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Title: Surgical Technique for the Implantation of a Biomimetic Artificial Intervertebral Disc in a Goat Animal Model

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Author Questionnaire

1. **Microscopy**: Does your protocol require the use of a dissecting or stereomicroscope for performing a complex dissection, microinjection technique, or something similar? **No**

2. **Software:** Does the part of your protocol being filmed include step-by-step descriptions of software usage? **No**

3. **Filming location:** Will the filming need to take place in multiple locations? **No**

4. **Testimonials (optional):** Would you be open to filming two short testimonial statements **live during your JoVE shoot**? These will **not appear in your JoVE video** but may be used in JoVE's promotional materials. **No**

Current Protocol Length
Number of Steps: 19
Number of Shots: 50

Introduction

Videographer: Obtain headshots for all authors available at the filming location.

INTRODUCTION:

1.1. **Bjorn Meij:** This study presents a novel surgical technique for implanting a biomimetic artificial intervertebral disc (BioAID).
   1.1.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera. *Suggested B-roll: 2.3.1*

1.2. **S. Amir Kamali:** The BioAID incorporates a viscoelastic core and a tensile fiber jacket, 3D-printed titanium endplates, and unique instruments for disc replacement.
   1.2.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera. *Suggested B-roll: 2.5.1*

CONCLUSION:

1.3. **Björn Meij:** Our disc replacement research provides a safe implantation protocol for a biomimetic artificial disc, demonstrating secure fixation and rapid recovery.
   1.3.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera. *Suggested B-roll: 3.2.1*

1.4. **S. Amir Kamali:** Future research of this novel artificial disc will focus on osseointegration, implant stability, tissue response, and long-term biomechanical performance.
   1.4.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera. *Suggested B-roll: 4.2.1*

Videographer: Obtain headshots for all authors available at the filming location.

Ethics Title Card

This research has been approved by the National Central Authority for Scientific Procedures on Animals

Protocol

2. Exposure and Preparation of the Animal

Demonstrators: Bjorn P. Meij, S. Amir Kamali

2.1. To begin, position the anesthetized animal on the surgical table and make a ventral midline skin incision **[1-TXT]**.

2.1.1. WIDE: Talent making a vertical midline incision through the skin at the identified spot. **TXT: Anesthesia: 2 - 4 mg/kg Propofol (Intravenous) Authors:** You may please perform the procedure on a fresh cadaver. But we need the anesthesia details (as mentioned in your manuscript) displayed on the screen according to our guidelines. Minor adjustments, some extra shots because otherwise two actions in one shot. ; ; ;

2.2. Dissect through the subcutis and the platysma muscle **[1]**. Separate and retract the muscle bellies of the sternohyoideus and sternomastoideus in the midline **[2]**. Then, perform blunt dissection to the right side of the trachea **[3]** and gently retract the trachea with the esophagus to the left side **[4]**.

2.2.1. Talent dissecting through the subcutis and exposing the platysma muscle.

2.2.2. Talent separating and retracting the sternohyoideus and sternomastoideus muscles in the midline.

2.2.3. Talent performing blunt dissection to the right of the trachea.

2.2.4. Talent gently retracting the trachea and esophagus toward the left side.

2.3. Now, laterally retract the right carotid sheath to the right side **[1]**.

2.3.1. Talent carefully retracting the right carotid sheath laterally to the right.

2.4. Identify the sixth cervical vertebra by palpating its left and right large transverse processes extending lateral-ventrally **[1]**. Palpate the singular ventral process of the fifth cervical vertebra in the midline **[2]**. Next, identify the singular ventral process of the fourth cervical vertebra **[3]**.

