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Understanding Scoliosis: What Caregivers and Patients Need to Know

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Understanding Scoliosis: What Caregivers and Patients Need to Know

by

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Abstract

Scoliosis is an abnormal curvature of the vertebral column that typically occurs in children approaching puberty. 80% of scoliosis cases are idiopathic (Scoliosis Research Society, 2022). The severity of a scoliosis curve is measured in degrees and is usually diagnosed when it is greater than 10 degrees. A severe curve exceeds 45 to 60 degrees and can require surgical treatment (Scoliosis Reduction Center, 2020). Severe scoliosis causes physical deformities, such as unaligned ribs, hips, and shoulders, but also may reduce the amount of space in the chest, affecting the function of the heart and lungs (Mayo Clinic, 2022).

The purpose of this project is to provide an array of educational materials to increase understanding of scoliosis and the surgical treatment of spinal fusion with growing rods. Currently, education about scoliosis and spinal fusion surgery is not easily accessible and information from the Internet can be overwhelming or scary to caregivers and patients during a stressful time in their lives. These materials will also allow a more effective use of time during patient-physician interactions, which can improve health care outcomes (Paterick et al., 2017).

A combination of interactive models and animations will be used to create a network of digital material that will be provided to caregivers and patients in an understandable and accessible way. Patient education materials are an important way to introduce biocommunication into everyday life. This project could be a steppingstone into a more integrated relationship between medical illustrators, healthcare professionals, and the general public.

Table of Contents **Page**

List of Illustrations

I. Introduction

Dr. David Borkholder, my content advisor, introduced me to Dr. John Heflin, a pediatric orthopedic surgeon at the Primary Children's Hospital in Salt Lake City, Utah. Dr. Heflin has been researching ways to improve surgical materials involved in scoliosis treatment to improve the patient experience over years of care. His research, along with his personal experience interacting with patients, revealed the lack of patient education materials that are easily accessible to patients and their caregivers. He expressed concern over his inability to spend a sufficient amount of time with each patient in order to adequately educate them about their scoliosis diagnosis. Dr. Heflin's concerns were translated into the objectives of this project through active communication between him, Dr. Borkholder, and myself.

The main objective of this project is to provide an understanding of scoliosis and surgical spinal fusion in a way that does not overwhelm or alarm the caregivers and patients. The medical field is often complicated and can lead to unnecessary stress and anxiety. The array of patient materials in this project are used to reduce feelings of uncertainty and fear that can arise with most diagnoses. The materials provide background about the disease and explain the complexities of this surgical procedure. The information in the models and animations is generalized, but still thorough so patients and caregivers understand their diagnosis and the extent to which treatment will improve their lives. The second aim is to give patients and caregivers access to the information post-doctor's appointment, especially if they may not have streamlined access to their healthcare provider. This is a vital step in narrowing the gap between healthcare providers and the people they help.

Due to most diagnoses occurring in adolescent patients, the primary audience for the patient education materials are the parents and/or caregivers. The secondary audience are the patients. It is important that adolescents understand the medical significance and possible physical changes that may occur, specifically the placement of growing spine rods. Healthcare providers can utilize these materials to aid in their explanation of diagnosis and treatment and increase patient understanding.

II. Scientific Background

a. The Spine

The spinal column consists of 33 separate bones, called vertebrae, separated by tough, elastic discs, allowing the spine to bend and twist. The vertebrae are separated into five different sections based on their position in the body. The cervical spine includes the top seven vertebrae, beginning at the base of the skull, and allow for the mobility and function of the neck. The next 12 vertebrae constitute the thoracic spine and contain sites where the ribs articulate posteriorly. Below the thoracic vertebrae are the 5 vertebrae of the lumbar region. This is the main weight-bearing portion of the spinal column. The sacrum is the fourth section located at the base of the spine. The 5 vertebrae of the sacrum are fused together and do not have discs between them. The coccyx connects to the base of the sacrum and consists of four fused vertebrae (Neurosurgical Associates, PC, 2022).

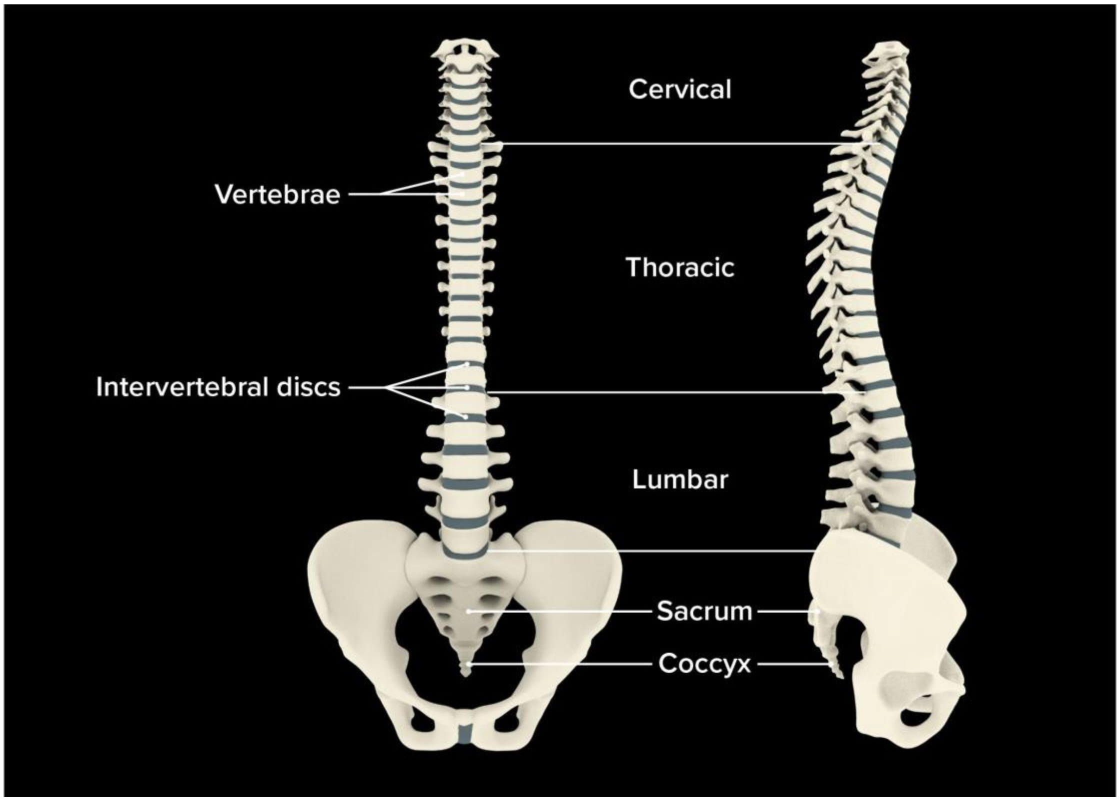

Figure 1. Sections and anatomy of the spine

Each section of the spine possesses a natural anterior or posterior curvature depending on the section. This natural curvature assists with balance, flexibility, stress absorption, and force distribution (Bridwell, MD, 2018). The cervical and lumbar spines have a natural anterior, or lordotic, curve. Lordosis can also be a spinal disorder where the anterior curve of the cervical spine and, more commonly, the lumbar spine can be excessive and cause abnormal posture leading to neck and lower back pain. The sacral and thoracic spines have a normal kyphotic curve towards the posterior aspect of the body. Abnormal kyphosis generally occurs in the thoracic spine and can cause the formation of a humpback and a pitched forward appearance (Eidelson, MD, 2014).

