Pilot Study for an Orthopedic Surgical Training Laboratory for Basic Motor Skills

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Abstract

The most effective way to teach and assess a resident's knowledge of musculoskeletal medicine, including orthopedic-specific surgical skills, remains unclear.

We designed a surgical skills training session to educate junior-level orthopedic residents in 4 core areas: comfort with basic power equipment, casting/splinting, suturing, and surgical instrument identification. As part of the study reported here, 11 orthopedic residents (postgraduate year 1-3) completed a skills session and were evaluated with written examinations and an ankle fracture model before and after the session. Four other junior residents were unable to attend the session because of clinical responsibilities.

For the group of 11 residents who completed the written examination, mean (SD) presession percentile was 87.3 (10.4), mean (SD) postsession percentile was 92 (8.4), median was 96, and mode was 96. There was a significant pre–post difference among all test takers, regardless of training level ($P < .05$). In the ankle fracture model, for the entire group, mean (SD) overall presession percentile was 68.6 (13.9), and mean (SD) overall postsession percentile was 95.2 (5.2). There was a significant pre–post difference among all test takers, regardless of training level ($P = .03$). An intensive laboratory has the potential to improve junior-level residents' basic surgical skills and knowledge.

For the resident, the surgical residency is physically, emotionally, and intellectually demanding, requiring longitudinally concentrated effort. Although education of orthopedic surgeons necessarily occurs within the context of the health care delivery system, vital lessons also are taught in laboratories, skill stations, and surgical simulators. Before practice-based learning can take place, residents must gain experience and demonstrate growth in surgical skills, including decision-making and technical skills. These skill sets are difficult to systematically teach and objectively analyze.

The most effective way to teach and assess a resident's knowledge of musculoskeletal medicine remains unclear at this point. Much of the current literature addresses the issue at the medical student level.[1-7] Some studies have shown the effectiveness of surgical training programs, both cadaveric and computer-based simulators, in teaching various surgical skill sets.[8-14] The orthopedic literature has seen a boom in surgical simulators aimed at the upper-level resident. Many of the topics involve use of arthroscopic simulators.[15-19] Evidence suggests that simulators can discriminate between novice and expert users, but discrimination between novice and intermediate trainees in surgical education should be paramount.[20]

The American Board of Orthopaedic Surgery (ABOS) and the orthopedic Residency Review Committee (RRC) recommended new requirements for structured motor skills training in basic orthopedic surgery education,[21] which were approved by the Accreditation Council for Graduate Medical Education (ACGME) board of directors and went into effect on July 1, 2013. In response to the new ACGME guidelines, our institution created a skills laboratory devoted to surgical simulation. Our focus in implementing this surgical skills simulation was junior-level, specifically postgraduate year 1 to 3 (PGY-1 to PGY-3), orthopedic residents. Our first goal was to set up a series of surgical training stations to educate junior-level residents in 4 core areas: handling and comfort with basic power equipment, casting/splinting, suturing, and surgical instrument identification. A secondary goal was to objectively evaluate the residents through written examinations (presession–postsession) and a novel ankle fracture model (pre–post).

Materials and Methods

Institutional review board approval was obtained before beginning the investigation.

Written Examination

We created a multiple-choice 25-question written examination (**Appendix**) and administered it to 11 junior residents before and after they participated in the training. This examination assessed their knowledge base of basic orthopedic tenets, including basic bone healing, basic fracture repair (Arbeitsgemeinschaft für Osteosynthesefragen [AO] principles[22]), suturing, surgical instrument identification, casting/splinting, and elementary implant-design rationale.

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Evaluator Scorecard

We created an evaluation scorecard (**Figure 1**) and had 2 faculty members and 2 senior-level residents complete it independently. Junior residents were evaluated on a sawbones lateral malleolar ankle fracture model at 2 time points. As with the written examinations, the junior residents completed the fracture model both before and immediately after the multiple skill sessions. Each of the 15 data points was scored from 1 to 4, for a total of 60 points.

