



## AOA Critical Issues in Education

# Orthopaedic Surgery Training and Education During COVID-19

### A Systematic Review

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**Background:** COVID-19 forced surgical resident training programs to adapt to meet educational requirements within the constraints of various guidelines. Some of the changes implemented during the pandemic have imparted a lasting effect on orthopaedic education. As such, the purpose of this article was to review how orthopaedic training and education were affected during the COVID-19 pandemic.

**Methods:** The published literature was queried using search strategies devised by a medical librarian, according to the Preferred Reporting Items for Systematic Review and Meta-Analyses guidelines. Studies eligible for inclusion were studies related to COVID-19, orthopaedic surgical training, and medical education. Studies were excluded if they (1) were abstracts, conference proceedings, letters, perspective pieces, reviews, or editorials; (2) evaluated medical student education; (3) included other specialties; or (4) were unrelated to COVID-19 and/or orthopaedic training.

**Results:** Eighty-three (n = 83) studies were included. Five themes emerged including (I) Fellowship Application, Interview, and Match Processes; (II) Social Media and Websites for Program Information; (III) Changes in Trainee Surgical Volume; (IV) Trainee Mental Health and Well-being; and (V) Innovations in Education. The pandemic decreased opportunities for medical students to gain exposure to orthopaedic surgery. Social media use, particularly Instagram, among orthopaedic residencies increased during the pandemic. Between the cancellation of away rotations and in-person interviews, applicants saved over \$6,000; however, both residency applicants and interviewers preferred in-person interviews. The pandemic led to decreased surgical volume and in-person didactics for trainees, thus relying more on virtual learning. Orthopaedic trainees had mixed feelings regarding online virtual education. Although some respondents reported that they preferred the convenience of online learning, others expressed dissatisfaction with the quality of virtual education.

**Conclusions:** The shift to virtual learning affected how applicants learned about residency programs, with many relying on virtual away rotations and social media to compare different programs. The pandemic also highlighted issues of

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diversity and accessibility within orthopaedic surgery, with cost savings from virtual interviews and canceled away rotations potentially benefiting applicants from lower socioeconomic backgrounds. Although some innovative approaches and adaptations to orthopaedic education and training have shown promise and may continue to be used in the future after the COVID-19 pandemic, the role of others, such as virtual interviews, is less clear.

## Introduction

COVID-19 was first identified in December 2019 and quickly spread globally, leading to the declaration of a pandemic. Studies projected a surge in inpatient demand that would exceed both general ward and intensive care unit (ICU) capacity by 10-fold<sup>1</sup>. The health care industry was forced to conserve resources and try to balance patients' safe access to non-COVID-19-related medical care<sup>2</sup>. By March 2020, the US Surgeon General urged the termination of elective surgeries, which was accompanied by a similar announcement by the American Academy of Orthopaedic Surgeons the following month<sup>3</sup>. As a result, orthopaedic surgical volume significantly decreased<sup>2</sup>. Moreover, the composition of surgical volume moved away from elective cases<sup>4</sup> and toward acute traumatic injuries and fracture care, causing a decrease in the diversity of cases for resident education<sup>5</sup>. Along with the decrease in surgical volume, COVID-19 also inextricably affected orthopaedic medical student experiences and surgical resident education and training<sup>6,7</sup>. Recommended educational priorities for orthopaedic surgical residents during the pandemic were previously delineated by Kogan et al. in early 2020<sup>8</sup> and programs had to adapt to meet educational requirements within the constraints of institutional, local, state, and national guidelines.

Although numerous changes and restrictions implemented during the pandemic have since faded, some systemic adaptations implemented during the early pandemic have imparted transformative changes on the orthopaedic community. For example, the evolution of outpatient total joint arthroplasty<sup>9,10</sup> and the increased use of telemedicine<sup>11</sup> have resulted in significant shifts in practice pattern. Similarly, although many of the challenges in medical student, resident, and fellow orthopaedic education have subsided, several innovations that occurred during the pandemic, such as virtual social events, virtual interviews, video tours, and protected time between interviews, have transformed the education process<sup>12-15</sup>. As such, the purpose of this article was to review how orthopaedic training and education were affected during the COVID-19 pandemic and to address what these changes portend for the future of orthopaedic education.

## Methods

### Information Sources

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analyses guidelines<sup>16</sup>. The published literature was queried using search strategies devised by a medical librarian. The search strategies used a combination of standardized terms and keywords including, but not limited to, (COVID-19 OR SARS-CoV-2) AND (orthopaedics OR bone surgery OR sports surgery) AND (residency OR fellowship OR medical education

OR distance education OR surgical training). The search was restricted to the English language (Supplement, <http://links.lww.com/JBJSOA/A540>).

### Eligibility Criteria

Studies eligible for inclusion were studies related to COVID-19, orthopaedic surgical training, and medical education. Given that COVID-19 was a global pandemic, we included international studies. We excluded studies that were published before 2018 and that were not written in English.

### Selection Process

Two authors (Z.R. and A.W.K.) independently screened and reviewed the full texts of returned studies, applying the above inclusion and following exclusion criteria. Studies were excluded if they (1) were abstracts, conference proceedings, letters, perspective pieces, reviews, or editorials; (2) evaluated medical student education; (3) included other specialties; or (4) were unrelated to COVID-19 and/or orthopaedic training. For studies that authors disagreed on, a third author (R.M.S.) acted as the arbitrator if needed. A kappa coefficient was calculated to assess interrater reliability agreement on inclusion. Two authors (Z.R. and A.G.) then worked independently to group, review, and extract data from each study.

## Results

### Study Selection

From the initial database searches, a total of 1,417 unique citations were returned. Six hundred thirty-six ( $n = 636$ ) were duplicates and removed for a total of 781 studies. Of these, 181 met the inclusion criteria. On independently reviewing the full texts of the 181 studies, the 2 reviewers (Z.R. and A.W.K.) reached 72.0% agreement on inclusion, exclusion, and reason for exclusion with a Cohen's kappa demonstrating "moderate" agreement ( $k = 0.43$ ). After deliberation between the authors, 100% agreement was obtained on inclusion/exclusion and 83 studies were included for analysis (Fig. 1).