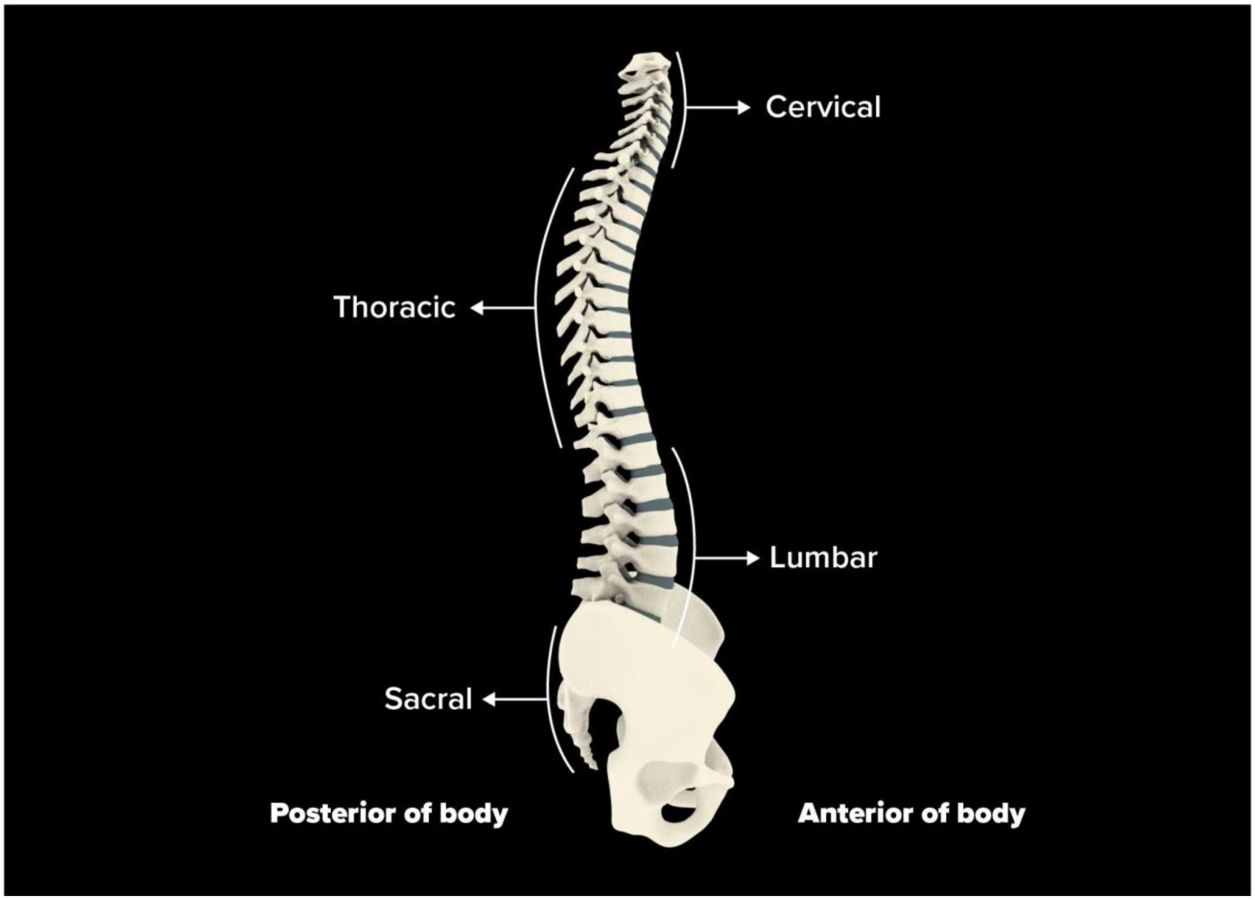

Figure 2. Direction of the spinal section curves

b. Scoliosis

Scoliosis, a disease that is typically diagnosed at a young age, is the abnormal lateral curvature of the spinal column. In addition to a lateral curvature of the spine, scoliosis can cause a longitudinal rotation and affect the natural lordotic curve of the vertebral column (Fadzan & Bettany-Saltikov, 2017). The structure of the individual vertebra is also affected in scoliosis. The nontypical curve of the vertebral column places asymmetric pressure on the still developing vertebrae causing the bone to form into an abnormal wedge shape, leading to increased pressure on the concave side of the spinal curve (Fadzan & Bettany-Saltikov, 2017). The increased pressure on one side of the vertebrae causes lateral movement towards the side with lesser resistance, exaggerating the convex curve of the column. The pressure imbalance and lateral shift lead to a rotation of the vertebrae where the body of the vertebrae travels toward the convex side of the curve and the spinous process travels to the concave curve. The vertebral body structure and position are not the only effect that scoliosis has on the bones. The pedicles, laminae, and transverse processes are similarly affected by the atypical pressure with a thickening of the sections on the convex side and a thinning on the concave side. In the thoracic region of the spinal column, this can lead to the pedicles becoming "wafer-thin" and a narrowing of the spinal canal (Fadzan & Bettany-Saltikov, 2017).

The shift in position of the vertebrae have significant effects outside the bony structure of the spine. The vertebral discs become compressed on the concave edge of the curve and extended on the convex edge. The soft tissue surrounding the column is also subject to structural and anatomical changes based on the side of the curve they are attached to. On the concave side of the column, the anterior and posterior longitudinal ligaments, ligamenta flava, interspinous ligaments, and intervertebral joint capsules, as well as the intervertebral muscles including the erector spinae, quadratus lumborum, psoas major and minor, and oblique abdominals are all shortened (Fadzan & Bettany-Saltikov, 2017).

The shifting, rotation, and shortening of these anatomical structures leads to physical deformities involving other bones in the thorax, abdomen, and pelvis. The ribs, which are attached to the vertebrae, follow the rotation and curvature of the spine. This causes a crowding and anterior shift on the concave side and an increased separation with a posterior shift on the convex side. The exaggerated anterior shift of the ribs can cause a physical hump on the anterior chest wall while the posterior shift can cause a hump on the posterior chest wall, as well as push the scapula out making it more pronounced through the skin. The movement of the spine also causes an imbalance in body position. The head and torso are no longer directly over the pelvis, but shift laterally depending on the curve (Fadzan & Bettany-Saltikov, 2017). The abnormal curvature of the spine can cause changes to the amount of space in the chest, affecting the function of the heart and lungs, or lead to degenerative joint disease (Mayo Clinic, 2022).

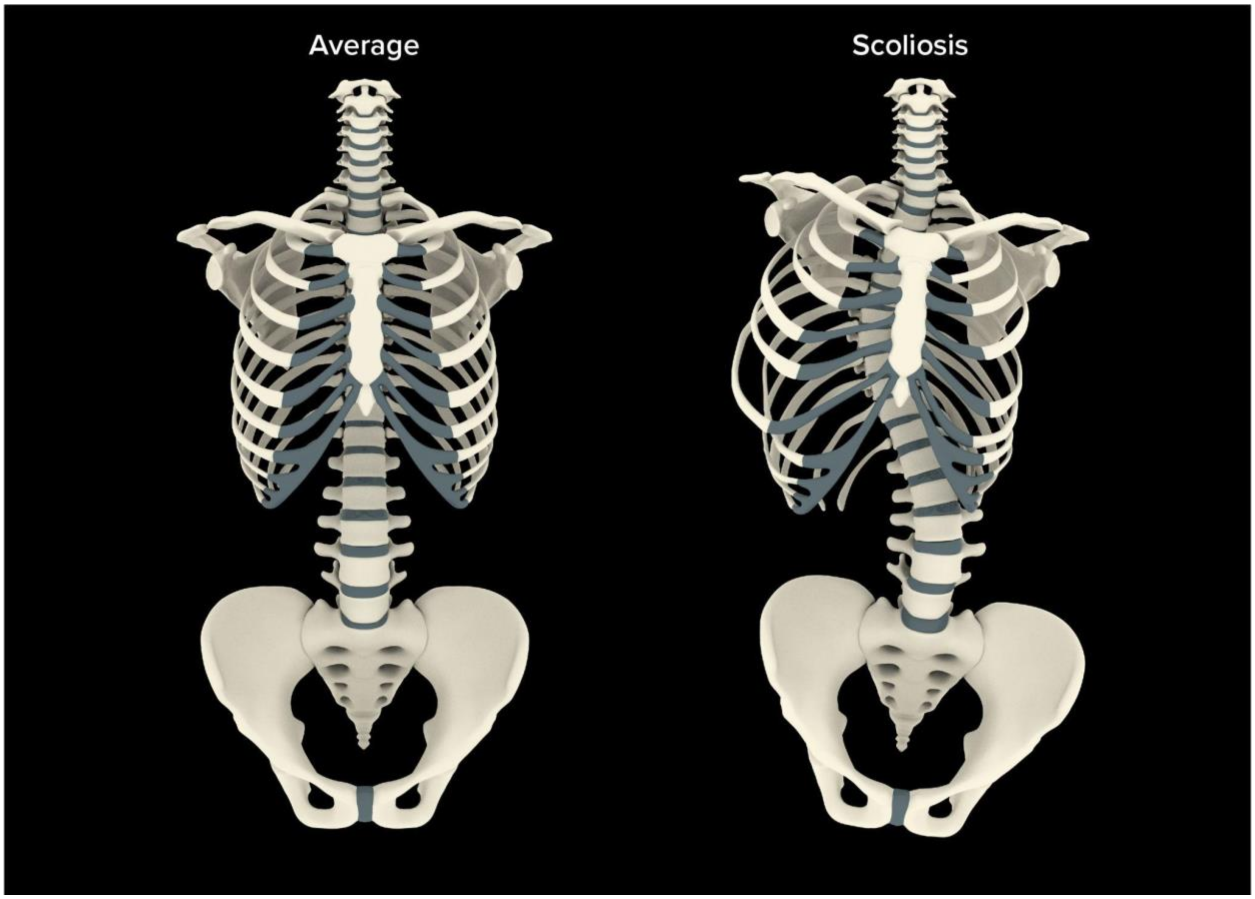

Figure 3. Anterior view of the bones in an average torso compared to a torso affected by scoliosis

c. Treatment

80% of scoliosis cases are idiopathic or have an undetermined cause. (Scoliosis Research Society, 2022). The severity of a scoliosis curve is measured in degrees and is typically diagnosed when it progresses past 10 degrees. A mild curve (10-25 degrees) does not require any treatment. A moderate curve is typically identified as greater than 25 degrees. Patients with a moderate curve are often prescribed a brace to prevent the curve from worsening. A severe curve exceeds 45 to 60 degrees and can require surgical intervention (Scoliosis Reduction Center, 2020).