2.4.1. Talent palpating the large transverse processes of the sixth cervical vertebra.

2.4.2. Talent palpating the singular ventral process of the fifth cervical vertebra in the midline.

2.4.3. Talent palpating the singular ventral process of the fourth cervical vertebra.

2.5. Bluntly separate the longus colli muscles to expose the ventral surfaces of the fourth and fifth cervical vertebral bodies **[1]**. Use two self-retaining Gelpi retractors to retract the longus colli muscle bellies **[2]** and localize the C4-C5 disc space immediately caudal to the ventral spinous process of the fourth cervical vertebra **[3]**. Then, perform a limited partial discectomy with a beaver knife **[4]**.

2.5.1. Talent bluntly separating the longus colli muscles to expose the ventral surfaces of the fourth and fifth cervical vertebral bodies.

2.5.2. Talent placing two self-retaining Gelpi retractors to retract the longus colli muscle bellies.

2.5.3. Talent pointing to and localizing the C4–C5 disc space caudal to the ventral spinous process of the fourth cervical vertebra.

2.5.4. Talent performing a limited partial discectomy using a beaver knife.

2.6. Next, place marks on the midline halfway between the vertebral bodies C4 and C5 for the application of the Caspar distractor **[1]**. Using a 2 millimeter drill bit attached to a low-speed drill, make a pilot hole on the marks, progressing through the cis-cortex and into the cancellous bone **[2]**.

2.6.1. Talent marking the midline between the vertebral bodies C4 and C5.

2.6.2. Talent drilling pilot holes with a 2.0 millimeter drill bit attached to a low-speed drill, progressing into the cancellous bone.

3. Distraction and Disc Preparation

3.1. Insert two 2.5-millimeter K-wires into the pilot holes using a low-speed drill **[1]**.

3.1.1. Talent inserting two 2.5 millimeter K-wires into the pilot holes with a low-speed drill.

3.2. Now, use fluoroscopy to confirm the correct placement of the K-wires, alignment with the C4-C5 disc space, and absence of involvement of the trans cortex **[1]**.

3.2.1. Shot of the fluoroscopic monitor confirming proper K-wire placement.

3.3. Then, connect the Caspar vertebral distractor to the K-wires on the C4 and C5 vertebral

bodies **[1]**. Use a spinal curette and Chevalier Jackson grasping forceps to completely empty the dorsoventral, central midline portion of the intervertebral disc **[2]**.

3.3.1. Talent connecting the Caspar vertebral distractor to the K-wires on C4 and C5.

3.3.2. Talent using a spinal curette and Chevalier Jackson grasping forceps to remove disc material.

3.4. Carefully debride the cartilaginous endplates using a Scoville disc curette **[1]**.

3.4.1. Talent debriding the cartilaginous endplates with a Scoville disc curette.

3.5. Next, insert the trial disc without keels to assess the proper artificial disc placement **[1]** and confirm placement using fluoroscopy **[2]**.

3.5.1. Talent inserting the trial disc without keels into the prepared space. **Videographer's NOTE**: This was extra CU

3.5.2. Shot of the fluoroscopic monitor confirming proper placement of the trial disc without keels.

3.6. Then, remove the trial disc without keels **[1].** Connect the saw guide to the holder and insert it into the prepared space **[2]**. After confirming the correct insertion of the saw guide, disconnect and remove the holder **[3]**.

3.6.1. Talent removing the trial disc without keels.

3.6.2. Talent connecting the saw guide to the holder and inserting it into the disc space.

3.6.3. Talent disconnecting the holder from the saw guide and removing the holder.

3.7. Line up a 0.6-millimeter-thick saw blade with the ventral midline vertebral crest of C4 and C5, within the open slot of the saw guide **[1]**, and start sawing using an oscillating sawing machine **[2]**. Stop sawing when the blade contacts the closed dorsal titanium side of the slot **[3]**. With the saw blade inserted, perform fluoroscopy **[4]**.

3.7.1. Talent aligning the 0.6 millimeter saw blade.

3.7.2. Talent beginning sawing with the oscillating sawing machine through the saw guide slot.

3.7.3. Close-up of the saw blade reaching the closed dorsal titanium side of the slot.

3.7.4. Show the fluoroscopic monitor view with the saw blade inserted in the correct position.

3.8. Next, reconnect the holder to the saw guide **[1]** and carefully remove the saw guide while maintaining distraction with the Caspar retractor **[2]**. Insert the trial disc with keels into the disc space and ensure proper placement **[3]**. Use fluoroscopy to confirm the alignment **[4]**.