Facility for Surgical Training Session

Our Clinical Skills Education and Assessment Center houses small-group interactive laboratories for administration, debriefing, and assessment of simulations with the latest in audiovisual equipment. Five stations were created: hands-on introduction to surgical power equipment using sawbones, wood, and polyvinylchloride (PVC) pipe; hands-on introduction to casting and splinting; hands-on introduction to suturing; hands-on interaction with surgical scrub technician as-

Resident Name: ______________________________

Evaluator Name: ______________________________

1-4 scoring system*

1. > 20 minutes/didn't complete
2. 17-20 minutes
3. 14-17 minutes
4. ≤ 14 minutes

Start Time: ______________ Total Time: ______________

End Time: ______________ Time Score: ______________

1-4 scoring system*

1. Didn't do
2. Fair
3. Satisfactory
4. Excellent

Skill	1	2	3	4
Anatomically reduced fracture with clamp (ie, point-to-point or lobster claw).				
Reduction clamp out of path of intended lag screw.				
Drilled using drill guide/"soft-tissue" protector correctly at all times.				
Drilled "near" cortex with correct 3.5-mm drill.				
Drilled "far" cortex with correct 2.5-mm drill.				
Used "top hat" or drill guide for 2.5-mm drill to avoid drilling eccentrically.				
Lag screw path perpendicular to fracture.				
Employed depth gauge correctly.				
Used appropriate-length 3.5-mm fully threaded cortical screw.				
Used countersink appropriately.				
Selected appropriate-length 1/3 tubular plate (ie, one that allows at a minimum 2 screws above and 2 below fracture).				
Preliminarily held plate in place with clamp (ie, lobster claw).				
Drilled with 2.5-mm drill for screw/plate construct.				
Again used appropriate-length 3.5-mm fully threaded cortical screws.				
Time score from above				
Overall total				

*Out of maximum 60 points.

Figure 1. Scorecard.

sisting with instrument identification; and didactic PowerPoint (Microsoft, Redmond, Washington) presentation focusing on core trauma competencies, basic orthopedic design rationale, and basic bone biology.

Development of Surgical Skills Training Session

Multiple faculty members and senior-level residents collaborated to create the skill stations (**Figure 2**), which were designed based on ACGME recommendations and on weaknesses our program had seen in junior-level residents. We devoted an afternoon to this session, excusing our program's junior residents from clinical responsibilities. Four PGY-1, 5 PGY-2, and 2 PGY-3 residents participated. (Four of our 15 junior residents were unable to attend because of clinical responsibilities.) The afternoon started by dividing the 11 junior residents into 2 groups. Before the session, while one group performed the ankle fracture model and was being evaluated, the other took the written examination. This closely timed portion was allotted only 20 minutes. Then residents were divided into 5 groups of 2 or 3 and were rotated through all 5 stations. Forty minutes were allotted for each station. Residents were not evaluated during this portion. The stations were intended solely for education, and each station was staffed by a faculty member and/or senior-level resident.

Figure 2. Junior residents rotate through 5 surgical training stations in skills laboratory. In foreground, residents practice basic skills with surgical screws and sawbones.

Cordless reciprocating saws and drills were purchased to introduce and refine junior residents' motor skills. Sawbones, 2×4-in sections of wood, and PVC pipe were used in the training. Emphasis was placed on tactile feel and feedback with both sawing and drilling. For the casting and splinting session, we used 4-in fiberglass, 4-in plaster rolls, and cotton soft roll to demonstrate a multitude of common casts and splints (**Figure 3**). Casts included short- and long-arm casts and short-leg casts. Splinting included coaptation, sugar tong, and ulnar gutter splints for the upper extremity and a short-leg posterior splint for the lower extremity.