There are three surgical treatment options for scoliosis: fusionless, fusion, and growing rods. Fusionless surgery utilizes a vertebral tethering system. This system alters the pressure placed on the spinal column to slowly straighten the spine. As of 2017, long term data of the risks and benefits of fusionless surgery are not available. Fusion surgery involves attaching, or fusing, two or more adjacent vertebrae using rods, wire, screws and hooks to form a single bone. This option decreases the patient's ability to bend or twist at the level where the vertebrae are fused. This option is not recommended for young children, as it can cause issues as they continue to grow, including decreasing the chest cavity space for the lungs or a shortened trunk compared to their limbs (Baaj, MD, 2017).

Another option has been developed for children who are still growing. Growing systems have been created to allow rods, which are attached to the spine, lengthen as the patient grows as they help correct or maintain the curvature of the spine (Baaj, MD, 2017). One form of rod system used by surgeons utilizes a magnetic external remote control to lengthen the device without the need for additional surgeries after the initial placement (NuVasive, 2016). A minimally invasive approach is used to place the rods by making small incisions at predetermined levels on the vertebral column. Two supralaminar hooks are placed on both sides of the T2 vertebra and two intralaminar hooks are placed on the T3 vertebra. Pedicle screws are then placed bilaterally into L3 and L4. Using these locations, the rods are trimmed to the appropriate length and contoured to match the sagittal alignment of the spine. The rod is then tunneled through the back along each side of the spine between the anchor locations. The proximal layout is attached first, then tightened to the distal pedicle screws. Bone grafts are then packed into the area of the anchors to allow for intervertebral fusion. Once the rods are placed, the patient returns every 3 to 6 months to have the rods expanded. The patient lays down on their stomach and a doctor holds the magnetic remote control over the location of the actuator, which will be the strongest point of attraction. This causes the internal magnet to release and rotate, which allows the rod to grow a few millimeters to match the growth of the patient (Akbarnia et al., 2016).

III. Body of Work

a. Audience and goals

It is the responsibility of physicians to influence patient behavior and attitude by improving knowledge about their diagnoses and providing them the opportunity and skills to cope with what can be life changing news. When first speaking with Dr. John Heflin, it was clear that his biggest concern for his patients is not having enough time with them and their caregivers to thoroughly educate them about scoliosis and the available treatment options, specifically the surgical placement of the growing rod system. Accessible patient education was the main goal of the materials created throughout this project. The finalized materials are an interactive 3D model and an animation.

Afflicted patients are the primary audience for most education materials. Most patients diagnosed with scoliosis are adolescents and therefore are not the primary decision makers for their own healthcare choices. This creates the need to not only educate the patient, but also their parents, guardians and/or caregivers. In addition to taking into account the vast age range, the emotional state of the audience has to be taken into account as well. Receiving a diagnosis such as scoliosis and finding out that a child is going to need surgery can cause distress, confusion, and fear in both the patient and their caregivers. It is important that the materials do not invoke negative feelings in patients, and to educate in a clear way that does not include difficult medical terminology and overly “graphic” medical images. The secondary audience are the clinicians and other healthcare providers that will be utilizing these materials for patient education.

b. 3D models

After receiving a diagnosis, a patient’s first step is to understand the physical impacts of the disease. While scoliosis is a condition in the spine, the shape and curvature of the spine will affect the bones in the thorax, abdomen, and pelvic regions which can cause an overall imbalance of the body. To help patients and their caregivers visualize this imbalance, I created a bone comparison interactive 3D model.

