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From Sawbones to Drill Machines: Revolutionising Orthopaedic Training for Medical Undergraduates

Muhammad Iftikhar Hanif [1,2,*], Ashwini Sood [3,4], Sumaya Elashmawy [1,2] and Ian Lam [1,2]

[1] Faculty of Medical Sciences, Newcastle University, Newcastle upon Tyne, NE1 7RU, United Kingdom
[2] Newcastle University Medicine Malaysia (NUMed), 1, Jalan Sarjana 1, Kota Ilmu, Educity@Iskandar, 79200 Iskandar Puteri, Johor, Malaysia
[3] School of Medicine, Monash University Malaysia, Jalan Lagoon Selatan, Bandar Sunway, 47500 Subang Jaya, Selangor, Malaysia
[4] Clinical School Johor Bahru, Monash University Malaysia, No. 8, Masjid Sultan Abu Bakar, 80100 Johor Bahru, Johor, Malaysia
* Correspondence: nmim5@ncl.ac.uk; Tel.: +60-12-794-0017

Abstract

Orthopaedic education for medical undergraduates has traditionally placed more emphasis on theoretical understanding than the acquisition of useful surgical skills. The increasing need for early clinical proficiency underscores the urgent need for innovative teaching methods. This paper explores how orthopedic bootcamps and workshops employing simulation techniques—such as sawbones models and internal fixation devices—can revolutionize undergraduate education across global institutions. By offering realistic, low-risk environments for hands-on practice, these workshops bridge the gap between didactic teaching and clinical application. The first sections examine deficiencies in traditional orthopedic education and review the emergence of simulation-based learning tools. Following this, the design of an ideal orthopedic bootcamp is outlined, emphasizing scalability, resource considerations, and assessment methods. A global implementation strategy is proposed, taking into account regional variations, partnerships, and sustainability challenges. Furthermore, educational outcomes are measured using frameworks like Kirkpatrick's Four Levels of Evaluation and the Objective Structured Assessment of Technical Skills (OSATS). This paper aims to portray a case example from Newcastle University Medicine Malaysia, demonstrating real-world applications of the concepts discussed. By implementing these innovative strategies, medical schools around the world can raise the bar for undergraduate surgical education by better preparing aspiring physicians with critical orthopedic competencies prior to clinical exposure.

Keywords: orthopedic education; simulation-based learning; surgical skills; bootcamp; osats

1. Introduction

Musculoskeletal conditions are considered one of the most common health issues worldwide. Their significant disability and costs are the main reasons behind their high global burden (Woolf and Pfleger, 2003). Regardless, undergraduate medical programs have always neglected orthopaedic education, focusing more on theoretical knowledge rather than hands-on experience. As a result, many fresh graduates feel ill-prepared for basic orthopaedic skills, including trauma and emergency care. These skills are not only important for potential orthopaedic specialists, but also for junior doctors and other specialities as well.

The challenges in undergraduate orthopaedic training have long been an issue for medical schools globally. In their systemic review, Dawe et al. (2004) concluded that surgical simulation-based training markedly improved surgical performers when participants were trained to a defined level of proficiency instead of a specific period. Nonetheless, medical undergraduates continue to report lack of confidence in caring for orthopaedic patients, including conducting a basic orthopaedic

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examination, managing fractures, performing simple procedures. As surgical advancements are slowly taking over, the gap in clinical practice medical students face is becoming more evident. This proves the importance of gaining early hands-on experience in the field. Simulation-based training ensures students have a safe and well-structed environment to refine their skills without causing harm to patients. In addition, combining theoretical information with clinical experience is one of the most effective ways to retain knowledge, increase students' confidence and prepare them for such cases in their clinical placements.

Significant advances in orthopaedic education are already in place. Sawbones (synthetic bone models) and internal fixation devices are amongst some of the widely used simulation tools. The basis behind sawbones is to replicate real bone in terms of structure and function. This allows students to practice drilling, plating, and fracture repair without putting any patients at risk. When combined with internal fixation devices, students get a more realistic experience to enhance their learning and skills.

The purpose of this paper is to investigate the creation, worldwide application, and pedagogical effects of orthopedic workshops that use simulation-based techniques. The study offers recommendations for institutions looking to enhance undergraduate surgical training by highlighting important gaps in conventional orthopedic education, assessing the usefulness of instruments like sawbones and internal fixation models, and laying out a structured bootcamp framework. It also addresses possible obstacles, describes evaluation techniques, and suggests a scalable worldwide implementation plan. To demonstrate how these tactics have been effectively implemented in actual educational environments, case studies from Newcastle University Medicine Malaysia and Monash University Malaysia will be provided.