### The Studies Were Organized into the following Themes Based on the Content of the Studies Returned

- (I) Resident and Fellowship Application, Interview, and Match Processes;
- (II) Social Media and Websites for Program Information;
- (III) Changes in Trainee Surgical Volume;
- (IV) Trainee Mental Health and Well-being; and
- (V) Innovations in Education.

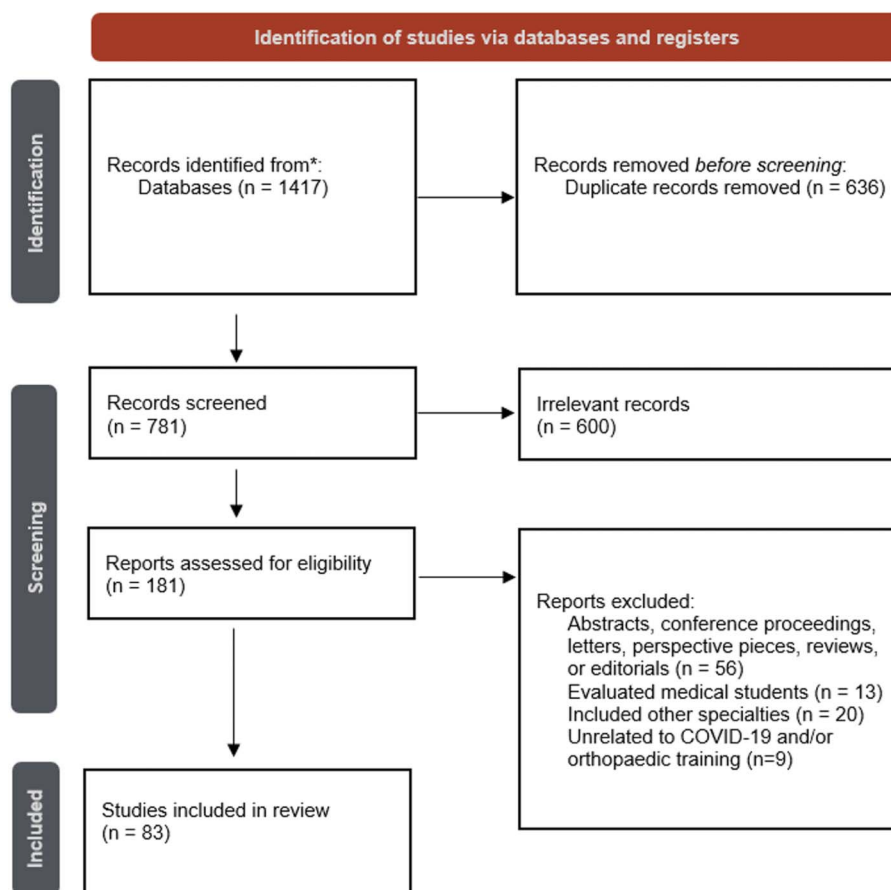


Fig. 1  
Flowchart demonstrating study selection method.

The 83 studies can be found delineated in the Supplemental Table (Table I).

#### Resident and Fellowship Application, Interview, and Match Processes

Medical students reported having “somewhat to many fewer” opportunities for exposure to orthopaedic surgery during the pandemic, and approximately one-third planned to take a research year<sup>17</sup>. With less clinical opportunities, applicants may have had more time to engage in research. The average number of research items reported on applications increased from 9.3 in 2015 to 16.6 in 2020, with a statistically significant increase to 18.9 in 2021<sup>18</sup>. During the 2020 to 2021 application cycle, 82.8% of students had their in-person away rotations canceled because of COVID-19<sup>17</sup>, and, on average, applicants participated in 2.4 virtual away rotations<sup>19</sup>. Virtual away rotations are online experiences without in-person components that commonly consist of didactics, “happy hours” with residents, case presentations, and resident lectures<sup>20</sup>. Overall, the lack of in-person away rotations during the COVID-19 pandemic affected applicant rank lists<sup>19</sup>.

The number of orthopaedic surgery residency applicants increased during the 2020 to 2021 academic year<sup>18,19,21</sup>. Although the overall number of applicants increased, there were concerns about how the pandemic affected diversity within the residency

application process. One study of rising fourth-year medical students interested in orthopaedic surgery found that women were less likely than men to ultimately apply for orthopaedic residencies during the pandemic<sup>17</sup>. This trend was consistent with the experiences of Black and Hispanic students compared with non-Hispanic, White students<sup>17</sup>. However, a separate study found no significant difference between the 2018 and 2020 application cohorts in the proportion of female or underrepresented minority applicants, or in the proportion of those groups that were invited to interviews<sup>22</sup>. Another reported a 1.6% increase in the number of female applicants to orthopaedic residency programs in 2020 to 2021 compared with 2019 to 2020<sup>18</sup> indicating that COVID may not have significantly affected the current lack of diversity among orthopaedic surgery applicants<sup>23</sup>.

Interviews were transitioned from in-person to virtual for the 2020 to 2021 application cycle, with many (82.3%) programs performing virtual interviews for the first time<sup>24</sup>. The median saving was \$3,000 in interview-related expenses because of the transition to virtual interviews<sup>25</sup>. Three additional studies, 2 that focused on fellowship applicants, also found that virtual interviews were more cost-effective for applicants<sup>26-28</sup>. That said, 2 studies found that most applicants preferred in-person interviews to virtual ones<sup>19,29</sup>. However, regarding fellowship interviews, a