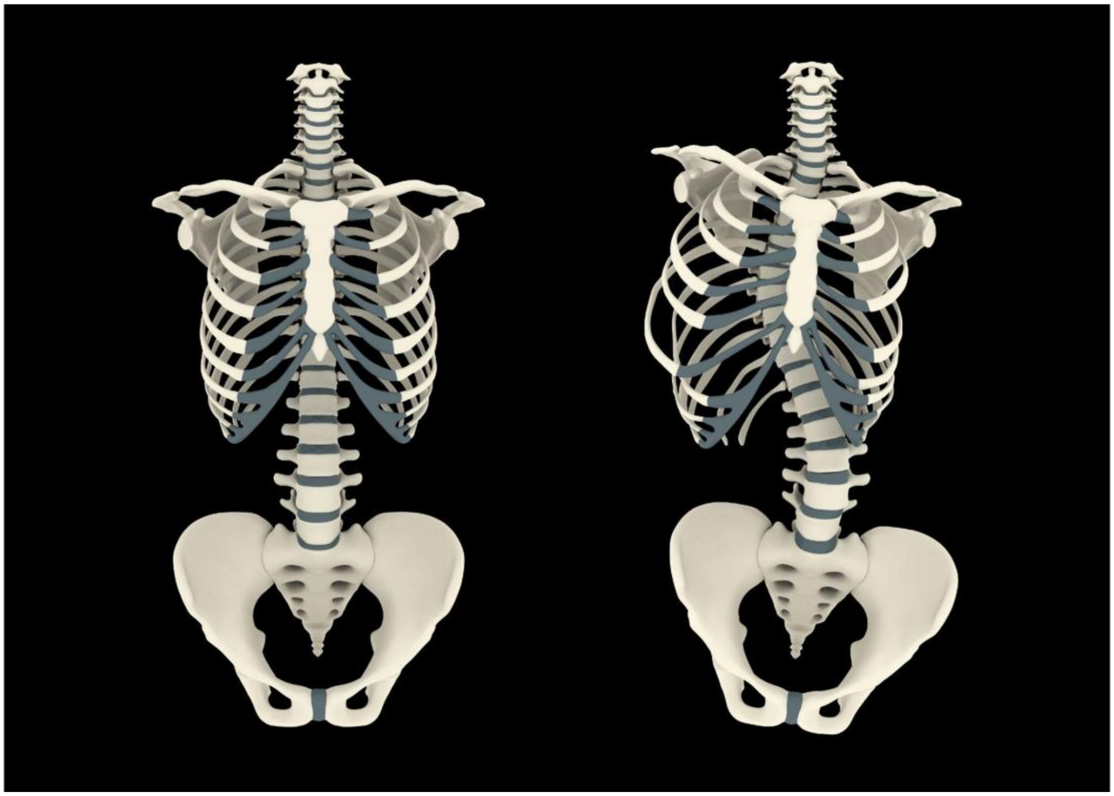

Figure 4. Anterior view of 3D models

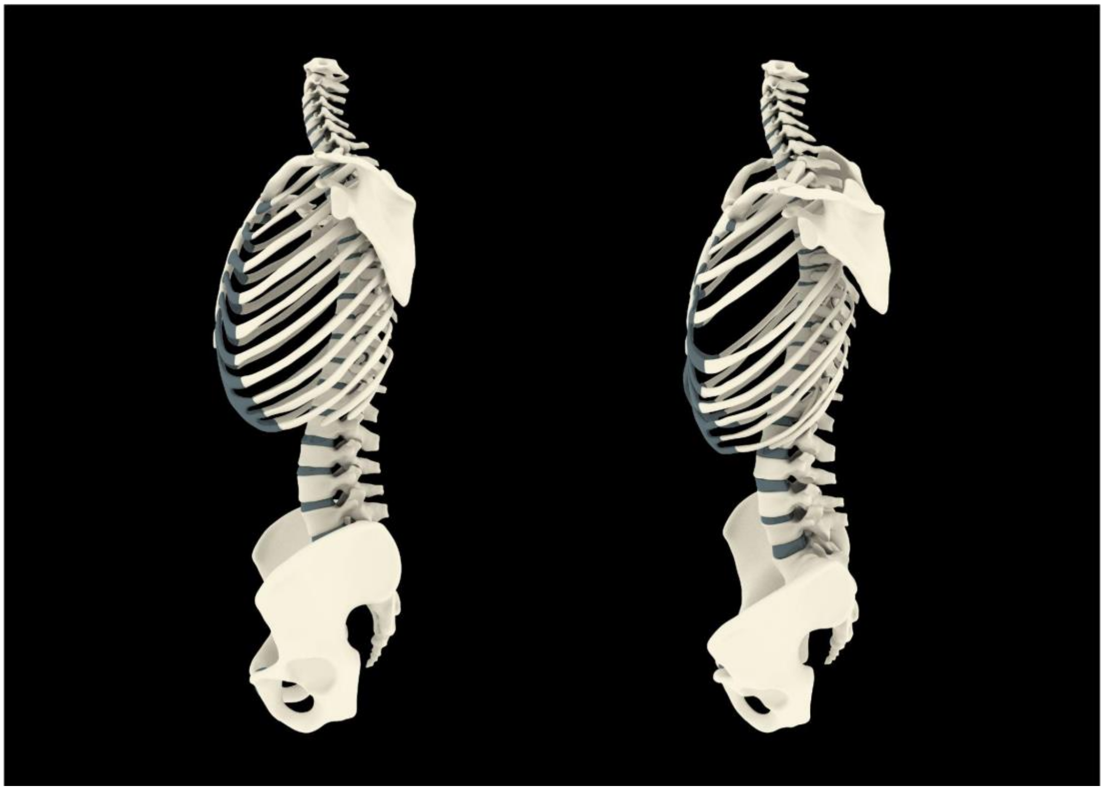

Figure 5. Lateral view of 3D models

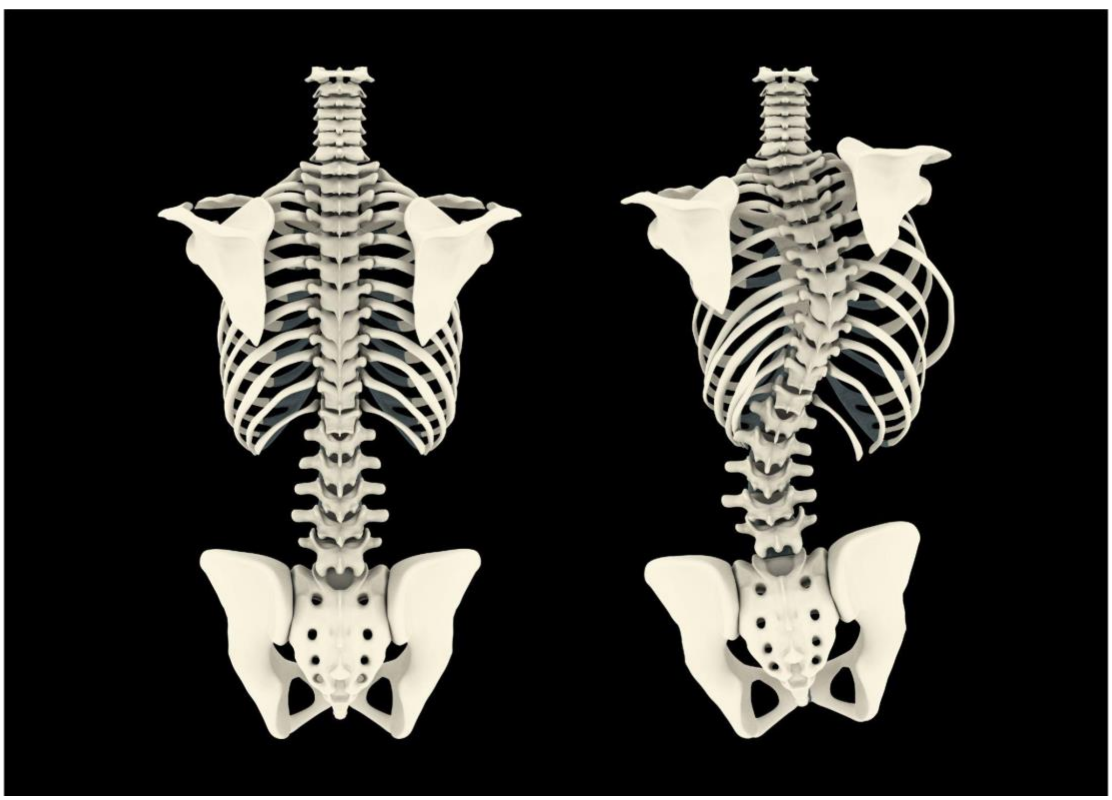

Figure 6. Posterior view of 3D models

The audience interacting with this 3D model will generally have a limited knowledge of human anatomy, so it was important to include a model of the normal bone positioning to highlight the changes caused by scoliosis. I decided that these models should be as anatomically accurate as possible, while also choosing the white color that is associated with bones by the general public and a light blue for the costal cartilage, pubic symphysis, and intervertebral discs. This allows the patient and caregivers to create an association with their own bodies and have a greater visual understanding of the skeletal system.

When looking at the anterior view of the 3D model (Figure 4), the normal skeletal structure on the left shows the healthy positioning of the bone with a straight spine and the ribs in line with the pelvic bone. On the model to the right, there is an extreme curve of the spine to the right, bringing the ribs on the left side closer to the base of the spine and each other while causing a separation of the ribs on the right side. This can be seen on the posterior view of the model (Figure 6) along with the scapulae, which are noticeably uneven. The right scapula rotates anteriorly, and the left scapula pushes out to the right and posteriorly. The last large difference that the models are showcasing is the loss of alignment of the ribs and pelvis.

The models were created in Autodesk Maya, beginning with basic polygons to build and connect the bones. I first created the model of the normal, healthy spine to make sure the bones were anatomically correct and start with a natural baseline to make the structural changes easier to make on the model with scoliosis.

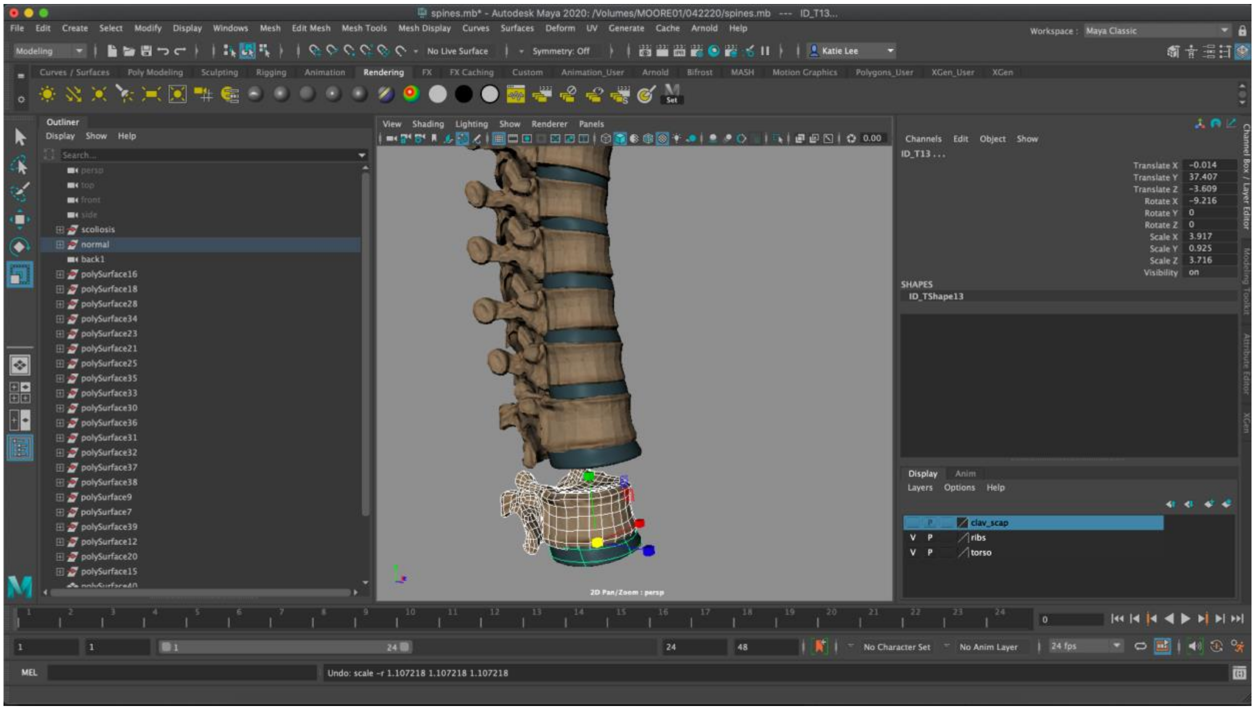

Figure 7. Screenshot of Maya while creating the healthy spine model vertebrae by building one vertebra for each section then using the rotate, scale and move tool to create differences in each

