platforms to continue to deliver educational material to students. As a result of this shift to online learning, other online tools have also become increasingly popular, such as interactive anatomy atlases, instructional podcasts and videos. (4) Social media is also quickly becoming a useful online tool in orthopedic surgical education. Students can use these platforms for discussion and to interact with leaders in their area of interest. (4) Clinicians can also use these platforms to provide educational material and information that is quick, interactive and easily accessed for residents and fellows. (4)

Of course, while these types of web-based resources are helpful (and one of the biggest examples of change brought about by COVID-19) (6), it is difficult to replace clinical educational and direct patient experiences (4). Helping with this are virtual consults with patients and telemedicine. Not only does offering these services help patients by continuing to offer safe and effective patient care, but they are also helping residents continue to benefit from clinical experiences (4). Virtual consults allow residents to interact with patients, take patient history and assess clinical presentation. Residents can then briefly log-off virtual sessions to present their assessment to an attending, discuss and then together with the attending, log back on to discuss with the patient further (4). Virtual consults with physiotherapists, wearable devices and other digital tools can also help to guide patients through their post-operative recovery (6). While virtual consults have shown to be convenient and efficient, one "glaring limitation of this method is the inability to perform a physical examination." (4)

> "Clinical education is harder to move online, but steps can be taken to ensure as much clinical exposure as possible. To overcome the lack of hands-on clerkship experience of medical students, Imperial College London has given access to an online video library of patient encounters and encouraged clinicians to deliver online teaching from the hospital where possible." (4)
>
> **Dedeilia et al. (2020)**

> "Initial telehealth related concerns regarding insurance resistance, billing complexities, and privacy have evaporated as everyone is now striving to keep providers and patients separate. We believe that long-lagging telehealth is here to stay and will become the norm for orthopedic surgery." (6)
>
> **The Codman Shoulder Society (2020)**

2. Orthopaedic Training "Bootcamps"

Just as rookies in other professions are conditioned ahead of formal training in training "boot camps", orthopaedic surgery residents may be no exception (7). The bootcamp concept can familiarize trainees with new processes and tools, and help them to develop fundamental skills ahead of facing more challenging scenarios (7). In some cases, these orthopaedic boot camps have even helped with "improving self confidence and rudimentary skills sometimes past the level of more senior but less familiarized learners." (7) The results from a study by Sonnadara et al. (2011) that examined the effectiveness of an intensive surgical skills course or bootcamp found that residents assigned to the bootcamp group performed significantly better on both checklist and global rating scale scores compared to two traditional residency groups (all groups showed no difference in pretraining scores). (8) Promising results from various orthopaedic training camps have been recognized by the American Board of Orthopaedic Surgery (ABOS) and Residency Review Committee for Orthopaedic Surgery, who now require all programs to incorporate these camps into their curricula. (7)

In another study done by Bhashyam et al. (2020), the efficiency of a virtual bootcamp for orthopaedic interns was examined. Residents were given access to lectures, necessary supplies and equipment, and supplemental reading/videos before beginning an 11-module skills training component. (9) After the bootcamp, the results of a survey showed that 100% of residents thought that the course improved their orthopaedic knowledge base and surgical skills and 92% felt like the bootcamp improved their preparedness for the operating room. All residents thought the bootcamp should become a permanent part of resident education. (9)

> "Orthopaedic surgery "boot camps" and small skills courses seem to help new trainees better acquiesce to the operating room. The modules are often home-grown stations, affordably directed, and result in skills which are maintained, especially when administered early. That being said, notable costs—of both time and money—are required for appropriate application of these programs...Nevertheless, several programs have adopted this method of surgical simulation and further research will be necessary to determine efficacy over the course of an entire residency and the most effective means of administration." (7)
>
> **Agyeman et al. (2020**

3. New Performance Assessments

The assessment of orthopaedic trainees is an essential component of their surgical education as appropriate assessment methods ensure that trainees have the necessary skill proficiency by the end of training (7). There are currently several different assessment methods that are being used but recently, a greater focus is being placed on ensuring assessment methods are procedure-appropriate and that their content and transferability is both valid and reliable. (7) Exhibit 2 lists a few examples of various assessment tools as outlined by Agyeman et al. (2020). (7)

Many assessment tools administered by experienced validators use global rating scales to rate procedure-specific skills. Evaluation through the use of global rating scales has been found to be effective. (7) Surgical checklists are another evaluation method used by different assessment tools and are considered a good alternative to global rating scales due to their increased simplicity and reproducible ratings (7). In some cases, assessment tools have chosen to use a combination of both a

global rating scale and surgical checklist to create a completely unique scale. (7) However, due to the subjectivity of both global rating scales and checklists, assessment through motion-tracking analysis is now being considered as a new assessment alternative. (7) Motion-tracking allows several objective metrics to be measured through the use of technology, such as the number of movements and distance travelled over a specific path, and have been found to be able to differentiate between novice and expert surgeons. (7)