2. The Gap in Traditional Orthopedic Education

In the past, textbook readings, didactic lectures, and little clinical experience constituted the mainstay of undergraduate orthopaedic education. Although this gives students a solid foundation of knowledge, it is devoid of the components needed to give them the clinical experience they need for procedures like internal fixation, cast application, and fracture reduction.

There is a clear disconnect between psychomotor performance and cognitive comprehension. Although students may grasp the theoretical underpinnings of fracture management, they frequently have difficulty carrying out simple tasks like hardware application or fracture alignment. The short orthopedic training duration in many medical programs exacerbates this problem. In the United States, orthopedic exposure is frequently provided as an elective rather than a required course of study, whereas in the United Kingdom, orthopedic rotations typically last only two to four weeks. Patient care suffers as a result of many graduates entering clinical practice lacking adequate orthopedic competence (Malik-Tabassum et al., 2020).

Feedback from students highlights this discrepancy even more. Medical students want more practical experience early in their education, according to numerous surveys. Skelley et al. (2012) found that 72% of medical students felt unprepared for musculoskeletal medicine and that more hands-on experience would greatly boost their confidence in treating orthopedic conditions.

According to a UK-wide survey-based study, final-year medical students consistently expressed low confidence in all fundamental trauma and orthopaedics skills, which is consistent with a larger failure of undergraduate training to meet clinical needs (Quan et al., 2020). These results highlight how urgently more workshops are needed to close the competency gap.

The early incorporation of practical skills is also supported by educational theory. According to Bloom's taxonomy (Bloom, 1956), meaningful learning encompasses the cognitive, affective, and psychomotor domains. Clinical proficiency requires the application, analysis, and evaluation of knowledge in practical contexts in addition to theoretical knowledge. Students' capacity to learn these crucial skills in time for clinical application is hampered when practical orthopedic instruction is postponed until later in the training process.

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Transitioning from passive to active learning is equally important. Rote memorization is dependent on didactic lectures. On the other hand, skills such as critical thinking, problem-solving and decision making are only enhanced by interactive workshops. Sawbone and other simulations workshops provide students with a safe yet realistic environment that allows them to practice a wide range of clinical skills, without putting any patients at risk.

Orthopaedic education faces significant global inequlities. This is largely due to restricted access to simulation technologies and lack of qualified faculty members, especially in low-resource countries. Even when resources are limited, research has shown that printed three dimensional (3D) and virtual models can provide scalable and affordable substitutes for cadaver approaches (Neijhoft, J. & IJpma, F. F., 2024). However, even in high-income countries, simulation tools are yet to be incorporated into the currently available undergraduate orthopaedic curricula.

Undergraduate orthopedic education needs to be fundamentally rethought in order to overcome these obstacles. Before students enter clinical settings, interactive, skills-based training programs that promote steady, self-assured competency development must be used in addition to, if not in place of, traditional didactic methods.

3. Sawbones and Internal Fixation as Teaching Tools

With sawbones models and internal fixation techniques at the forefront, simulation models have emerged as essential resources in orthopaedic education. With the help of these instructional resources, students can efficiently, ethically, and realistically acquire critical surgical skills while bridging the gap between theory and practice.

Sawbone models are synthetic representations of human bones that are intended to closely mimic their anatomical characteristics and biomechanical characteristics. Smith et al. (2023) discovered that sawbones models offered students an outstanding balance of realism, accessibility, and educational value when contrasted with cadaveric specimens in orthopaedic skills workshops. Sawbones, which range in size and shape from simple long bones to complex joint structures, give students a controlled setting in which to practice drilling, sawing, plating, and screw insertion. Teachers can model various fracture patterns thanks to their modular design, which exposes students to a variety of orthopaedic scenarios.

Using screws, plates, and intramedullary nails—essential components of contemporary orthopedic surgery—is part of the training for internal fixation on sawbones. Students can better understand important ideas like fracture stabilization, load distribution, and implant mechanics by practicing these techniques on artificial bones. Importantly, the ethical issues surrounding cadaver-based training can be avoided. Additionally, sawbones models are reusable and long-lasting, allowing for repeated practice to strengthen procedural knowledge and develop muscle memory.