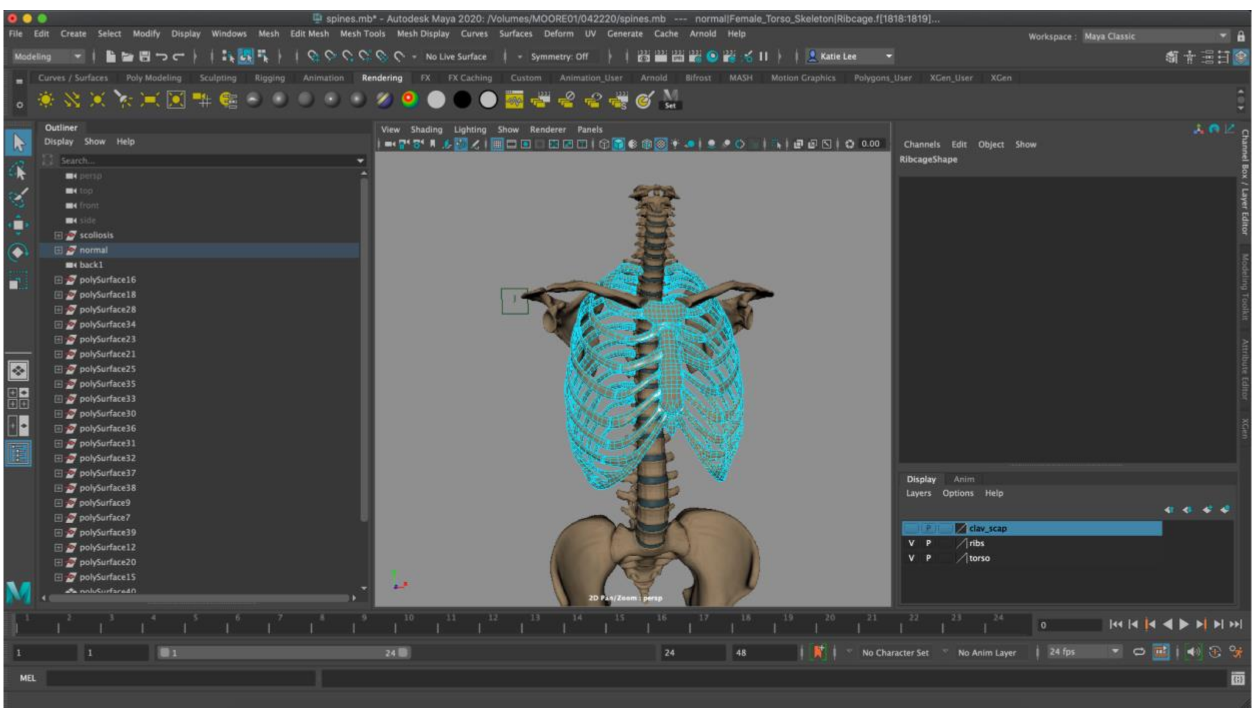

Figure 8. Screenshot of Maya finalizing the ribcage of the healthy spine model

After the healthy model was completed, I used example x-rays to slowly adjust, move, and rotate the modeled bones into the positioning of severe scoliosis.

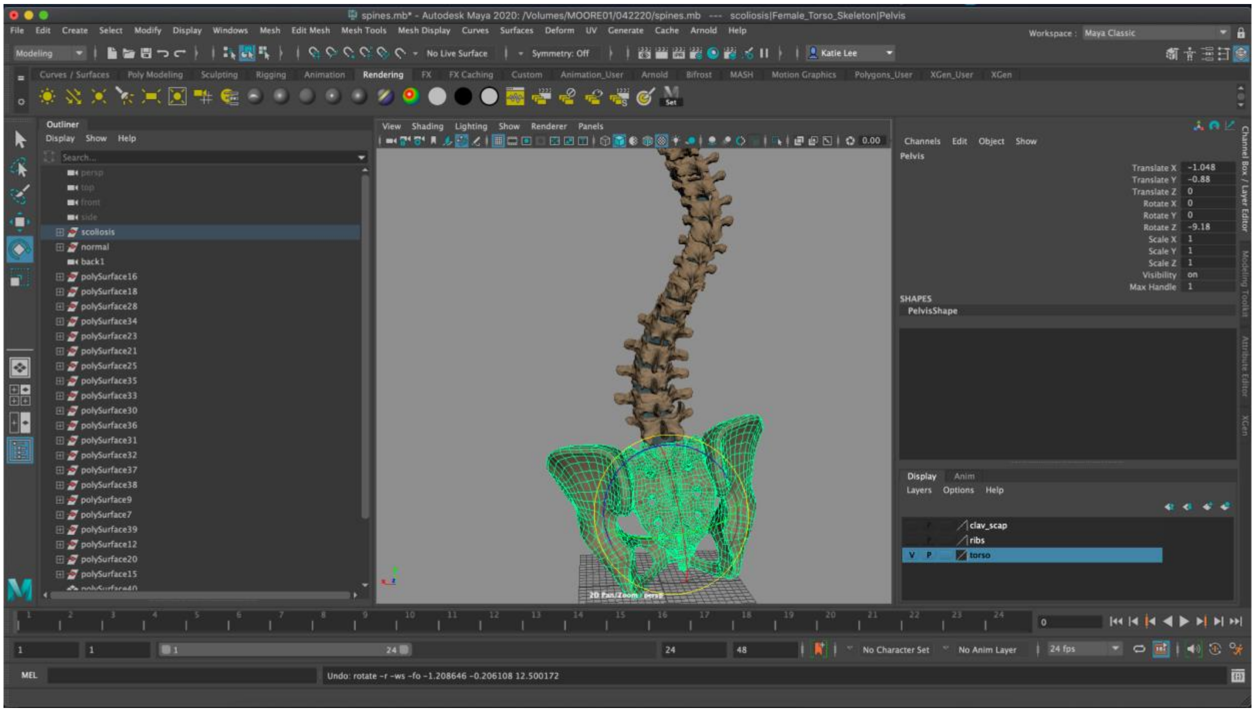

Figure 9. Screenshot of Maya rotating the vertebrae and pelvic bones to create a scoliosis curve after duplicating the model of the healthy spine

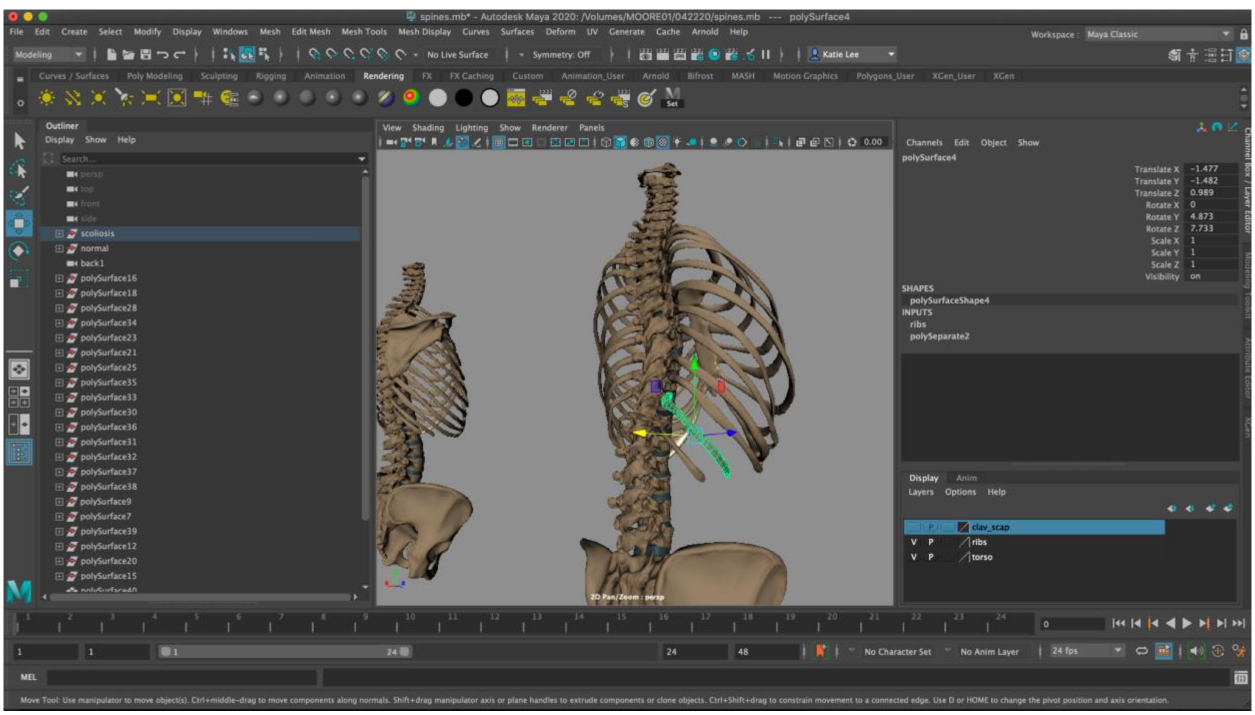

Figure 10. Screenshot of Maya showing the adjustment of the ribcage to show the effects the scoliosis curve on the other bones in the torso

I decided to store these models on Sketchfab so that the healthcare providers and caregivers would all have easy access to them. Sketchfab is an online 3D and AR platform where creators can showcase their work the way it was intended to be seen and not as static imagery (Sketchfab, 2022). This platform not only allows interactivity with the models that let the users zoom, rotate, span across the screen and view labels on sections of the models, but also allows the model to be shared and viewed via hyperlink at home or in the doctor's office or hospital. These models can be used to make the diagnosis explanation clearer and easier to recall when talking about the condition post-appointment.