Assessment Tool Name	Associated Procedure(s)	Evaluation Method Details
Arthroscopic Surgical Skill Evaluation Tool (ASSET)	Knee, shoulder	Global rating scale; video evaluation using a single camera
Basic Arthroscopic Knee Skill Scoring System (BAKSSS)	Knee	Combined scale (global rating scale and checklist); live evaluation
Bankart Performance Metrics (BPM)	Shoulder	N/R
Imperial Global Arthroscopy Rating Scale (IGARS)	Shoulder	Global rating scale and self evaluation; video evaluation using dual cameras
Cumulative Summation Test for Learning Curve (LC-CUSUM)	Hip, knee	Combined scale (global rating scale and checklist); live evaluation
Objective Assessment of Arthroscopic Skills (OAAS)	Knee	Global rating scale; video evaluation using dual cameras
Objective Structured Assessment of Technical Skills (OSATS)	Various	Global rating or pass/fail scale; live evaluation
Shoulder Objective Practical Assessment Tool (SOPAT)	Shoulder	N/R

Exhibit 2. New assessment tools, their associated procedures and evaluation method details. (8)

4.Simulation and Virtual Reality

"Few topics have garnered as much attention as computer and virtual reality simulations of surgical experiences. Technological advancements have furthered the utility of simulation from preoperative planning to preoperative practice to perioperative assessment." (7)

Agyeman et al. (2020)

Computerized and virtual reality (VR) simulation software aim to teach surgical trainees basic skills by guiding them through simulated scenarios that mimic actual surgical procedures. They allow trainees to practice their skills while also mitigating the risks to patients. (7) There is also an increased interest in simulations as they can ensure the continuation of technical skills training during COVID-19. (4) VR takes surgical simulation one step further and "creates immersive, realistic, three-dimensional environments that involve visual feedback from body movement." (5) Although many computerized and VR simulation tools provide the opportunity for basic psychomotor skill development, they currently lack the tactile feedback for the advanced skill and technique development that is needed for the safe and efficient reproduction of more complex procedures (like revision arthroplasty). (5) However, technology in this area is developing rapidly, including the development of touch sensors/feedback modalities that might address the lack of haptic feedback. (7) Currently, studies have shown that computerized and VR simulations outperformed dry models in surgical skill acquisition and differential assessment. (7) Studies examining the transfer validity of these simulations have shown mixed results. (7)

In the area of orthopaedic surgery education, a study by Hooper et al. (2019) examined the effect of VR training on resident knowledge and surgical ability in cadaveric total hip arthroplasty (THA). (10) For residents who were assigned to the VR-THA simulation group, overall surgical ability scores were significantly improved from baseline compared to the control group (P=0.048), with the only statistically significant improvement seen in technical skills (P=0.009). (10) The results showed that VR had no effect on knowledge. (10) Another study by Lohre et al. (2020) compared traditional learning to immersive VR in the acquisition of both technical and non-technical skills relating to learning and performing a glenoid exposure (11). The results revealed that immersive VR was superior in teaching glenoid exposure. The immersive VR group performed learning and knowledge tasks significantly faster ($P = < 0.001$; mean time of 11 ± 3 minutes versus 20 ± 4 minutes), and completed the glenoid exposure significantly faster ($P = 0.04$; mean time of 14 ± 7 versus 21 ± 6 minutes) compared to the traditional learning control group. The immersive VR group also showed a superior OSAT instrument handling scores ($P = 0.03$). (11)

However, computerized and VR simulations come at a cost. Surgical simulators can be very expensive and access to these simulators is somewhat limited. This has motivated the creation of low-cost simulation modules that can be performed anywhere. (7) One example is the low-cost arthroscopic surgical box simulator evaluated in a 2016 study by Colaco et al. (12) The total cost of the simulator was $70.88 and it consisted of a plastic box, USB powered pencil "scope", kitchen utensil hooks and rubber bands. The results showed a clear difference in time to complete the task and number of look-downs between three groups (attending, resident, medical student), showing construct validity. All three groups showed improved performance with practice. (12)

Final Thoughts

Technological innovations that have been developed over the past few years are now key players in the effort to close the educational gap caused by COVID-19. Not only do these technologies have the potential to solve some of our most pressing issues but future ones as well. These new technologies offer conveniences and efficiencies that can greatly benefit orthopaedic education. These technologies have also inspired many new innovative ideas that are challenging more traditional ways of approaching resident training.

Contributors

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