The secure and stress-free learning environment that sawbones-based training offers is one of its main benefits. Errors made during simulation practice do not endanger patient safety, in contrast to cadaveric or live surgical settings. Because of the decreased anxiety, students are more willing to participate fully in the learning process. Teachers can also offer prompt feedback, which encourages in-the-moment correction and enhanced skill development.

Sawbones and cadaver models have been compared in studies. Although cadaveric training provides unparalleled anatomical realism, sawbones offer a more feasible and expandable option, especially for organizations with financial or logistical constraints. Additionally, sawbones circumvent the ethical, legal, and preservation-related concerns that frequently restrict the use of cadavers (Hetaimish, 2016).

Studies involving procedural workshops further support the benefits of simulation-based training. As an illustration of the wider applicability and efficacy of hands-on learning models in musculoskeletal education, arthrocentesis workshops have shown notable increases in student confidence and competence (Ladurner et al., 2020).

Sawbones workshops' adaptability to a range of educational contexts is one of their main advantages. They can be offered through extracurricular surgical interest groups, incorporated into

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immersive bootcamp-style programs, or included straight into the main curriculum of medical school. These workshops' modular design allows them to be customized to fit particular learning goals, from simple drilling methods to intricate multi-fragment fracture reconstruction.

To sum up, internal fixation methods and sawbone models represent a major advancement in undergraduate orthopaedic education. They give students practical, risk-free hands-on training opportunities, which improves their confidence and procedural skills. More significantly, these advancements guarantee that all aspiring doctors can execute fundamental orthopaedic procedures while putting patient safety first.

4. Designing an Orthopedic Bootcamp

Creating an effective orthopedic bootcamp requires meticulous planning, structured content delivery, and hands-on practice opportunities aligned with established educational objectives. A well-designed program can significantly enhance undergraduate students' cognitive, psychomotor, and affective domains, directly addressing the limitations of traditional orthopedic education.

4.1. Key Components of an Orthopedic Workshop

A balanced union of theoretical knowledge and practical skill-building should be incorporated within an orthopaedic bootcamp. As a general rule of thumb, the bootcamp should begin with concise, interactive lectures that broach the essential principles of fracture management, such as fracture classifications, healing processes, biomechanics, the fundamentals of bone stabilization and surgical fixation. These theoretical sessions should be in synchrony with the upcoming hands-on components of the bootcamp which promotes student engagement and fortifies applied and experiential understanding. Importantly, even brief workshops can be impactful. For example, a study in St. George's Hospital, London, United Kingdom has shown that a one-day orthopedic course had delivered high quality training and valuable career insights for undergraduates with 87% of the participants in support of the integration of the program into the readily available curriculum based on the 92% reports of inadequate current training (Soukup et al., 2012).

Following the didactic portion, students rotate through skill stations, each focused on a specific technique. Stations may include:

- Drilling techniques and screw insertion
- Plating of simple transverse fractures
- Management of comminuted fractures
- Intramedullary nailing techniques

At each station, a faculty member should demonstrate briefly before students can proceed using sawbone models. Instant feedback is pivotal at this juncture, as it allows students to improve their technique and correct errors in real time.

4.2. Use of Simulation Sawbones Fractures

To ensure alignment in achieving the bootcamp's learning objectives, pre-fabricated Sawbone models can accommodate different fracture types similar to real-world fractures. Bootcamp learners may start with a simpler fracture such as diaphyseal fractures which only requires two-point fixation and gradually proceed to more advanced fractures that include angular stability plates or locking compression plates. This allows for the gradual inclination of technical proficiency through simulated stages of complexity which further supports progressive learning.

As a means of additional enhancement of educational outcomes, the inclusion of commonly encountered fracture types in clinical practice is imperative. Examples of such fractures encompass, midshaft femur fracture, distal radius fractures and simple ankle fractures. This further ascertains that students acquire skills relevant to real world settings by emphasizing on high yield clinical scenarios.

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4.3. Assessment Strategies: Pre- and Post-Training

Evaluations both prior to and following training are essential for figuring out how educational orthopedic bootcamps are. Assessments should ideally be carried out concurrently before and after training:

- Knowledge assessments use short-answer or multiple-choice questions to gauge theoretical comprehension.
- Evaluation of skills: As part of the Objective Structured Assessment of Technical Skills (OSATS), students are graded during practical stations using structured checklists.
- Self-evaluation: Confidence questionnaires were distributed prior to and following the workshop in order to measure perceived increases in competence.