3.8.1. Talent reconnecting the holder to the saw guide.

3.8.2. Talent removing the saw guide while keeping distraction with the Caspar retractor.

3.8.3. Talent inserting the trial disc with keels into the disc space and positioning it properly.

3.8.4. Show fluoroscopy confirming alignment of the trial disc with keels.

4. Artificial Disc Insertion and Fixation

4.1. Remove the trial disc with keels **[1]** and unpack the artificial disc device **[2]**.

4.1.1. Talent removing the trial disc with keels from the disc space.

4.1.2. Talent unpacking the artificial disc device.

4.2. Now, press the ventral side of the artificial disc fiber jacket firmly into the disc insert holder **[1]** and push the artificial disc into the prepared disc space **[2]**. Use fluoroscopy to confirm correct artificial disc placement and seating of the dorsal and ventral keels on both cranial and caudal sides **[3]**. Then, release the distraction on the Caspar distractor **[4]**.

4.2.1. Talent pressing the ventral side of the artificial disc fiber jacket into the insert holder.

4.2.2. Shot of inserting the artificial disc into the disc space. **Videographer's NOTE:** added deep insertion

4.2.3. Show fluoroscopy confirming the correct placement of the artificial disc and proper seating of the dorsal and ventral keels.

4.2.4. Talent releasing the distraction on the Caspar distractor.

4.3. Next, remove the Caspar distractor and the 2.5-millimeter K-wires **[1]**. With a high-speed 1 to 2-millimeter burr, create a round hole with a diameter of 5 millimeters within the ventral saw slit caudally on C4 and cranially on C5 **[2]**.

4.3.1. Talent removing the Caspar distractor and the 2.5 millimeter K-wires. **Videographer's NOTE:** removing caspar distractor in one take and separate shot for removing 2.5 pins (=K wires)

4.3.2. Talent using a high-speed burr to create a 5 millimeter round hole at the ventral saw slit on C4 and C5.

4.4. Finally, prepare the bone cement according to the manufacturer's instructions **[1]**. Apply the bone cement into the channel holes and allow it to cure for approximately 10 minutes **[2]**. Use two plates of 2-millimeter titanium with three holes to cover the cemented channels **[3]** and fixate each plate with two 2-millimeter locking screws **[4]**.

4.4.1. Talent showing the prepared bone cement.

4.4.2. Talent applying the bone cement into the channel holes. **Videographer's NOTE:** the first part is applying cement in only one hole. The second part is a shot of the two holes filled with cement. (Filling up the second hole did not go as smoothly as the surgeon wanted so he cleaned up and then we could do the finished second hole.

4.4.3. Talent placing two 2.0 millimeter titanium plates with three holes to cover the cemented channels.

4.4.4. Talent securing the titanium plates with two 2.0 millimeter locking screws. **Videographer's NOTE:** took 3 separate shots for this scene.

Results

5. Results

5.1. In vivo implantation of the artificial disc at the C4-C5 level in goats showed accurate placement and immediate stability as confirmed by intra- and postoperative imaging **[1]**.

5.1.1. LAB MEDIA: Figure 7 A B C.

5.2. Computed tomography imaging enabled multiplanar views that confirmed proper alignment of the artificial disc with the intervertebral disc space and vertebral endplates **[1]**, restoration of disc height, and symmetrical keel channel preparation **[2]**.

5.2.1. LAB MEDIA: Figure 7 D E.

5.2.2. LAB MEDIA: Figure 7 F.

5.3. Follow-up fluoroscopy at 24 hours **[1]** and 21 days post-implantation confirmed the artificial disc's maintained position and the integrity of the surrounding vertebrae **[2]**.

