Module: #12 – Pedicle Screw Purchase

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Summary: Students will perform a basic biomechanics experiment to determine the relationship between the purchase of pedicle screws and the diameter of the screw drill hole. The instructor will provide a basic overview of vertebral anatomy and spine fusion using pedicle screws and rods. Students will install bilateral pedicle screws and conduct a simple pull-out test using a portable mechanical test frame. They will develop a hypothesis on the relationship between drill diameter and screw purchase, plot their observed relationship from the experiment, and assess whether the experimental data support or refute their initial hypothesis.

Learning Objectives
- Understand basic anatomy of the lumbar spine and vertebrae
- Understand mechanics of drilling and tapping operations
- Develop hypothesis on relationship between drill size and screw pull-out strength and test hypothesis by performing a simple biomechanics experiment
- Apply manual skills working with power drill, taps, and drivers

Teaching Aids
- 8.5 x 11” laminated slides
- Models
  1. Lumbar spine with single level screw-rod fusion
  2. Lumbar vertebra with cut-aways showing cortical and trabecular bone
  3. Types of pedicle screws

Detailed Instructions
1. Overview from Instructor
   1.1. (Models #1 & #2, Slide #1) Identify/define the following:
      1.1.1. (Slide #1) Three regions of the spine (# vertebrae): Cervical (7), Thoracic (12), Lumbar (5)
      1.1.2. (Slide #1 and Model #1) Anatomic directions: Anterior/posterior (ventral/dorsal), medial/lateral, superior/inferior (cranial/caudal)
      1.1.3. (Slide #1 and Model #1) Joints of the spine: intervertebral disc (anterior), facet joints (posterior)
      1.1.4. (Model #2 and Slide #1) Anatomy of a lumbar vertebra: vertebral body, pedicle, inferior and superior facets, lamina, transverse processes, spinous processes
      1.1.5. (Model #2) Cortical and trabecular bone
1.1.6. *Model #1* Spinal cord, nerve roots

1.2. **Pedicle Screws** *(Slide #2 and Model #3)*

1.2.1. Pedicle screws are a common orthopaedic device used for spine fusions.

1.2.2. The pedicle is a good location for placing screws because it contains dense bone, and it is the only portal for posterior-to-anterior placement of screws (without impinging on spinal cord or nerve roots).

1.2.3. Screws interlock with posterior fusion rods.

**Discussion Point**

Q. *Model #1* What direction(s) of loading will pedicle screws experience in the body?

A. Pedicle screws are connected to fusion rods. The rods load the screws inferiorly (standing, walking) and posteriorly (forward bending).

1.2.4. There are different kinds of pedicle screws

1.2.4.1. Different lengths, widths, and thread pitches

1.2.4.2. Fixed versus polyaxial screw heads

1.2.4.3. Tapered versus straight designs

1.2.5. Because pedicle screws experience high loads in the body, they must have good “purchase” with the bone (also referred to as “bite”).

**Discussion Point**

Q. Why do pedicle screws come in different lengths, widths, and thread pitches *(Model 3)*?

A. This is mainly to accommodate different sized patients and also different spinal levels. The pedicles get shorter and narrower as you move caudally to cranially in the spinal column. Children and young adults will have smaller pedicles than full-grown adults.

**Discussion Point**

Q. Some of the pedicle screws in Model #3 have some very sophisticated engineering design components, namely: (1) a “polyaxial” head design; and (2) a conical shape with different depth of threading. Both of these design components should be discussed, with students being asked to hypothesize on their purpose.

A. (1) The polyaxial head can swivel and tilt to accommodate the rod coming in from different angles. (2) The conical shape and different threading depth increases screw purchase. The drill hole and tapping for the screw is sized for the threading at the screw tip, which means that the larger core diameter, thicker threads at the near end (closer to the screw head) will “press fit” into the threads cut by the screw tip.

2. **Workshop Objective**

2.1. Install pedicle screws bilaterally into lumbar vertebra

2.2. Choose maximum drill size for drill/tap operation and develop hypothesis for how tap size will relate to amount of screw purchase

2.3. Test hypothesis by performing tensile test until pedicle screw pulls out of the bone

3. **Logistics**
3.1. Students are divided into small groups of 3-4 students and given an intact model of the lumbar spine.
3.2. One fully-trained volunteer can oversee screw insertion, with another managing pull-out testing.
3.3. Students are guided through Steps 5-9 in small groups.

4. Safety
4.1. Model should be held in universal bone holder during pedicle screw insertion.
4.2. Safety glasses should be worn by person using power drill.

5. Screw Insertion
5.1. Blindingly pick drill bit for maximum drill diameter from “grab bag”
5.2. Measure size of drill bit (in fractions of an inch) using digital calipers.
5.3. Mark hole start location on the pedicle.
5.4. Drill pilot hole with 1/16” drill bit. Check that pilot hole does not penetrate pedicle medially or laterally nor does it penetrate the anterior cortex.
5.5. Use incrementally larger drill bits up to final drill diameter (Step 5.1-2)
5.6. Tap hole
5.7. Insert screw with Allen wrench
5.8. Repeat Steps 5.1-8 for contralateral side.

6. Hypothesis Generation
6.1. Develop a hypothesis on the relationship between screw purchase and drill diameter.
6.2. This hypothesis will be tested in Step 8.

7. Pull-out Testing
7.1. Instructors should set up a single test station prior to the start of the workshop
7.1.1. Secure wooden handscrew clamp atop plastic block via large c-clamp
7.1.2. Wrap sandpaper around ends of handscrew clamp to better grip vertebrae
7.1.3. Pour sand into 2-10 lb plastic bags. Label bags with weight.
7.1.4. Loop chain through bucket and attach with carabiner. Adjust length of chain so that bucket will hang freely when vertebra is loaded.
7.2. For each pull-out test
7.2.1. Load vertebrae into handscrew clamp with pedicle oriented vertically towards the floor.
7.2.2. Attach custom loading fixture to pedicle screw head, and then attach carabiner to loading fixture.
7.2.3. Add sand bags until screw pulls out.
7.2.4. Record load at pull-out.

8. Hypothesis Testing
8.1. On the provided graph, label x and y axes.
8.2. Plot screw purchase (pull-out strength) versus drill diameter.
8.3. After all groups have finished, answer the questions:
8.3.1. Does this data support or refute your initial hypothesis?
8.3.2. What is the nature of this relationship? Linear versus non-linear? Proportional or inversely proportional?
8.3.3. Explain in simple terms the mechanisms driving this relationship.

9. Break-Down
   9.1. Students should remove all hardware and place into appropriate bins.
   9.2. Students may keep the vertebrae, so long as both pedicles have been drilled. If not, save the model for future use.