These numbers provide educators and curriculum developers with crucial details regarding the program's advantages and disadvantages.

4.4. Duration, Faculty Requirements, and Materials

Depending on the complexity of the material, an orthopedic bootcamp should last one to two days. A two day workshop enables more practice and deeper engagement with advanced procedures, even though a one-day intensive session might focus on basic concepts. The faculty should include senior residents, clinical educators with simulation-based instruction experience, and orthopedic surgeons. Maintaining a low student-to-faculty ratio—ideally 4:1 or 5:1—is essential for the best learning outcomes and personalized feedback.

For a workshop to be successful, the following necessary supplies are required:

- Models of sawbones that depict different anatomical locations
- Drill sets for orthopedics with the right drill bits
- Plates, screws, nails, and related instruments inside the medullary
- Safety gear includes things like gloves, masks, and protective eyewear
- Separate stations for hands-on learning and a special lecture room

A comprehensive materials checklist and logistical plan can help ensure effective execution and minimize disruptions

4.5. Global Scalability Considerations

Orthopedic bootcamps should be scalable in order to guarantee wide impact. Among the crucial factors are:

- Cost-effectiveness: Make use of reusable models and tools whenever you can.
- Faculty training: Establishing "train-the-trainer" programs to empower local educators.
- Curriculum adaptability is the capacity to change fracture types and procedures in accordance with local epidemiology and surgical resources.
- Utilizing online lectures and digital modules to improve program accessibility and lower logistical barriers—particularly in low- and middle-income nations—is known as virtual integration.

Institutions around the world can unleash the transformative potential of simulation-based, hands-on training by customizing orthopedic bootcamps to local needs while maintaining fundamental educational principles

5. Global Implementation Strategy

To optimize educational effectiveness, orthopaedic bootcamps must be customized and implemented globally, taking into account variations in educational systems, clinical demands, and available resources. To make sure that these programs are sustainable and widely available, careful planning is necessary

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5.1. Pilot Programs Across Continents

Orthopedic bootcamps' viability and advantages have been repeatedly shown by pilot projects conducted on several continents. For instance, the Orthopedic Surgery Interest Group at the University of Miami Miller School of Medicine in North America held a "Sawbones" benchtop workshop. After the session, 86.4% of participants said they were more interested in pursuing orthopedics, and 100% of participants expressed high satisfaction (Donato et al., 2023).

Using locally accessible resources, educators have implemented creative orthopedic bootcamps in parts of Asia and Africa where standardized models are hard to find. One noteworthy method from India was the use of fracture models that were 3D printed. Compared to their peers who used traditional solid models, medical students who trained with these models showed significantly better retention of anatomical knowledge and enhanced fracture management skills. They also expressed greater satisfaction with the learning process, according to a randomized preliminary study (Zhang et al., 2024)

5.2. Partnerships With Universities and Orthopedic Societies

For expansion to be successful, cooperation with professional associations and academic institutions is essential. For scalability and quality assurance, groups like the AO Foundation offer professional advice, logistical support, and standardized curricula (AO Foundation, 2024). Working together with these groups guarantees that you will have access to international best practices, educational materials, and certified teachers.

By combining their infrastructure, academic resources, and faculty expertise, universities can collaborate regionally to develop training facilities that serve wider geographic areas. These partnerships promote academic exchange and expand access to orthopaedic education in underprivileged areas.

Additionally, it has been demonstrated that interest groups like the Orthopaedic Surgery and Sports Medicine Interest Group are successful in increasing student engagement, mentorship, and interest in musculoskeletal medicine (Mickelson et al., 2017). These groups are helpful additions to formal training because they combine structured learning with peer-driven support and career guidance

5.3. Virtual Collaboration, Local Adaptations, and Sustainability

Innovative solutions for worldwide implementation are provided by virtual platforms. In-person sessions can concentrate on practical application while theoretical instruction is delivered through online lectures, seminars, and interactive modules. Before practical workshops, resources like gamified tests, virtual classification tasks, and recorded surgical demonstrations can improve learning. The effectiveness of virtual strategies is demonstrated by large-scale events such as the national virtual orthopaedic symposium, which significantly improved students' knowledge and engagement across institutions (Quan et al., 2022).