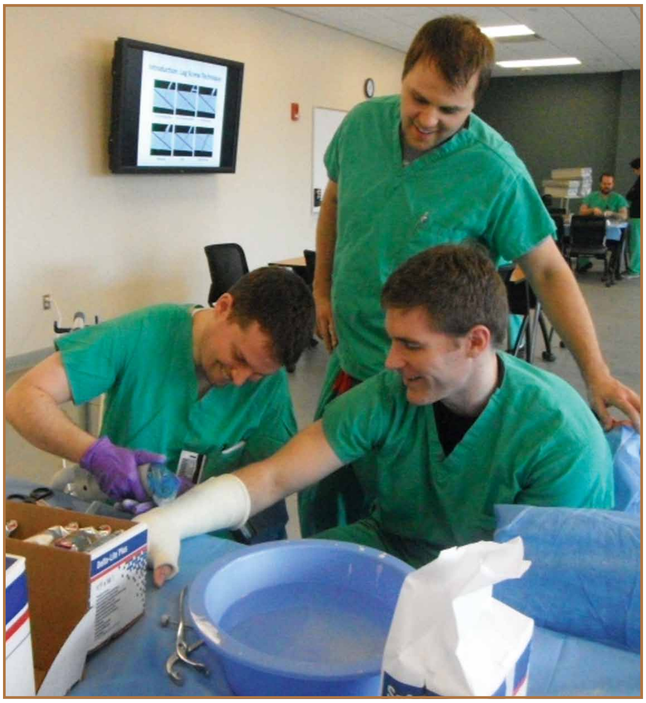

Figure 3. Postgraduate year 2 resident, left, practices casting techniques under supervision of senior residents.

The didactic PowerPoint presentation drew largely from content in chapters of the book *AO Principles of Fracture Management*.[22] Content included condensed, to-the-point high-yield summaries of AO tenets, basic bone healing and biology, and orthopedic implant-design rationale focused on these elementary principles:

- Basic screw design, including cortical, cancellous, and locking screw designs.
- Evolution of plate osteosynthesis to currently used locking compression plate.
- Locking plate principles.
- Lag technique.
- Plate use: compression mode, neutralization, bridging, buttress, anti-glide.

The suturing portion was performed with thawed ham hocks (**Figure 4**). This model replicates live tissue layers and allows a layered closure technique as a training tool. Both 0 and 2-0 absorbable suture were available for a layered, deep fascial closure; also available was 2-0 nonabsorbable nylon for the skin. Staple guns were available, as were basic surgical instruments, including quality needle drivers, Adson forceps, and suture scissors. The knots demonstrated included simple,

Figure 4. Faculty member, left, demonstrates basic suturing technique, using ham hock, to postgraduate year 1 resident.

horizontal mattress, vertical mattress, and tension-relieving. One- and 2-hand tying and instrument tying were reinforced.

The final session consisted of surgical instrument identification. A certified orthopedic scrub technician participated. On site were multiple trays, including a basic bone set, a hand-and-foot set, small and large fragment sets, and a hip set. A detailed review of each set was led by the surgical technician. This review was followed by a question-and-answer session with the junior residents. After the session, we ended with the written examination and the ankle fracture model.

Statistical Methods

We report presession and postsession means, modes, and medians as measures of score-central tendencies. Our small sample size makes the assumption of Gaussian distribution tenuous and more susceptible to outliers. Therefore, in addition to reporting means, we include medians and modes to more accurately account for outliers. Moreover, the κ statistic is a robust measure of interrater agreement for 2 or more groups. We report κ statistics to determine the interrater reliability of 4 independent observers.

Table 1. **Test Scores of the 11 Residents**

Resident Level (Postgraduate Year)	Percentile	
	Presession	Postsession
1	96	96
	72	76
	84	92
	68	76
2	88	100
	88	96
	96	100
	96	92
	80	92
3	100	96
	92	96

Results

Written Examination

Eleven residents (PGY-1 to PGY-3) completed the examination (**Table 1**). For the entire group, mean (SD) presession percentile was 87.3 (10.4), median was 88, and mode was 96; mean (SD) was 80 (12.6) for PGY-1, 89.6 (6.7) for PGY-2, and 96 (5.7) for PGY-3. For the entire group, mean (SD) postsession percentile was 92 (8.4), median was 96, and mode was 96; mean (SD) was 85 (10.5) for PGY-1, 96 (4) for PGY-2, and 96 (0) for PGY-3 (**Table 2**).

There was a significant presession–postsession difference in scores among all test takers, regardless of training level ($P = .019$). The PGY-1 level did not reach statistical significance in improvement from presession to postsession ($P = .080$); the PGY-2 level also did not reach statistical significance in improvement ($P = .099$); the PGY-3 level did not have enough participants to calculate a P value based on a paired Student t test.