TABLE I COVID-19 Orthopaedic Surgery Training and Education Studies

Study Content Section	Title	Authors	Published Year	Journal
Resident and Fellowship Interview and Match Processes	Orthopaedic surgery residency application process in 2020—has diversity been affected?	Caldwell et al.	2021	<i>The Iowa Orthopaedic Journal</i>
	Impacts of COVID-19 on orthopaedic surgery residency/spine trainee application trends	Gardezi et al.	2021	<i>North American Spine Society Journal</i>
	Applying to fellowship during a pandemic: lessons learned from the 2020-2021 orthopaedic spine fellowship application cycle	Jami et al.	2022	<i>Cureus</i>
	Orthopaedic surgery residency application, and selection criteria adaptations, in times of COVID-19: a survey study	Khalafallah et al.	2022	<i>JB &amp; JS Open Access</i>
	Perspectives on the orthopaedic surgery residency application process during the COVID-19 pandemic	Tawfik et al.	2021	<i>Journal of the American Academy of Orthopaedic Surgeons. Global Research &amp; Reviews</i>
	Effect of the COVID-19 pandemic on the orthopaedic surgery residency application process: what can we learn?	Wang et al.	2021	<i>Journal of the American Academy of Orthopaedic Surgeons. Global research &amp; Reviews</i>
	Cost analysis of medical students applying to orthopaedic surgery residency: implications for the 2020-2021 application cycle during COVID-19	Gordon et al.	2021	<i>JB &amp; JS Open Access</i>
	Orthopaedic surgery residency match trends during COVID-19 pandemic: a cross-sectional study	Hayward et al.	2022	<i>Current Orthopaedic Practice</i>
	Effects of COVID-19 on geographical trends in the orthopaedic surgery residency match	Holderread et al.	2022	<i>JB &amp; JS Open Access</i>
	Orthopaedic surgery residency program adherence to universal interview offer day guidelines: a retrospective analysis	Hutchison et al.	2022	<i>The Journal of the American Academy of Orthopaedic Surgeons</i>
	The impact of COVID-19 on the orthopaedic surgery residency match	Whisonant et al.	2022	<i>Surgery Journal (New York, N.Y.)</i>
	The impact of the COVID-19 Pandemic on orthopaedic surgery residency applicants during the 2021 residency match cycle in the United States	Danford et al.	2020	<i>Journal of the American Academy of Orthopaedic Surgeons. Global Research &amp; Reviews</i>
	Virtual interviews in the era of COVID-19: expectations and perceptions of orthopaedic surgery residency candidates and program directors	Brueggeman et al.	2021	<i>JB &amp; JS Open Access</i>
	How real is a virtual interview? Perspectives of orthopaedic surgery residency directors	Elmorsi et al.	2021	<i>European Review for Medical and Pharmacological Sciences</i>
	Virtual pediatric orthopaedic fellowship interviews during the pandemic: what did the applicants and programs think?	Inclan et al.	2022	<i>Journal of Pediatric Orthopaedics</i>
	The use of virtual interviews and new trends in orthopaedic surgery residency match	Metrione et al.	2022	<i>Journal of Orthopaedic Research</i>
	Adult reconstruction fellowship interviewee perceptions of virtual vs. in-person interview formats	Pathak et al.	2021	<i>Arthroplasty Today</i>
	Perceived effectiveness of video interviews for orthopaedic surgery residency during COVID-19	Warren et al.	2022	<i>BMC Medical Education</i>

continued

TABLE 1 (continued)

Study Content Section	Title	Authors	Published Year	Journal
Social Media and Websites for Program Information	Perception of the virtual interview format in hand surgery fellowship applicants	Major et al.	2022	<i>The Journal of Hand Surgery</i>
	Instagram use among orthopaedic surgery residency programs	Bixby et al.	2022	<i>The Journal of the American Academy of Orthopaedic Surgeons</i>
	Orthopaedic surgery residency program social media presence during the COVID-19 pandemic	Bram et al.	2021	<i>JB &amp; JS Open Access</i>
	Social media and the orthopaedic surgery residency application process	Butler et al.	2022	<i>Cureus</i>
	Social media growth of orthopaedic surgery residency programs in response to the COVID-19 pandemic	Geller et al.	2022	<i>World Journal of Orthopaedics</i>
	The effect of the COVID-19 pandemic on orthopaedic residency program social media utilization	Holderread et al.	2021	<i>JB &amp; JS Open Access</i>
	Social media utilization trends in orthopaedic surgery residency programs during the COVID-19 pandemic	LeDuc et al.	2021	<i>The Iowa Orthopaedic Journal</i>
	Utility of social media for recruitment by orthopaedic surgery residency programs	Malyavko et al.	2021	<i>JB &amp; JS Open Access</i>
	Social media use by hand surgery fellowship programs	Wilson et al.	2022	<i>The Journal of the American Academy of Orthopaedic Surgeons</i>
	Analyzing the proliferation of social media use among orthopaedic surgery residency programs	Yong et al.	2021	<i>JB &amp; JS Open Access</i>
	Orthopaedic surgery residency program website content and accessibility during the COVID-19 pandemic: observational study	El Shatanofy et al.	2021	<i>JMIR Medical Education</i>
	The content and accessibility of spine surgery fellowship websites and the North American Spine Surgery (NASS) fellowship directory	Gerlach et al.	2021	<i>The Spine Journal: Official Journal of the North American Spine Society</i>
	Match for orthopaedic fellowship programs in the united states: online accessibility, content, and accreditation comparison between subspecialties and review of alternative resources	Jain et al.	2021	<i>Cureus</i>
	Do orthopaedic surgery residency program websites address diversity and inclusion?	Mortman et al.	2022	<i>HSS Journal: the Musculoskeletal Journal of Hospital for Special Surgery</i>
Trainee Training Volume	The effect of COVID-19 on the trauma burden, theatre efficiency, and training opportunities in a district general hospital: planning for a future outbreak	Karia et al.	2020	<i>Bone &amp; Joint Open</i>
	Decreased case volume for orthopaedic sports medicine fellows during the early stages of the coronavirus disease 2019 pandemic	Testa et al.	2022	<i>Arthroscopy, Sports Medicine, and Rehabilitation</i>
	Evaluating the early impact of the COVID-19 pandemic on sports surgery fellowship education	Swiatek et al.	2021	<i>Cureus</i>
	Effects of the SARS-CoV-2 pandemic on residency training in orthopaedics and traumatology in Germany: a nationwide survey	Amini et al.	2022	<i>Orthopadie (Heidelb)</i>
	Determining the impact of the COVID-19 pandemic on hand surgery fellowship education	Weiner et al.	2022	<i>Journal of Surgical Orthopaedic Advances</i>

continued

TABLE 1 (continued)