Sustainability requires careful local adaptation. Designers of programs should:

- Focus on the fracture types and surgical methods that are most relevant to the local epidemiology.
- Adjust the technical complexity of the stations to take into account the institutional resources and the abilities of the learners.
- Train local faculty to guarantee program continuity and lessen dependency on outside teachers

Continuous improvement of bootcamp content and delivery in response to learner needs and changing clinical priorities is made possible by integrating feedback mechanisms, such as pre- and post-workshop evaluations.

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5.4. Potential Barriers and Solutions

There are challenges in implementing orthopedic boot camps around the world. However, with careful planning, these difficulties can be foreseen and lessened:

- Financial limitations:
  - Solution: Partner with medical device companies for equipment sponsorship or discounted supplies. Use cost-effective, reusable sawbones models and streamline workshop formats to reduce expenses.
- Shortage of qualified instructors:
  - Solution: Implement "train-the-trainer" models, where a core group of local educators is intensively trained and tasked with disseminating knowledge within their regions.
- Limited access to materials:
  - Solution: Use hybrid models combining online theoretical instruction with hands-on training using alternative tools such as wooden models or 3D-printed bones when standard materials are unavailable.
- Problems integrating curricula:
  - Solution: Provide proof of enhanced student competency, confidence, and clinical results to justify the formal inclusion of orthopedic boot camps in medical curricula.

Orthopedic bootcamps can be effectively implemented in a variety of healthcare and educational settings by proactively addressing these issues and customizing programs to local contexts. By democratizing access to necessary surgical training, this global approach can give aspiring doctors the hands-on experience they need to provide patients with high-quality care

6. Measuring Success: Educational Outcomes and Student Transformation

To make sure orthopedic bootcamps achieve their stated learning objectives and make a substantial contribution to medical education, their efficacy must be assessed. To measure the programs' efficacy and encourage continued development, a variety of quantitative and qualitative assessment frameworks and instruments are available

6.1. Kirkpatrick's Four Levels of Evaluation

Kirkpatrick's Four Levels of Evaluation (Kirkpatrick & Kirkpatrick, 2006) is one of the most popular models for evaluating training effectiveness because it offers a methodical way to assess the complete impact of educational programs:

- Level 1: Reaction: Indicates how pleased participants were with the bootcamp right away. Surveys conducted after the workshop can determine whether or not students thought the experience was interesting, pertinent, and well-structured.
- Level 2: Learning — Evaluates the growth of abilities and understanding. Multiple-choice tests and the Objective Structured Assessment of Technical Skills (OSATS) are examples of pre- and post-workshop assessments that can be used to measure this. These assessments gauge improvements in theoretical knowledge and procedural proficiency.
- Level 3: Behavior: Evaluates students' application of the skills they acquired during clinical rotations. Changes in clinical behavior, such as the capacity to diagnose and treat simple fractures with little supervision, can be monitored by supervisors.
- Level 4: Results — Looks at wider effects, such as better patient outcomes or fewer mistakes in the process. Although measuring this level at the undergraduate level is more challenging, sustained monitoring may provide useful insight.

A thorough evaluation of the bootcamp's educational impact is ensured by incorporating all four levels of Kirkpatrick's model, which also yields data that can guide future curriculum decisions.

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6.2. Objective Structured Assessment of Technical Skills (OSATS)

An objective, standardized way to evaluate technical surgical skills is provided by the OSATS framework. OSATS can be used in the orthopedic bootcamp environment in a number of ways:

- Checklist-based evaluations for particular processes (such as applying plates or inserting screws)
- Worldwide rating systems to assess things like efficiency, procedural knowledge, and instrument handling.
- Error tracking and time-based metrics are used to evaluate the precision and velocity of skill execution.

Procedural workshops like the knee examination bootcamp, where quantifiable gains in OSCE performance were documented following practical practice, provide supporting evidence (Miniato, Schaefer, & Weldy, 2019). Assessing students using OSATS before and after bootcamp provides measurable indicators of their development and aids in pinpointing areas that require more work.