Ankle Fracture Model

Actual percentile scores are listed in **Table 3**. For the entire group, mean (SD) overall presession percentile was 68.6 (13.9), median was 67, and mode was 67; mean (SD) was 58.8 (9.8) for PGY-1, 76.1 (13.6) for PGY-2, and 69.5 (9.8) for PGY-3. For the entire group, mean (SD) postsession percentile was 95.2 (5.2), median was 97, and mode was 97; mean (SD) was 91.8 (6.3) for PGY-1, 97.1 (3.5) for PGY-2, and 97.3 (2.4) for PGY-3.

There was a large and significant presession–postsession difference in scores among all test takers, regardless of training level ($P = .03$). Each group reached statistical significance in improvement from presession to postsession: PGY-1 ($P = .04$), PGY-2 ($P = .01$), and PGY-3 ($P = .03$).

Table 2. **Presession and Postsession Statistics**

Statistic	Written Examination		Ankle Fracture Model	
	Presession	Postsession	Presession	Postsession
Mean	87.27273	92	68.61364	95.15909
SD	10.4028	8.390471	13.86851	5.198136
Mode	96	96	67	97
Median	88	96	67	97
Maximum	100	100	95	100
Minimum	68	76	45	77

Table 3. **Ankle Fracture Model Percentile Scores**

Resident Level (Postgraduate Year)	Evaluator	Percentile	
		Presession	Postsession
1	Faculty	48	93
	PGY-5	67	95
	PGY-4	63	97
	Faculty	67	97
	Faculty	50	93
	PGY-5	70	97
	PGY-4	68	97
	Faculty	75	98
	Faculty	55	83
	PGY-5	60	90
	PGY-4	57	85
	Faculty	67	98
	Faculty	45	77
	PGY-5	47	85
	PGY-4	45	90
	Faculty	57	93
2	Faculty	55	93
	PGY-5	68	97
	PGY-4	68	98
	Faculty	75	98
	Faculty	65	97
	PGY-5	87	97
	PGY-4	90	100
	Faculty	92	100
	Faculty	78	90
	PGY-5	90	100
	PGY-4	85	100
	Faculty	95	100
	Faculty	62	95
	PGY-5	87	97
	PGY-4	87	100
	Faculty	88	100
	Faculty	48	87
	PGY-5	67	97
	PGY-4	65	97
	Faculty	70	98
3	Faculty	60	93
	PGY-5	68	97
	PGY-4	67	100
	Faculty	77	98
	Faculty	55	95
	PGY-5	77	97
	PGY-4	67	98
	Faculty	85	100

Abbreviation: PGY, postgraduate year.

For κ calculations, we adjusted all scores to ordinal data and thus used a standard grading system:

Score	*Grade*
90–100	A
80–89	B
70–79	C
60–69	D
0–59	F

For the presession fracture model, the κ among the 4 independent observational scorers was 0.1148 (**Table 4**), which is poor based on κ scoring criteria and which we attribute to the particularly harsh grading by 1 observational scorer (faculty 1) relative to the other scorers'. Examination of the κ scores of faculty 1 and faculty 2 indicated only 9.09% agreement. Conversely, the κ among resident scorers agreed 54.55% of the time. Removing faculty 1 as an outlier raised the κ score dramatically, to 0.3125 (fair interobserver agreement).

For the postsession fracture model, the κ among the 4 independent observational scorers improved only marginally, to 0.1156 (still poor), again attributed to a difference in severity of grading: faculty 1 (harsh) versus faculty 2 (relatively kind). Examination of the κ scores of faculty 1 and faculty 2 revealed 72.73% agreement; residents agreed 81.82% of the time.