Study Content Section	Title	Authors	Published Year	Journal
	[Translated article] Has 2020 been a lost year in orthopaedic surgery and trauma training? Residents' perceptions	Vazquez Gomez et al.	2022	<i>Revista Espanola De Cirugia Ortopedica y Traumatologia</i>
	Assessing the early impact of the COVID-19 pandemic on spine surgery fellowship education	Swiatek et al.	2021	<i>Clinical Spine Surgery</i>
	The impact of COVID-19 on total joint arthroplasty fellowship training	Silvestre et al.	2022	<i>The Journal of Arthroplasty</i>
	Quantifying the impact of the COVID-19 pandemic on orthopaedic trainees: a national perspective	Sheridan et al.	2020	<i>Bone &amp; Joint Open</i>
	Impact of the COVID-19 pandemic on orthopaedic and trauma surgery training in Europe	Megaloikonomos et al.	2020	<i>International Orthopaedics</i>
	The impact of COVID-19 on the sports medicine fellowship class of 2020	Perrone et al.	2020	<i>Orthopaedic Journal of Sports Medicine</i>
	Access and feasibility of orthopaedic training in the independent sector—a deanery's experience	Lenihan et al.	2022	<i>The Surgeon: Journal of the Royal Colleges of Surgeons of Edinburgh and Ireland</i>
	The impact of the COVID-19 pandemic on orthopaedic services and training in the UK	Khan et al.	2021	<i>European Journal of Orthopaedic Surgery &amp; Traumatology: Orthopedie Traumatologie</i>
Trainee Mental Health and Well-Being	Resident wellness during the COVID-19 pandemic: a nationwide survey of orthopaedic residents	Nolte et al.	2021	<i>The Journal of the American Academy of Orthopaedic Surgeons</i>
	Has the COVID-19 pandemic changed the daily practices and psychological state of orthopaedic residents?	Castioni et al.	2021	<i>Clinical Orthopaedics and Related Research</i>
	Implementing mindfulness meditation in hand surgery training: a feasibility study	Cooper et al.	2022	<i>European Journal of Plastic Surgery</i>
	The impact of the COVID-19 pandemic on the orthopaedic residents: a pan-Romanian survey	Moldovan et al.	2022	<i>International Journal of Environmental Research and Public Health</i>
Innovations in Education	Online instruction to measure axial alignment with the Bonesetter app	Bernstein et al.	2022	<i>Medicina (Kaunas, Lithuania)</i>
	The SpineBox: a freely available, open-access, 3D-printed simulator design for lumbar pedicle screw placement	Clifton et al.	2020	<i>Cureus</i>
	Technology-enhanced learning in orthopaedics: virtual reality and multimodality educational workshops may be effective in the training of surgeons and operating department staff	Hall et al.	2022	<i>The Surgeon: Journal of the Royal Colleges of Surgeons of Edinburgh and Ireland</i>
	Implementation of a virtual learning and simulation curriculum for orthopaedic resident training during COVID and beyond	Hoyt et al.	2021	<i>Current Orthopaedic Practice</i>
	“Virtual” boot camp: orthopaedic intern education in the time of COVID-19 and beyond	Bhashyam et al.	2020	<i>The Journal of the American Academy of Orthopaedic Surgeons</i>
	Evaluating the effectiveness of the imperial femoral intramedullary nailing cognitive task analysis (IFINCTA) tool in a real-time simulation setting (distributed interactive simulation): a randomized controlled trial	Bhattacharyya et al.	2021	<i>Injury</i>

continued



TABLE 1 (continued)

Study Content Section	Title	Authors	Published Year	Journal
	Procedural simulation training in orthopaedics and traumatology: nationwide survey among surgeon educators and residents in France	Bouthors et al.	2022	<i>Orthopaedics &amp; Traumatology, Surgery &amp; Research: OTSR</i>
	Investigating a newly developed educational orthopaedic application for medical interns in a before-after quasi-clinical trial study	Daliri et al.	2021	<i>BMC Medical Education</i>
	Resident, fellow, and attending perception of e-learning during the COVID-19 pandemic and implications on future orthopaedic education	Essilfie et al.	2020	<i>The Journal of the American Academy of Orthopaedic Surgeons</i>
	Virtual examination for final year orthopaedics postgraduate residents during COVID-19: is it a viable alternative?	Farooq et al.	2021	<i>Journal of Clinical and Diagnostic Research</i>
	Orthopaedic surgery residents' perception of online education in their programs during the COVID-19 pandemic: should it be maintained after the crisis?	Figuerola et al.	2020	<i>Acta Orthopaedica</i>
	Adult hip and knee reconstruction education during the COVID-19 pandemic	Hamilton et al.	2021	<i>The Journal of Arthroplasty</i>
	Cadaver vs. simulator based arthroscopic training in shoulder surgery	Huri et al.	2021	<i>Turkish Journal of Medical Sciences</i>
	Sicot pioneer (programme of innovative orthopaedic networking education and research): re-inventing global orthopaedic education, training and research	Thevendran et al.	2022	<i>International Orthopaedics</i>
	COVID-19 as a disruptor: innovation and value in a national virtual fracture conference	Stein et al.	2021	<i>OTA international: the Open Access Journal of Orthopaedic Trauma</i>
	Virtual vs. in-person grand rounds in orthopaedics: a framework for implementation and participant-reported outcomes	Reddy et al.	2022	<i>Journal of the American Academy of Orthopaedic Surgeons. Global Research &amp; Reviews</i>
	A prospective assessment of knee arthroscopy skills between medical students and residents-simulator exercises for partial meniscectomy and analysis of learning curves	Putzer et al.	2022	<i>Surgical Innovation</i>
	The emergence of collaboration in the education of fellows and residents during COVID-19	Moschetti et al.	2021	<i>The Journal of Arthroplasty</i>
	Conducting orthopaedic practical examination during the COVID-19 pandemic	Malhotra et al.	2020	<i>Journal of Clinical Orthopaedics and Trauma</i>
	COVID-19 and the transition to virtual teaching sessions in an orthopaedic surgery training program: a survey of resident perspectives	Kruse et al.	2022	<i>BMC Medical Education</i>
	Good morning, orthopods: the growth and future implications of podcasts in orthopaedic surgery	Jella et al.	2021	<i>The Journal of Bone and Joint Surgery. American Volume</i>
Applicable to Multiple Categories	Orthopaedic training during COVID-19 pandemic: should action be taken?	Abdelazeem et al.	2022	<i>International Orthopaedics</i>
	Insight into the changing patterns in clinical and academic activities of the orthopaedic residents during COVID-19 pandemic: a cross-sectional survey	Barik et al.	2020	<i>Knee Surgery, Sports Traumatology, Arthroscopy: Official Journal of the ESSKA</i>

continued

TABLE 1 (continued)