5.3.1. LAB MEDIA: Figure 9 A B.

5.3.2. LAB MEDIA: Figure 9 C D.

1. Propofol
   Pronunciation link: https://dictionary.cambridge.org/us/pronunciation/english/propofol Cambridge Dictionary+1
   IPA: /ˈproʊ.pəˌfɔːl/
   Phonetic Spelling: PROH-puh-fawl
2. Platysma
   Pronunciation link: https://dictionary.cambridge.org/us/pronunciation/english/platysma Cambridge Dictionary
   IPA: /pləˈtɪz.mə/
   Phonetic Spelling: puh-TIZ-muh
3. Sternohyoideus
   Pronunciation link: https://www.wiktionary.org/wiki/sternohyoideus Wiktionary
   IPA: /ˌstɝ.noʊ.haɪˈɔɪ.di.əs/
   Phonetic Spelling: STUR-noh-HY-oy-dee-us

4. Carotid (as in "carotid sheath")
   Pronunciation link: https://www.merriam-webster.com/dictionary/carotid (if needed) — you can check that site.
   IPA: /kəˈrɑːtɪd/
   Phonetic Spelling: kuh-RAH-tid
5. Disc (as in "C4-C5 disc space")
   Pronunciation link: https://www.merriam-webster.com/dictionary/disc
   IPA: /dɪsk/
   Phonetic Spelling: disk
6. Debride (as in "debride the cartilaginous endplates")
   Pronunciation link: https://www.merriam-webster.com/dictionary/debride
   IPA: /dɪˈbraɪd/
   Phonetic Spelling: dih-BRYED

- sternomastoideus

Pronunciation link: https://glosbe.com/en/en/sternomastoideus Glosbe
IPA: /ˌstɝ.noʊˌmæsˈtoʊ.iˌdi.əs/
Phonetic Spelling: STUR-noh-mas-TOH-ee-dee-us

- longus colli

Pronunciation link: https://www.howtopronounce.com/longus-colli howtopronounce.com
IPA: /ˈlɔːŋgəs ˈkɒli/ (US approx: /ˈlɔŋgəs ˈkɑli/)
Phonetic Spelling: LAWNG-guhs KAH-lee

- Gelpi retractor

Pronunciation link: https://www.howtopronounce.com/gelpi-retractor howtopronounce.com
IPA: /ˈdʒɛlpi rɪˈtræktər/
Phonetic Spelling: JEL-pee re-TRAK-tur

- curette

Pronunciation link: https://www.howtopronounce.com/curette howtopronounce.com
IPA: /kjʊˈrɛt/
Phonetic Spelling: kyoo-REHT

- Chevalier Jackson (as in "Chevalier Jackson grasping forceps")

Pronunciation link: https://www.howtopronounce.com/chevalier-jackson howtopronounce.com
IPA: /ʃəˈvæl.i.ər ˈdʒæk.sən/
Phonetic Spelling: shuh-VAL-ee-ur JAK-sun

- oscillating

Pronunciation link: https://www.howtopronounce.com/oscillating
IPA: /ˈɑːsəˌleɪ.tɪŋ/
Phonetic Spelling: AH-suh-LAY-ting

- intervertebral disc

Pronunciation link: https://dictionary.cambridge.org/us/pronunciation/english/intervertebral-disc
IPA: /ɪnˌtəˌvɝːtəˌbrəl ˈdɪsk/
Phonetic Spelling: in-TER-ver-TEH-bruhl DISK

- cancellous (as in cancellous bone)

Pronunciation link: No confirmed link found
IPA: /ˈkæn.sə.ləs/
Phonetic Spelling: KAN-suh-lus

- keels (in context “dorsal and ventral keels”)

Pronunciation link: https://www.merriam-webster.com/dictionary/keel
IPA: /kiːl/
Phonetic Spelling: keel

- burr (as in “high-speed burr”)

Pronunciation link: https://www.merriam-webster.com/dictionary/burr
IPA: /bɝː/
Phonetic Spelling: burr