Discussion

The importance of surgical skill development in resident education is emphasized in the ACGME Core Competencies.[23] The ACGME instructed all programs to require residents to gain competency in 6 areas: patient care, interpersonal and communication skills, medical knowledge, professionalism, practice-based learning and systems-based practice. Although many surgeon educators and residents are focused on these 6 Core

Table 4. **κ Scores[a] for Ankle Fracture Model**

Grade	κ	*Z*	Probability > *Z*
Presession			
F	0.2323	1.89	0.0296
D	0.0179	0.15	0.4423
C	−0.0759	−0.62	0.7313
B	0.2281	1.85	0.0320
A	0.2667	2.17	0.0151
Combined	0.1148	1.72	0.0423
Postsession			
C	−0.0233	−0.19	0.5749
B	0.0833	0.68	0.2492
A	0.1726	1.40	0.0804
Combined	0.1156	1.09	0.1375

[a]κ strength of agreement: 0-0.20, poor; 0.21-0.40, fair; 0.41-0.60, moderate; 0.61-0.80, good; 0.81-1.00, very good.

Competencies, current standards do not require surgical skills laboratory training and simply require residents to log cases into the ACGME website. Minimal case number recommendations are in place for graduating senior residents, but these numbers are based on averages with no strong scientific basis.

Although sweeping changes in orthopedic residency training went into effect July 1, 2013, this system remains untested and may offer room for improvement. One change is the restructuring of the PGY-1 internship. A basic surgical skills curriculum must include goals, objectives, and assessment metrics; skills used in the initial management of injured patients, including splinting, casting, application of traction devices, and other types of immobilization; and basic operative skills, including soft-tissue management, suturing, bone management, arthroscopy, fluoroscopy, and use of basic orthopedic equipment.[21]

Orthopedic program directors and residents were recently surveyed regarding the current state of orthopedic motor skills training.[24] Three key findings deserve emphasis: There is a lack of objective criteria for evaluating resident performance in the skills laboratory; most program directors who have a laboratory do not understand the associated costs; and the most significant issue for program directors is the financial challenge of operating a motor skills laboratory. The survey findings strongly suggest that proposed changes in skills training should be accompanied by careful cost analysis before widespread implementation.

Although various online demonstrations of entire surgeries are available, as are textbooks describing a generalized approach to musculoskeletal surgery, we assume that, as laid out in the Core Competencies, residents are fine-tuning their surgical skills by actively participating in operating rooms under direct observation of attending physicians. To our knowledge, however, there are no data regarding how often this happens in the operative setting, where volume and efficiency are becoming increasingly scrutinized. There has been much concern over how hour restrictions will affect residents' total operative experience.[25,26] Finally, we have no means to objectively evaluate residents' surgical skills on graduation.

Other programs have implemented surgical skill simulators, but an orthopedics-specific surgical skills laboratory, to our knowledge, has been discussed in only 1 study.[21] Results from randomized controlled trials reported in the general surgery literature have proved simulation-based training leads to detectable benefits for learners in clinical settings.[27-29] Over the past decade, some alternative surgical skills training methods have been adopted in orthopedic surgery as well. These methods include hands-on training in specifically designed surgical skills laboratories using cadaver models or synthetic bones; software tools; and computerized simulators. In recent years, numerous studies reported in the orthopedic literature have examined arthroscopic simulators in residency training.[18-20,30-34] However, these studies are arguably more specific to sports subspecialties and thus more pertinent to upper-level trainees.

Our study results showed that surgical skills laboratory training should be a required aspect of our residents' training. Although less of a dramatic improvement was noted in the written examination component of the laboratory, the overall knowledge base improved (**Table 3**). This was especially evident at the PGY-1 level, where written examination scores increased from a presession median of 80% to a postsession median of 85%. A larger degree of improvement was found with the ankle fracture model, and there was statistical improvement at all training levels, from PGY-1 to PGY-3. Previous work has shown that intensive laboratory-based training can be effective, particularly for first-year residents. Sonnadara and colleagues[35] demonstrated that a 30-day intensive surgical skills course effectively helped first-year orthopedic residents develop targeted basic surgical skills. In a follow-up study, Sonnadara and colleagues[36] demonstrated that a surgical skills course completed at the beginning of a residency was effective in teaching targeted technical skills, and that skills taught in this manner can have excellent retention rates.