Study Content Section	Title	Authors	Published Year	Journal
	The impact of COVID-19 pandemic on orthopaedic resident education: a nationwide survey study in South Korea	Chang et al.	2020	<i>International Orthopaedics</i>
	The role of orthopaedic trainees during the COVID-19 pandemic and impact on post-graduate orthopaedic education: a 4-nation survey of over 100 orthopaedic trainees	Gonzi et al.	2020	<i>Bone &amp; Joint Open</i>
	Has 2020 been a lost year in orthopaedic surgery and trauma training? Residents' perceptions	Gómez et al.	2022	<i>Revista española de cirugía ortopédica y traumatología</i>
	The impact of COVID-19 on orthopaedic surgery fellowship training: a survey of fellowship program directors	Heaps et al.	2022	<i>HSS Journal: the Musculoskeletal Journal of Hospital for Special Surgery</i>
	Impact of COVID-19 on orthopaedic specialist training: a nationwide survey of orthopaedic residents in Singapore	Hey et al.	2022	<i>Singapore Med J</i>
	The impact of COVID-19 on the orthopaedic surgery residency experience	Higginbotham et al.	2021	<i>Spartan Medical Research Journal</i>
	Impact of COVID-19 on post-graduate orthopaedic training in Delhi-NCR	Upadhyaya et al.	2020	<i>Journal of clinical Orthopaedics and Trauma</i>
	In response to COVID-19: current trends in orthopaedic surgery sports medicine fellowships	Liles et al.	2021	<i>Orthopaedic Journal of Sports Medicine</i>
	Impact of COVID-19 on orthopaedic residents-an Indian perspective	Kumar et al.	2021	<i>OTA International: the Open Access Journal of Orthopaedic Trauma</i>
	The impact of the COVID-19 pandemic on Polish orthopaedics, in particular on the level of stress among orthopaedic surgeons and the education process	Kolodziej et al.	2021	<i>PLoS One</i>
	Collaborative overview of coronavirus impact on orthopaedic training in the UK (COVI-ORTH UK)	Jayatilaka et al.	2021	<i>The Surgeon: Journal of the Royal Colleges of Surgeons of Edinburgh and Ireland</i>

study of pediatric orthopaedic fellowship applicants found that 67% did not feel that the virtual interview format negatively affected the process, and nearly half (48.5%) preferred to keep fellowship interviews virtual in the future<sup>24</sup>. These authors suggest that the role for virtual interviews for a 1-year fellowship may be different than for a -year orthopaedic residency. Another study of adult reconstruction fellowship applicants found no statistically significant differences in reported enjoyability, ability to transmit personality, or perception of the interviewer's ability to evaluate the applicant when comparing in-person and virtual interviews<sup>27</sup>. A study of hand surgery fellowship applicants found that 79.4% recommended keeping virtual interview formats in the future, and 47.1% preferred virtual interviews<sup>28</sup>.

Perhaps the most innovative addition to application and interview process was virtual open houses<sup>30</sup>. Virtual events were more common with larger programs than smaller programs and most of the programs held multiple of these events during the application cycle. A study reported that spending time virtually in small groups or one-on-one learning about the hospital

and facilities was very important or extremely important to applicants<sup>17</sup>; however, applicants did not think social events were well replicated in virtual settings<sup>19</sup>. Virtual events did not play a large role in determining rank lists for applicants<sup>19</sup>.

COVID-19 also affected the match selection process. Program directors (PDs) placed more weight on communication from faculty mentors, emails from applicants, home applicant status, and virtual information session attendance<sup>31</sup>, whereas less importance was given to virtual away rotations and virtual interviews<sup>30,32</sup>. PDs and faculty generally preferred in-person interviews<sup>19,26,29</sup>, given the perceived inability to assess candidate fit, social, interpersonal, clinical, and surgical skills; commitment; and genuine interest through the virtual format<sup>25,26</sup>. However, some programs continued to place significant weight on faculty and resident interviews, although they were virtual<sup>19</sup>. A survey of pediatric orthopaedic fellowship PDs found that half would offer virtual interviews, even if in-person interviews were possible<sup>24</sup>. In a study of fellowship PDs, half responded that they would likely consider a combination of virtual and in-person interviews, but most answered that it was



unlikely virtual interviews would completely replace in-person interviews<sup>33</sup>. Compared with the 2019 to 2020 application cycle, the number of interviews offered by orthopaedic spine fellowship programs increased by 1.5 times in the 2020 to 2021 cycle (32.7 vs. 21.9 interviews,  $p = 0.024$ )<sup>33</sup>. Another study found that pediatric orthopaedic fellowship programs interviewed more applicants for the 2020 to 2021 cycle than in the previous 5 years<sup>24</sup>.

Given that applicants may have been more likely to apply to more programs during the 2020 to 2021 year<sup>18,19,21</sup>, some programs implemented additional supplemental application requirements beyond the Electronic Residency Application Service application to better differentiate applicants, although on average, only 60% of applications were completed<sup>31</sup>. Most programs (89%) did not add supplemental requirements<sup>30</sup>. A “universal interview offer day,” where programs release interviews on the same day, was implemented to prevent hoarding of interview offers and improve efficiency of The Match. One article found that while 60% of orthopaedic surgery residency programs agreed to participate, less than half strictly adhered to the guidelines<sup>34</sup>.

PDs indicated that applicants were either more accomplished (41.2%) or similar in accomplishment (58.8%) during the pandemic compared with previous years<sup>24</sup>. A majority of programs (89%) in the 2020 to 2021 cycle matched applicants at the same ranking or better as previous cycles, whereas 11% went further down their list in comparison with previous cycles<sup>19,21</sup>. During the 2020 to 2021 cycle, there was a statistically significant increase in the proportion of students who matched at their home program, from 19.8% prepandemic to 29.5% postpandemic<sup>35</sup>. The same study also reported a 5.3% increase in matching in the same region as the students' medical school, but this difference was not statistically significant<sup>35</sup>. Another study found that 39.6% of applicants matched to a program within their state, compared with 33.1% prepandemic, which was a statistically significant difference<sup>36</sup>. A third study also found increased home program matches, at 27.4% compared with 21.2% prepandemic, and home state matches at 37.8% vs. 33.4% prepandemic<sup>37</sup>. Social media also became an important consideration for applicants because 34% of applicants said that social media influenced their rank lists<sup>38</sup>.