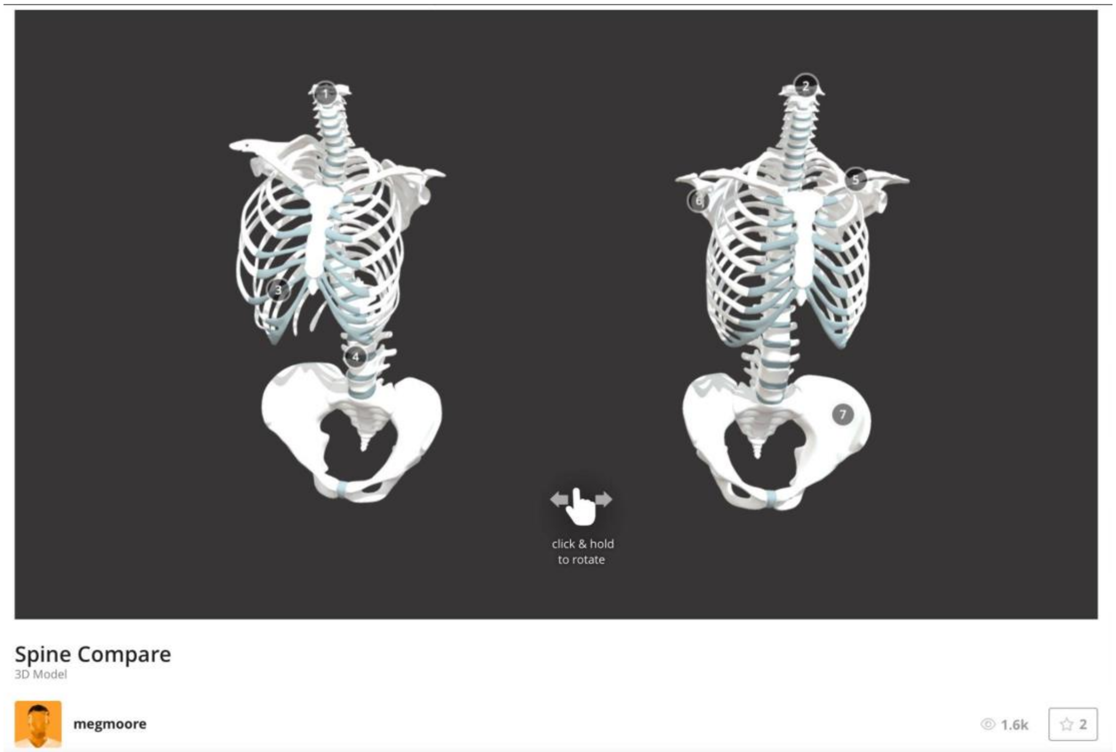

Figure 11. Screenshot of interactive interface on Sketchfab (link to models: https://skfb.ly/6TqxI)

b. Animation

While the main goal of the 3D model is to educate the user on the effect scoliosis has on the body, the animation is intended to explain the surgical process. This animation is intended to be shown during an appointment where the healthcare provider, patient, and caregiver are deciding on the best course of action to treat scoliosis. This is directly related to Dr. Heflin's concerns of not being able to spend adequate time with the patients to provide thorough detail, while also trying to calm their fears of surgical intervention. The animation not only explains and visualizes the surgical steps in a concise, clear way, but also explains the benefits of using a growing rod system to avoid future surgeries for the patient. This will ideally answer most questions that the patient and caregivers will have about the procedure itself, freeing up time for their healthcare provider to focus on making them feel secure and prepare for the surgery. An added benefit of the animation is that it can be stored online on a public forum, such as Vimeo or YouTube, so that it can be reviewed at any time by the patients and caregivers.

The first step in the process for making this animation was to research what information was already available to the public about the surgical process. I found a lot of information about the treatment options, but very little on the actual surgical process. This gave me an interesting insight on patient education materials. I realized that while many materials give great detail about the actual condition of scoliosis, the treatment options are usually very surface level until speaking with a doctor. Even the manufacturers of the growing rod system lacked a thorough explanation of how they are placed into the body. It is my opinion that a patient should know step-by-step what will be happening during a surgery in order to make the most informed treatment choice possible.

After a large amount of research, I located a video of a growing rod implant surgery (Akbarnia et al., 2016). As a medical illustrator, I watched the surgery and was able to understand the medical terminology used. However, a lay audience may not be able to handle the graphic nature of a surgical video, and the terminology may be above their level of understanding. This had a large impact on my first step of the animation: writing a script. I worked with Dr. Heflin to create a narration that is accurate and thorough but not overly scientific. First, the patient and caregivers need to understand the general anatomy of the spine, as well as how scoliosis affects that anatomy. This is followed by an explanation of the surgical steps with the use and function of the growing rod system. Originally, the script named the MAGEC System by NuVasive as the equipment that is used for the surgery, because it is the brand used by Dr. Heflin, but it was decided to remove the specific branding to allow a wider use of the animation, and not create an advertisement for NuVasive. The narration then explains the post-operative process of lengthening the growing rods throughout the natural development of the pediatric patient. It concludes by highlighting the results of the surgery and having a call to action about speaking with a doctor for any additional questions.

Once the script was complete, I began compiling and creating the assets for the animation. I first built the spine and sacrum in Autodesk Maya, which is used throughout the animation to demonstrate the general anatomy, scoliosis presentation, the surgical steps, and desired results of treatment. For this model, I decided to only use the vertebrae and sacrum and leave out the other bones of the trunk and pelvis, and the intervertebral discs to provide enough background, but not focus on the anatomy. Once I had the spine model, I was able to use it to show the healthy spine, a 60-degree spinal curve and a 30-degree post-surgical curve by adjusting the positioning and rotation of each individual vertebra.

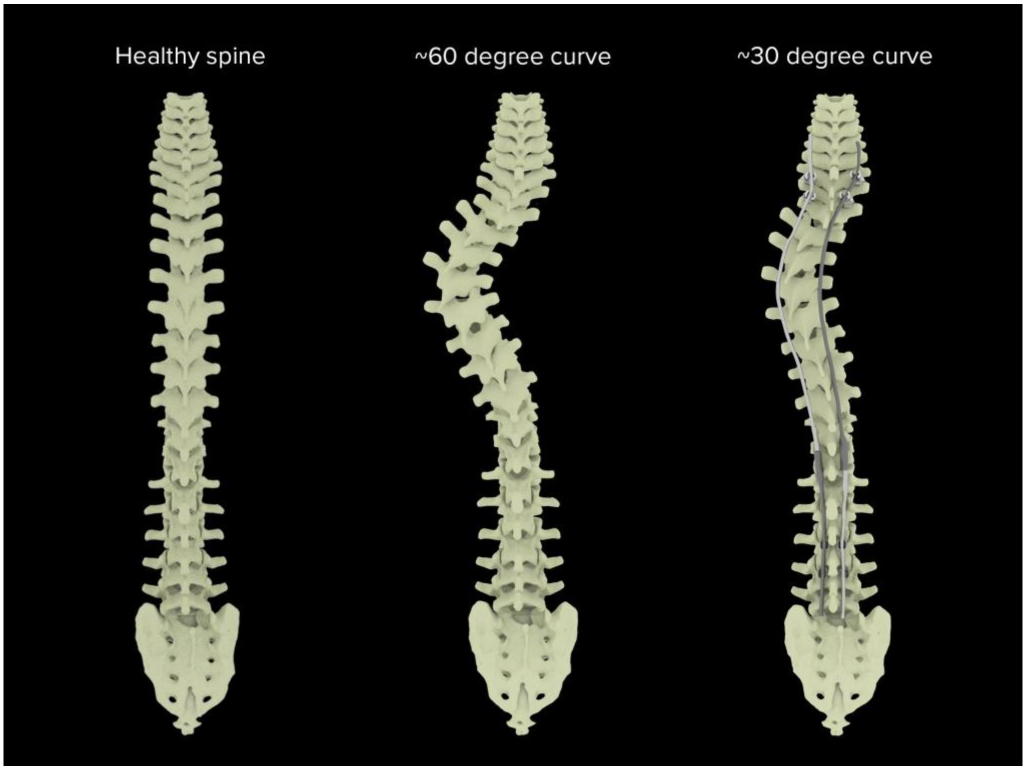

Figure 12. Spine model variations

I based the look of the surgical equipment assets on the design of the NuVasive MAGEC system (NuVasive, 2022). This model was chosen because it is commonly used by Dr. Heflin, although we avoided naming the specific brand. The equipment included two growing rods, four supralaminar hooks, four pedicle screws, and one remote control for the magnetic expansion of the rods. These assets were also created using Autodesk Maya. To illustrate the metal material that the screws, hooks, and rods are made of, I chose a metallic silver coloring on those assets. The rods are each made of two separate pieces that move independently from each other, and to highlight that movement I made one piece a darker silver and the other lighter. When both pieces were the same color, there was no contrast to highlight the separation, making it hard to distinguish any change in positioning. Even with the two colors, I decided that it would be best to make another zoomed in view of the actuator where the rods lengthen in order to make the movement more visible. The remote control that causes the rod expansion is made of plastic with a small screen in the middle. To give it the look of plastic I made a matte, slightly textured material in different colors, while giving the screen a reflective material.