There are limitations inherent in our skills course. The κ agreement in the ankle fracture model was low before and after administration, which we attribute to 1 observer outlier. This could be amended by removing outliers and further objectifying and simplifying the scoring system (A–F). Right now, we do not have enough data to determine whether the scores actually improve significantly through the training years or whether they will correlate with operating room experience. Our study had no control. For future investigations, we are considering having general orthopedic surgeons from the community perform the same scenarios and be graded with the same checklists as a control. Implementation, however, may be a challenge. Both our written examination and our ankle fracture model checklist have not been validated—this is one of our next steps. The point system used to score the ankle fracture model was subjectively developed and would benefit from further standardization before drawing conclusions about true validity.

Conclusion

Orthopedic residency programs, like programs in other surgical specialties, are increasingly focused on teaching and documenting the learning of core competencies, even as work-hour restrictions and demands for clinical efficiency limit the amount of time residents spend in the operating room. We have demonstrated the potential value of an intensive laboratory in improving junior-level residents' basic surgical skills and knowledge. We will continue to refine our methods, with a goal being to create reproducible models that could be adapted by other orthopedic residency programs and by other surgical educators.

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Appendix on next page ➢

This paper will be judged for the Resident Writer's Award.

Appendix. Orthopedic Basic Knowledge Questions

1. **The following X-ray(s) is/are very useful for preoperatively planning a severe fracture:**
   A. Normal side X-ray, if available.
   B. Highest quality injury X-rays.
   C. Injury X-rays with joint unreduced or dislocated.
   D. X-ray showing the injury, but not including adjacent joints.
   E. A and B.

2. **Name this instrument:**

   A. Richardson retractor
   B. Army/Navy retractor
   C. Hohmann retractor
   D. Gelpi retractor

3. **Primary bone healing:**
   1. is also called direct bone healing.
   2. has only a fibrous callus with no cartilaginous intermediary.
   3. has an abbreviated inflammatory response.
   4. is always associated with rigid fixation.
   A. 1, 3, and 4.
   B. 2, 3, and 4.
   C. 1, 2, and 3.
   D. 1, 2, 3, and 4.

4. **Treatment with anatomical reduction and plate fixation encourages direct bone healing. When treating long-bone fractures with locked intramedullary nailing, which of the following describes the bone-healing process?**
   A. "Relative stability" is achieved promoting "indirect" bone healing.
   B. Callus formation is expected on follow-up radiographs during the healing process.
   C. Micromotion is expected at the fracture site, which stimulates the healing process.
   D. All of the above.

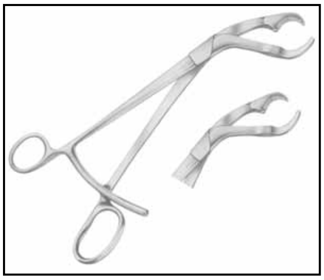
5. **Choose the correct order for accurately placing a lag screw across an oblique fracture plane:**
   1. Measure the screw length with a depth gauge.
   2. Anatomically reduce the fracture and hold with pointed reduction forceps.
   3. Drill the threaded hole (far cortex) with a 2.5-mm drill bit and drill sleeve.
   4. Use the 3.5-mm drill bit and sleeve to create a gliding hole (near cortex).
   5. Insert screw of desired length.
   A. 4, 3, 2, 1, 5.
   B. 2, 4, 3, 1, 5.
   C. 2, 4, 3, 5, 1.

6. **The drill guides for use with the DCP and LC-DCP implants (Dynamic Compression Plate and Limited Contact Dynamic Compression Plate; Synthes, West Chester, PA) are intended to allow for neutral or eccentric drill position with respect to the oblong plate holes. Placement of a screw in the eccentric position will allow for 1 mm of axial compression at the fracture site in a plate previously secured on the other side of the fracture.**
   A. True.
   B. False.

7. **Which drill guide/sleeve should be used for the insertion of an independent 6.5-mm cancellous lag screw in dense bone where tapping is required?**
   A. 4.5/3.2-mm Double Drill Sleeve.
   B. 6.5/3.2-mm Double Drill Sleeve.
   C. DCP Drill Guide.
   D. LC-DCP Drill Guide.
   E. Universal Drill Guide.