### Social Media and Websites for Program Information

In lieu of in-person away rotations and interviews during the COVID-19 pandemic, many programs turned to social media and websites as a way to connect with applicants. A study found that 67% of programs used social media for recruiting applicants in 2020 to 2021, compared with only 15% in 2019 to 2020<sup>39</sup>. Another study reported that in response to the pandemic, 79% of PDs generated increased social media content<sup>38</sup>. In addition, 87.8% of accounts were found to be resident-managed, whereas 12.2% were department-managed<sup>40</sup>. Two studies reported on what content was being posted on Instagram by residency programs. One found that Instagram posts often featured resident introductions, content about camaraderie, and the resident social lives<sup>41</sup>. Another study found that 54% of Instagram posts contained departmental content, 13% were social posts, and 10% were related to COVID-19<sup>42</sup>. A study reported that 69.2% of applicants used In-

stagram to learn about programs, with 34% saying that a program's Instagram content affected their rank list<sup>38</sup>. According to 8 studies, the percentage of orthopaedic residency programs on Instagram ranged from 41.6% to 88%, with a median of 65.9%<sup>30,36,40-46</sup>. Having a program Instagram account and having more “followers” were positively associated with a higher ranking for orthopaedic residency programs on Doximity<sup>42</sup>. A study found that 21 of 89 hand surgery fellowship programs had Instagram accounts (24%), and 81% of these accounts were created after the onset of the COVID-19 pandemic<sup>47</sup>. Fewer orthopaedic surgery programs were using Twitter and Facebook at the time of the pandemic<sup>48</sup>.

Six studies looked at the increase in social media profiles after the onset of the COVID-19 pandemic. Four studies reported that 65% to 85% of residency program Instagram accounts were created after the pandemic onset<sup>40-42,44</sup>. One study evaluated new Twitter accounts and found that 41.2% joined after the pandemic<sup>40</sup>. A study looking broadly at all social media platforms (Instagram, Twitter, and Facebook) reported that 86.4% of all social media accounts were created after the pandemic's onset<sup>46</sup>.

Almost all orthopaedic surgery residency programs (98.4%) had functional websites during the pandemic<sup>49</sup>. These websites often included information on the program, curriculum, and sample rotation schedules<sup>49</sup>. The percentage of program websites containing informative videos rose significantly from 12.2% in July to 48.1% in November 2020<sup>49</sup>. Similarly, the percentage of websites with virtual tours rose from 0.5% to 13.2% over the same period<sup>49</sup>. Another article found that 29.1% of residency program webpages contained information on diversity and inclusion. The most common type of information found was a commitment to improving diversity and inclusion, although only 15% of program websites contained such a commitment<sup>50</sup>.

### Trainee Training Volume

To support patients with COVID-19 during the pandemic, many hospitals postponed or canceled nonemergent surgical procedures, and individuals were shifted from the elective operative settings to emergency departments and ICUs<sup>51,52</sup>. Outpatient clinics shifted to telemedicine appointments when possible to decrease the number face-to-face visits<sup>53</sup>. This reduction in case volume led to decreased surgical experience for trainees. Six studies measured overall training volume for either orthopaedic residents or fellows before and during the pandemic. Three measured training volume by surgical caseload<sup>54-56</sup>, and 3 measured training volume by hours worked weekly<sup>57-59</sup>. The mean decrease in annual surgical caseload was 29.3 cases, 95% CI (9.0-49.5), and the mean decrease in training volume by hours worked weekly was a decrease of 29.7 hours, 95% CI (32.1-27.3). All 6 studies reported a significant decrease in overall training volume<sup>54-59</sup>. Hedges' (adjusted)  $g$  was calculated yielding a standardized mean difference of  $-1.02$ , 95% CI ( $-1.2$  to  $-0.0$ ), during the pandemic. Heterogeneity was measured using the  $I^2$  (97%) and  $Q$  test which revealed a  $p$  value of  $< 0.01$  (Fig. 2).

It is important to consider the context of trainees rather than experienced surgeons. While 29 surgeries may seem

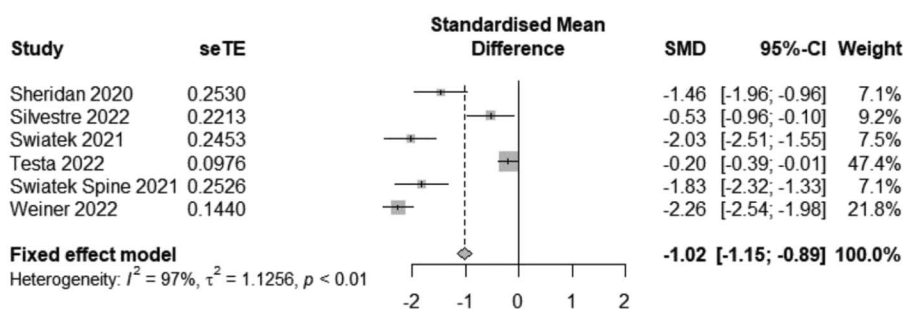


Fig. 2

Forest plot of 6 studies examining decreased surgical caseload during COVID-19 pandemic.

relatively small in the context of a surgeon with a large annual caseload, for trainees, this decrease could represent a significant proportion of their total surgical experience during their training period, especially if certain elective surgical opportunities are lost entirely as a result.

Owing to COVID restrictions, some residents were allocated to nonacademic independent sector practices to increase social distancing and provide more opportunities for education; only 52% of trainees reported achievement of their learning goals, the main obstacles were lack of opportunity (51%) and paperwork issues (22%)<sup>60</sup>. In a survey of sports fellowship applicants from the class of 2020, 8% of applicants had their previous contract or job offer rescinded, 6% of which now plan to go into a different fellowship specialty<sup>61</sup>.