6.3. Qualitative Feedback From Students

Qualitative feedback offers more profound insights into students' experiences and perceptions than quantitative evaluation. This can be obtained by:

- Interviews or focus groups
- Open-ended questions for surveys
- Essays that reflect on individual learning experiences

Recurring themes include suggestions for bettering workshop logistics or content, greater self-assurance in procedural skills, and improved preparedness for clinical settings. The psychological effects of the program on students, especially in relation to motivation and self-efficacy, can be validated and improved upon using these accounts in subsequent sessions

6.4. Case Examples: Pre- and Post-Workshop Skill Levels

To complement quantitative data, individual case examples offer compelling illustrations of student transformation. For example:

- During a pre-workshop evaluation, a student who is initially not familiar with surgical drills may have trouble with tool angulation and stability. Following the bootcamp, the same student may show improved confidence and technical proficiency by successfully aligning plates on a sawbones model.
- Another student might not be able to correctly classify fractures at the start of the session. Following instruction, the student demonstrated a clear clinical progression by being able to accurately identify fracture types and suggest suitable fixation techniques.

When demonstrating the bootcamp's worth to institutional leaders and educational stakeholders, these real-world examples humanize statistical findings and act as effective advocacy tools

7. Newcastle University Medicine Malaysia Workshop

Early orthopedic exposure and the development of basic procedural skills are vital, especially during the undergraduate years. Hence, Newcastle University Medicine Malaysia (NuMed) has taken the initiative to incorporate the knowledge and skills learned during the workshop into its undergraduate program. This workshop provides the students with a safe and supervised environment where they can practice their orthopaedic skills, such as fracture reduction, cast application, and surgical fixation. This acts as an interactive link between classroom education and clinical practice. Early exposure to orthopaedic through workshops guided by experienced orthopedic surgeons and facilitators helps students develop their confidence, competence, and might even develop their interest in orthopedics.

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Details of the Workshop

NUMed organised an Orthopaedics Workshop in April 2025, bringing 32 medical undergraduates from both NUMed and Monash University Malaysia. This half-day workshop featured four practical stations designed to provide essential skills in orthopaedic practice:

Station	Description
Plaster of Paris (POP) Backslab Application	Participants practised applying below-elbow POP backslabs on one another, reinforcing techniques in preparation, moulding, and alignment. This station emphasised foundational immobilisation skills essential in emergency fracture care.
Closed Manual Reduction and Orthosis Braces	Students learned fracture reduction methods (e.g., for Colles' fractures), performed neurovascular assessments, and explored a variety of braces and orthoses, gaining knowledge in their indications, fitting, and patient education. This highlighted conservative management strategies.
Skin and Skeletal Traction	Participants assembled and applied skin traction kits, while skeletal traction techniques were demonstrated using simulation models. This provided essential training in alignment and stabilisation practices commonly encountered in trauma cases.
Introduction to Basic Implants and Plate Fixation	Under expert supervision, students handled real implants, inserted dynamic compression plates, and practised using electric drills on synthetic bones. This built hands-on familiarity with operative fracture fixation techniques.

Student feedback has been extremely positive. Descriptions of the workshop included terms like "awesome," "excellent," and "very informative". The students appreciated the good balance between theory and practical exposure, as well as the facilities and equipment provided. They also commented on the facilitators being very friendly and professional. The use of surgical tools, implants, and drills allowed students to apply the knowledge learnt from the textbook to real clinical scenarios.

The students emphasise that this early, structured exposure enhanced their understanding of orthopaedics and better equipped them for upcoming foundation training and clinical rotations. Given their desire to become proficient in these fundamental skills, many argued for longer or more frequent sessions to enable more immersive hands-on practice.

This workshop acts as a good example of how early exposure is important in forming the clinical and procedural confidence of future physicians. Through teaching undergraduates about casting, traction, reduction, and implant handling, these workshops enhance their clinical knowledge and procedural skills, equipping graduates to be more prepared once they are in the real-life setting.

8. Conclusions

An advancement in surgical education has been made with the inclusion of orthopaedic workshops in undergraduate medical programs. These workshops help to resolve two significant disadvantages of traditional orthopaedic training, which are slow procedural skill development and limited hands-on exposure.

Because of partnerships with academic institutions and orthopaedic associations, these workshops have been implemented globally, showing that they can work well in different places with different budgets, hence their adaptability and scalability. The promising outcomes of these training programs held internationally highlight the importance of early, skills-based training. Furthermore, the use of the framework, Kirkpatrick's Four Levels, ensures that the educational outcomes are continuously optimised.

In conclusion, orthopedic workshops are essential components of medical education. We can improve the quality of the workshops by concentrating on standardising the workshop models and incorporating these workshops into the university curriculum. This will guarantee that everyone has equal access to orthopedic training worldwide. Orthopaedic workshop not only can enhance student

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competency and their procedural skill, but it will also greatly improve patient outcomes, particularly in the healthcare setting.

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