8. **To minimize damage to the bone while drilling, proper techniques should be used. This includes thorough irrigation of the site, use of drill guides/sleeves, and use of sharp drill bits.**
   A. True.
   B. False.

9. **Name this instrument:**



   A. Kelly clamp.
   B. Verbrugge reduction clamp.
   C. Pointed reduction clamp.
   D. Lobster claw reduction clamp.

10. **Initial loosening of screws prior to removal should be done using:**
   A. Manual screwdriver or power equipment with screwdriver shaft.
   B. Power equipment with screwdriver shaft only.
   C. Manual screwdriver only.

11. **The countersink has which of the following functions?**
   A. To allow the lag screw to reach the far cortex.
   B. To cut a hole so that the screw head will be recessed.
   C. To minimize soft-tissue irritation.
   D. All of the above.
   E. B and C.

12. **The major determinant of bending and shear strength in a screw is the:**
   A. Core diameter.
   B. Thread diameter.
   C. Core diameter to thread diameter ratio.
   D. Pitch.

13. **The major determinant of pullout strength in a conventional screw is:**
   A. Head size.
   B. Surface area of contact between thread and bone.
   C. Head shape.
   D. Self-tapping tip.

14. **The purpose of a tap is to:**
   A. Ease placement of screws in cancellous bone.
   B. Improve bending strength of screw.
   C. Provide for more rapid screw insertion.
   D. Cut threads for non-self-tapping screw insertion.

Continued

15. Cancellous screws have deeper threads and a coarse pitch in order to:

A. Increase the bending strength of the screw.
B. Allow for easier insertion in cortical bone.
C. Maximize surface area of thread in contact with bone in order to improve holding power.
D. Provide for slower screw insertion.

16. Conventional screw-plate constructs achieve stability by:

A. Compression-creating friction.
B. Achieving a fixed-angle relationship between the screw and the plate.
C. Increasing endosteal contact between the implant and the bone.
D. Preventing periosteal compression.

17. Locking screw-plate constructs achieve stability by:

A. Compression-creating friction.
B. Achieving a fixed-angle relationship between the screw and the plate.
C. Increasing endosteal contact between the implant and the bone.
D. Preventing periosteal compression.

18. Locking screws have a larger core diameter than conventional screws do in order to:

A. Increase pullout strength.
B. Create less compression.
C. Create less endosteal damage.
D. Improve bending and shear strength.

19. In order to achieve a lag screw technique with a fully threaded screw, it is necessary to:

A. Drill with only one drill bit.
B. Tap.
C. Drill the gliding hole the same diameter as the thread diameter of the screw.
D. Use a plate.

20. Which of the following is not a standard AO principle?

A. Anatomical reduction.
B. Stable fixation.
C. Early mobilization.
D. Meticulous reassembly of all fracture fragments with interfragmental screws.

21. In order to appropriately dissipate forces on the cancellous screw heads, it is useful to:

A. Countersink in cancellous areas and use a washer in strong cortical bone.
B. Countersink in good bone and use a washer in cancellous areas.
C. Place them only perpendicular to the surface of the bone.
D. Place them only at large angles.

22. Each plate has a general mechanical function and a specific design name. All of the following are mechanical functions except:

A. Neutralization.
B. Precontoured.
C. Compression.
D. Tension band.
E. Bridge.
F. Buttress.

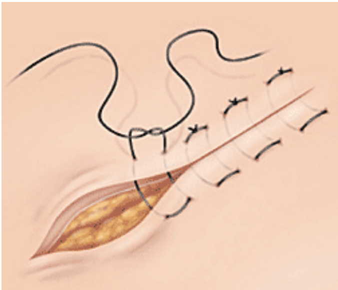
23. The mechanical function of a plate is determined by:

A. The size.
B. Whether it is precontoured.
C. The shape of its holes.
D. How it is used.
E. The metallurgy.

24. All of the following are complications of cast or splint immobilization except:

A. Compartment syndrome.
B. Heat injury.
C. Pressure sores and skin breakdown.
D. All of the above are potential complications.

25. Name this type of surgical stitch:



A. Vertical mattress.
B. Horizontal mattress.
C. Allgower-Donati.
D. Subcuticular.