### Trainee Mental Health and Well-Being

There is evidence that the COVID-19 pandemic has had a significant impact on the mental health of orthopaedic surgery trainees<sup>62-64</sup>. The stress and demands of working during the pandemic, as well as the risk of exposure to the virus and the possibility of bringing it home to their families, all contributed to increased levels of anxiety and depression<sup>62</sup>. A survey of orthopaedic residents found their biggest concern was getting family members sick, followed by personally getting sick<sup>62</sup>. In addition, 44.5% reported that time away from coworkers had a negative effect on overall cohesiveness<sup>62</sup>. An Italian study measuring the mental health of orthopaedic residents found a significant increase in both depression and anxiety during the pandemic, whereas 18% of responding residents in Italy had to temporarily change their household of stay because of the risk of COVID-19 transmission to susceptible family members<sup>63</sup>. A Romanian study found that overall, well-being was significantly decreased in residents during the pandemic<sup>64</sup>. Furthermore, 45% reported stress levels being higher than prepandemic levels<sup>64</sup>. Mindfulness meditation was implemented in a group of hand surgery trainees and found that the meditation group felt more relaxed and calm as measured by self-reported mood scores<sup>65</sup>.

### Innovations in Education

Many previously held in-person educational sessions for orthopaedic surgical trainees were transitioned to virtual learning because of the pandemic<sup>13-15</sup>. There were mixed opinions on quality,

with 8 studies reporting high learner satisfaction<sup>14,66-71</sup>; however, 7 of the studies reported negative learner perceptions<sup>72-78</sup>. In 1 study, most residents felt that the quality of education was superior (72%), their level of engagement improved (64%), and they were able to acquire more knowledge (68%) with the virtual format<sup>69</sup>. Other studies found new online teaching methods and webinars to be effective, with over 70% of residents rating them as good or useful<sup>66,68</sup>. National virtual conferences were shown to be successful in only a single study where 96% of participants rating them as similar or improved compared with in-person conferences, with some participants claiming they learned just as much (35%) or even more (57%)<sup>70</sup>. Particular difficulties were reported regarding the inability to maintain attention (63.8%) with a virtual format<sup>72</sup>. Overall, 48.9% of respondents reported their resident education was worse because of the impact of COVID-19<sup>75</sup>, and only 38.7% believed online learning had a positive effect<sup>76</sup>. Although 51.4% of trainees favored virtual learning, attendings were more disapproving with only 32.2% favoring virtual learning<sup>74</sup>. Virtual grand rounds were more convenient to attend and participants were more satisfied with the virtual format compared with in-person grand rounds<sup>79</sup>. However, in-person grand rounds were perceived as more effective for facilitating collaboration between presenters and participants, promoting networking, and retaining audience attention<sup>79</sup>. Majority overall preferred a hybrid approach for the future<sup>79</sup>. Most attendings and trainees felt virtual learning should only play a supplemental role in future education<sup>74</sup>. Finally, fully virtual examinations were used with high satisfaction for both examiners and examinees<sup>80,81</sup>. Nearly 86% of orthopaedic fellowship PDs agreed they will continue to use aspects of virtual education after the pandemic<sup>82</sup>. During the COVID-19 pandemic, the shift to virtual learning for orthopaedic surgical trainees led to mixed opinions on the quality of education. Although some studies reported high learner satisfaction and effectiveness of online teaching methods, others highlighted negative learner perceptions and challenges in maintaining attention. The pandemic may have accelerated the adoption of certain established trends, such as virtual grand rounds and online examinations, which garnered high satisfaction levels. However, it also led to the exploration of new virtual methods, such as national virtual conferences, with varying degrees of success. Overall, most participants preferred a hybrid approach for the future, suggesting that COVID-19 both accelerated the use of pre-existing virtual education methods and introduced novel

approaches that could be incorporated into a more balanced educational model.

Other surgical training innovations during the COVID included simulations and podcasts<sup>83,84</sup>. Virtual reality (VR) simulation was shown to increase the efficiency of learning surgical strategy and the anticipation of operative steps<sup>85</sup>. Furthermore, 1 study even found VR simulation to be as effective as cadaver training, and residents rated VR education as comparable in effectiveness to surgical experiences, although further research is required to determine the applicability and usage of VR<sup>86</sup>. By contrast, more traditional physical surgical simulators showed learner improvement in arthroscopy skills<sup>87</sup>. Other technologies such as 3D-printed lumbar spines showed feasibility to practice pedicle screw placement in an affordable and remote manner<sup>88</sup>. One program used a virtual bootcamp for new interns and reported effectiveness in training learners basic orthopaedic skills<sup>89</sup>. Although programs and residents both recognize the strengths of simulation training, they report obstacles such as insufficient funding (81%), lack of time (67%), lack of supervisors (48%), and lack of space (25%)<sup>90</sup>. It remains to be determined how virtual and simulation training will continue to be implemented in curricula post-COVID.

Orthopaedic educational podcasts have been increasing recently, around 1 new podcast per month from 2016 to 2020<sup>91</sup>. As of October 2020, there were 62 active orthopaedic educational podcasts; however, the effect of the pandemic on podcast trends was not reported<sup>91</sup>.

## Discussion

This systematic review highlighted the ways in which the COVID-19 pandemic disrupted the orthopaedic educational spectrum and how it affected residency applicants, residents, fellows, and orthopaedic programs. Although many aspects discussed may represent transient changes within orthopaedic education, many innovations during the COVID-19 pandemic may impart a lasting effect on medical education, particularly the implementation of virtual interview processes and the increase in technology used for resident education.

The COVID-19 pandemic decreased the opportunities for medical students, especially students from nondominant groups, to gain exposure to orthopaedic surgery. An uptick in virtual learning may have provided medical students with increased time for research, resulting in more research items reported on applications, although this may have also been a result of higher percentages taking gap years<sup>17,18</sup>. Laboratory restrictions may have shifted many students toward epidemiologic research where projects can be performed more expeditiously and remotely<sup>92</sup>. With a historically high rate of unmatched applicants in the 2022 match cycle and changes to United States Medical Licensing Examination scoring criteria, the shift toward an increase in dedicated research time should be monitored by the orthopaedic education community.