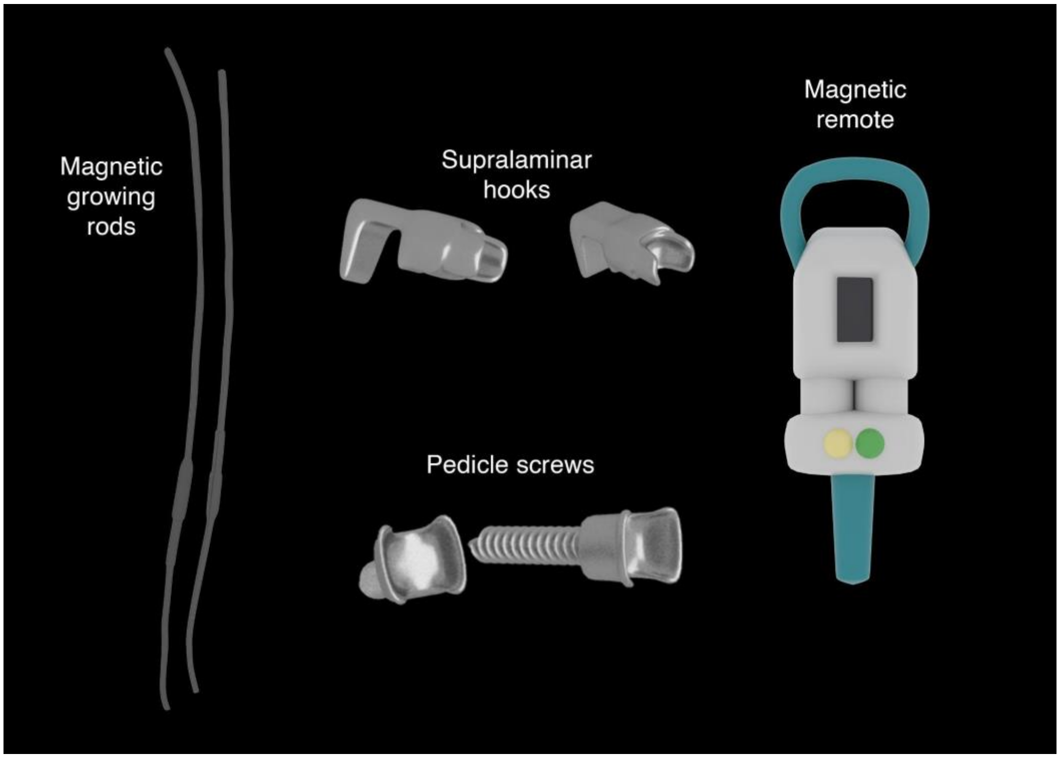

Figure 13. Models of surgical equipment

The final asset needed for the animation was the example patient. I purchased a rigged model of "Percy" from the online model library Renderpeople. I chose to purchase a model to meet the time constraints of the project, and because I did not have experience building and rigging a realistic human model. I had a few reasons to choose "Percy" as my patient. The first is that his looks fall at the young age group that is most commonly receiving a scoliosis diagnosis. He is visibly older than a toddler and younger than a teen but does not seem to represent any age specifically. The second reason that "Percy" was chosen is that he is ethnically ambiguous. By not representing any single race, this allows more people to relate to the patient as he can be perceived differently by everyone. The benefit of having Percy pre-rigged allowed me to seamlessly contort his body to mimic the curvature of the spine and give him different facial expressions, such as a smile in the title scene and a more serious look when talking about scoliosis and anatomy.

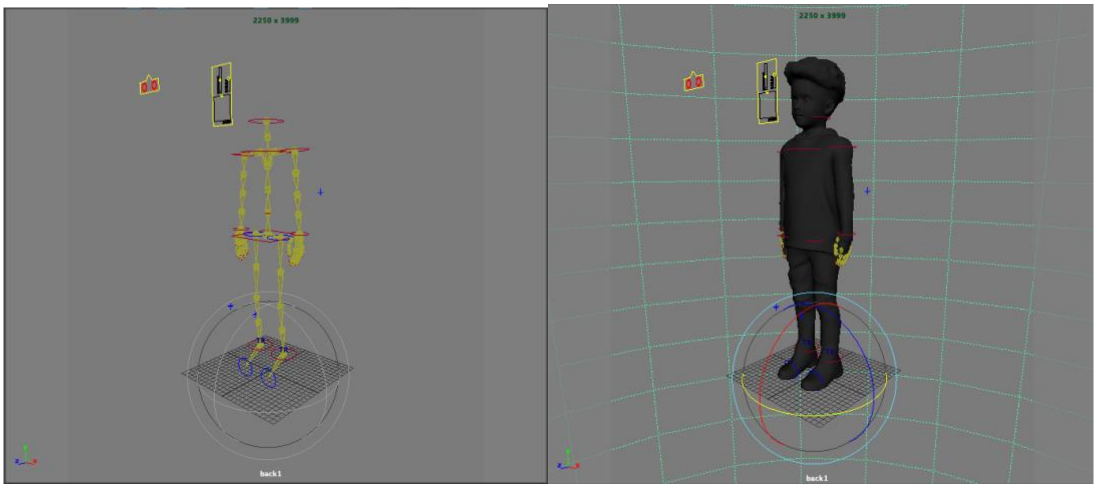

Figure 14. "Percy" rig and model in Autodesk Maya

Figure 15. Final "Percy" patient model

One minor problem with "Percy" being relatable is that using his realistic features during the surgical scene could cause a negative reaction for being too graphic or scary for the real-life patients as they picture themselves going through the surgery like "Percy." To solve this problem, I created a model of another child the size of "Percy" but did not give them any distinguishing features. I colored this model blue to provide one more detail of separation between an actual patient and this silhouette. In addition to using this child during the surgical scenes, I also placed them in the scenes where the rods are extended to keep the focus on the rods, remote control, and movement and not on the patient or “Percy’s” clothing.