The pandemic also had a significant impact on the manner in which applicants learn about residency programs. Many applicants were unable to participate in in-person away rotations and instead had to rely on virtual away rotations as a way to gain

exposure to different programs, which impaired applicants abilities to compare different programs<sup>17,19</sup>. Virtual social events were commonly used<sup>21,30,33</sup>; however, the importance of these virtual events in affecting ranking decisions was unclear<sup>17,19</sup>. Finally, social media use, particularly Instagram, among orthopaedic residencies skyrocketed during the pandemic<sup>30,38</sup>. Lifestyle became highly valued because posts demonstrating social lives of residents were of particular importance to applicants<sup>30,40-46</sup>. Although some programs may decrease their use of social media with the return of traditional recruiting, the pandemic ultimately caused refinement of program social media accounts and residency websites that will serve as valuable recruiting tools for residency applicants going forward.

The pandemic and its resultant disruptions and changes brought further attention to the issue of diversity in orthopaedic surgery<sup>18,22,93</sup>, which is commonly reported as the least diverse specialty<sup>94</sup>. Caldwell et al. demonstrated loss of prospective diverse candidates who are greatly needed in the field<sup>22</sup>. Decreased exposure to the field and mentorship may account for some of these losses. A driving force for the discontinuation of in-person educational opportunities and away rotations was from the Coalition for Physician Accountability's Work Group on Away Rotations published guidelines recommending limiting student travel to away rotations during the 2020 to 2021 and 2021 to 2022 academic years<sup>95</sup>. Medical students particularly those from underrepresented groups benefit from mentorship and exposure to the field; the limitations imposed by the guidelines in 2020 to 2022, although understandably made for sensible safety reasons, may have come at the detriment of increasing diversity. They have since updated their guidelines and removed all restrictions for 2022 to 2023 away rotations due to concern about the consequences of negatively affecting professional development and readiness for residency<sup>95</sup>. In the future, increased targeted mentorship and exposure to underrepresented groups could improve the issue of diversity in orthopaedics; however, further research is needed.

Another notable change brought on by the pandemic was the cost savings for residency applicants. Orthopaedic surgery is an expensive field for applicants to apply into<sup>96</sup>. Between the cancellation of away rotations and in-person interviews, applicants were saving over \$6,000<sup>25,97</sup>. As mentioned previously, diversity is a paramount issue for the field of orthopaedics, and the costs associated with applying into orthopaedics are more harshly felt by those of lower socioeconomic status. Some programs have created scholarships for underrepresented minority students to offset their away rotation cost, which is not widespread. Despite recognizing the interpersonal and social benefits of in-person interviews<sup>19,26,29</sup>, both applicants and interviewers acknowledge the importance of retaining the option for virtual interviews because of financial reasons and wish to have the flexibility to conduct virtual interviews<sup>24,28,33</sup>. The benefits of virtual interviews may be most pronounced for fellowship applicants, given clinical responsibilities and financial limitations<sup>24</sup>. In addition, PDs will need to consider the biases inherent to a hybrid approach where those selecting virtual option, possibly due to socioeconomic factors, may be graded lower than in-person counterparts due to lack of personability. It is unsurprising given these limitations that orthopaedic

surgery residency applicants were more likely to match in the same state or region during the pandemic<sup>35-37</sup>.


The pandemic led to decreased surgical volume and in-person didactics for trainees, thus increasing virtual learning. Across the studies reviewed, orthopaedic trainees had mixed feelings regarding online education. Although some respondents reported that they preferred the convenience of online learning, others expressed dissatisfaction with the quality of virtual education compared with in-person instruction<sup>14,67-71,74,79,86,89</sup>. One common theme was that residents found it difficult to fully engage with online lectures, with many reporting a lack of interaction and difficulty maintaining attention<sup>14,67-72,74,79,86,89</sup>. Virtual methods of education can be effective, but they may not be a perfect substitute for in-person teaching. Many trainees have reported they prefer traditional teaching, and some have expressed outright dissatisfaction with virtual methods. The change to virtual education came at a time when the American Board of Orthopaedic Surgery board examination pass rates dipped significantly lower than in past years raising concerns about the impact of virtual learning<sup>95</sup>. These findings suggest a balance may need to be struck between in-person and online education. Finally, the utility of VR and simulations was recognized and accelerated as a result of the pandemic for socially distanced surgical training; future directions will focus on augmenting long-term skill retention and transferability<sup>85-87,90</sup>. By providing a safe, controlled, and customizable environment for skill development, these technologies can accelerate learning, promote interdisciplinary collaboration, and improve overall surgical competence, ultimately benefiting both trainees and patients.

## Conclusion

The COVID-19 pandemic had a significant impact on orthopaedic surgery, including the medical student and resident application process, education and training, and the mental health of trainees. The pandemic led to a decrease in opportunities for medical students, particularly those from nondominant groups, to gain exposure to orthopaedic surgery. The shift to virtual learning affected how applicants learned about residency programs, with many relying on virtual away rotations and social media to compare different programs. The pandemic also highlighted issues of diversity and accessibility within orthopaedic surgery, with cost savings from virtual interviews and canceled away rotations

potentially benefiting applicants from lower socioeconomic backgrounds. Orthopaedic trainees had mixed feelings about online education, with some appreciating the convenience while others felt that it was less effective than in-person instruction. The pandemic also led to an increase in the implementation of VR and simulations for surgical training, although it is unclear whether these tools will be integrated into future curricula. Although some of these innovative approaches, such as VR simulation and hybrid access to grand rounds, showed promise and may continue to be used in the future, the role of others, such as virtual interviews, is less clear. Virtual away rotations, on the other hand, did not show any evidence of benefit and are unlikely to be used going forward. In addition, virtual education programs are less engaging and of lower perceived quality compared with in-person and may contribute to increased failure rates in American Board of Orthopaedic Surgery certification examinations. Although virtual or online methods can be effective in the short term, it is likely that a balance between in-person and online education will be needed in the future.

## Appendix

 Supporting material provided by the authors is posted with the online version of this article as a data supplement at [jbjs.org \(http://links.lww.com/JBJSOA/A540\)](http://links.lww.com/JBJSOA/A540). This content was not copyedited or verified by JBJS. ■

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