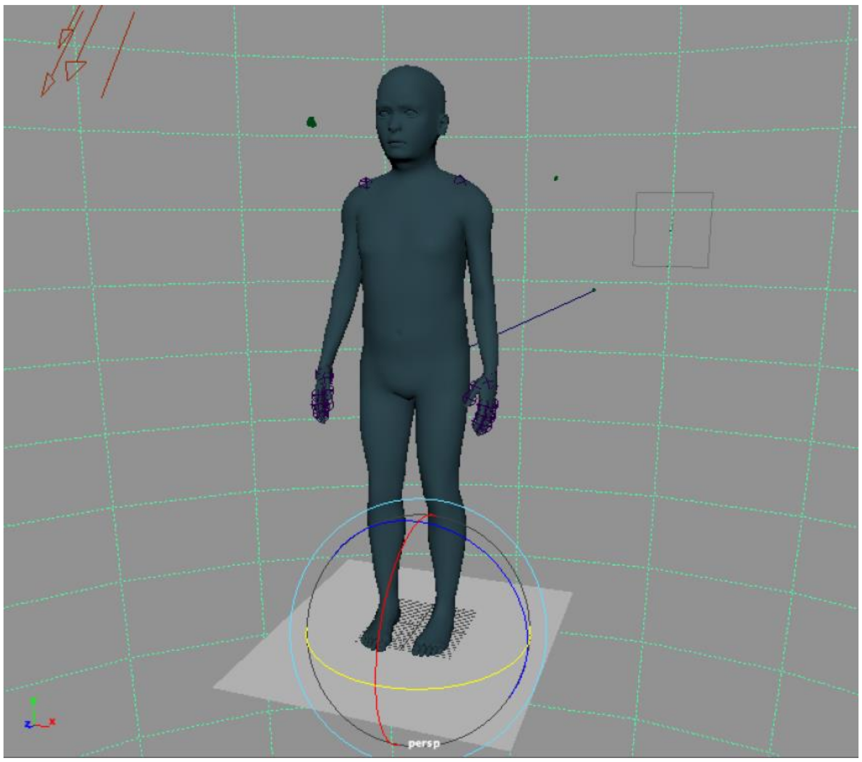

Figure 16. Rigged model of nonspecific patient

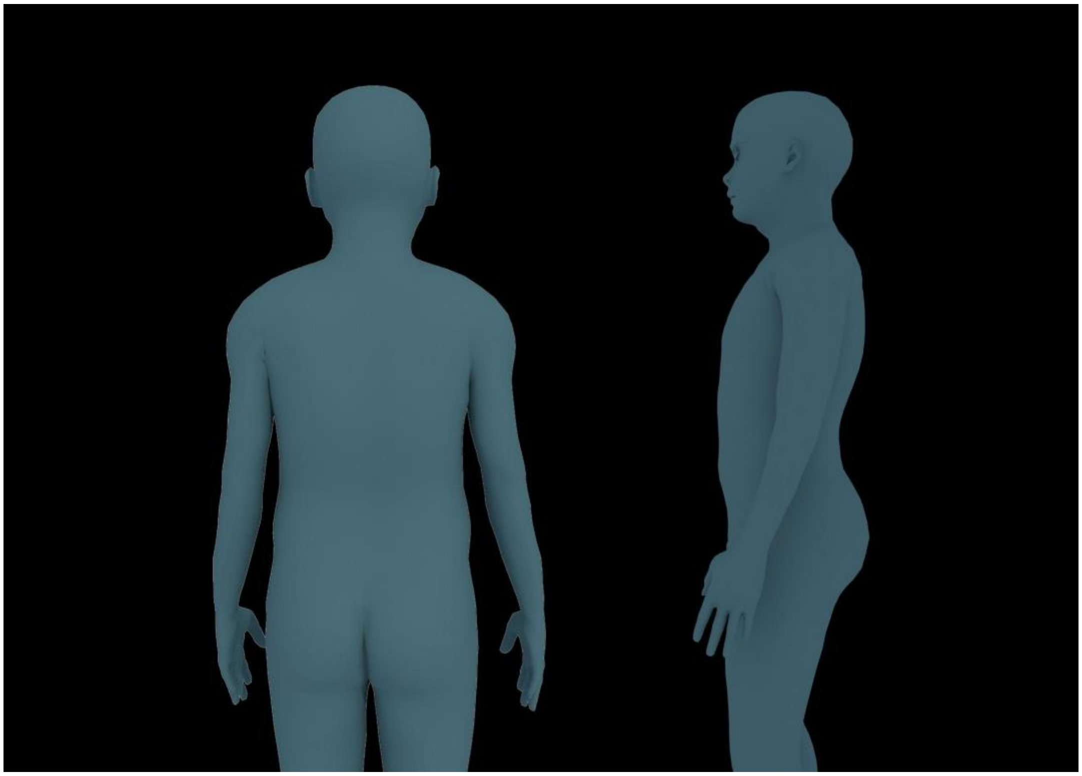

Figure 17. Model of nonspecific patient

The completed assets were used to create an initial storyboard presentation in Adobe Photoshop. For each line in the script, I created a still image that would mimic the scene in the animation that would align with what was being narrated. I also added a description below the image of the movement I intended the scene to have. I shared the storyboard with Dr. Heflin and Dr. Borkholder, to receive approval on the script, assets, and flow of animation.

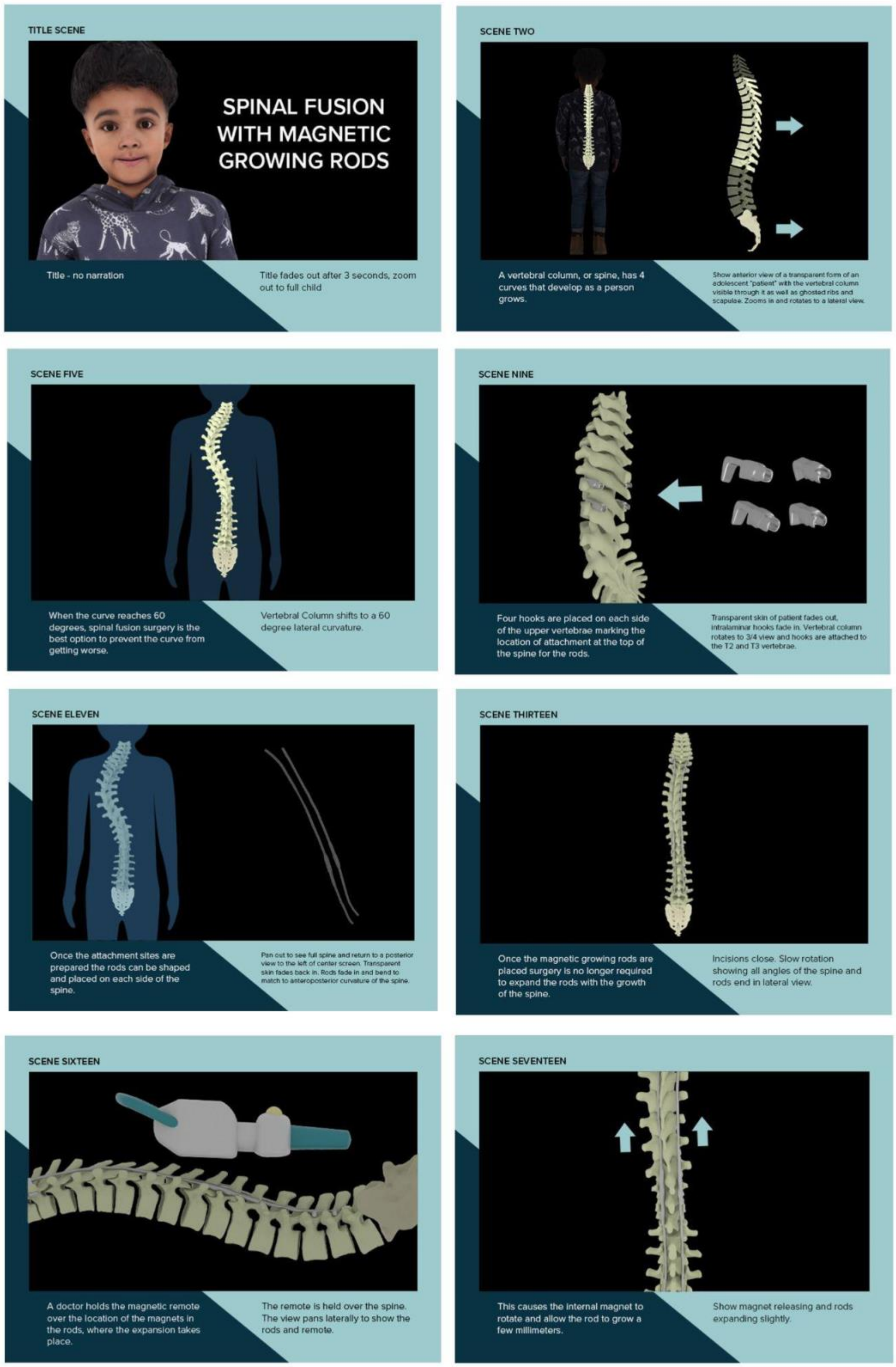

Figure 18. Examples of storyboard slides

With their approval, I began animating in Autodesk Maya and Adobe AfterEffects using the 3D modeled assets. I recorded the script for the voice-over myself, using the sound booth on the Rochester Institute of Technology campus, to make sure the pronunciation and cadence was correct. The timing of the animation is based on the recording. First, I split the sound file into sections. This allowed me to control the pauses between each scene, making sure the voice-over was aligned to the visualization that was taking place.

The first section of the animation is an overview of the anatomy of the spine. To provide basic anatomical education for the positioning of the spine, I placed the spine behind the model of the patient with a decreased opacity to give the impression that the spine was inside the body. I then rotated the models from a posterior view to a lateral view to show the natural anterior and posterior curvature of the spine. I separated the cervical, thoracic, lumbar, and sacral regions into their own models and placed them at full opacity in front of the patient and full spine two at a time to highlight the sections. I added arrows in the direction that each spinal section curves.

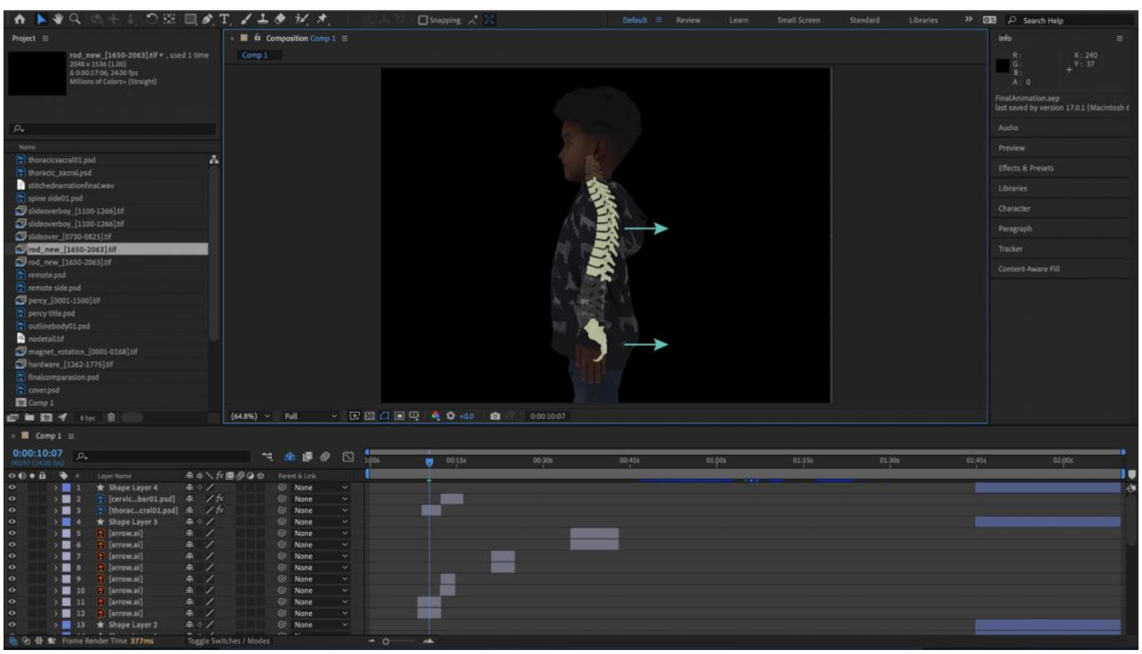

Figure 19. Highlighted thoracic and sacral curves

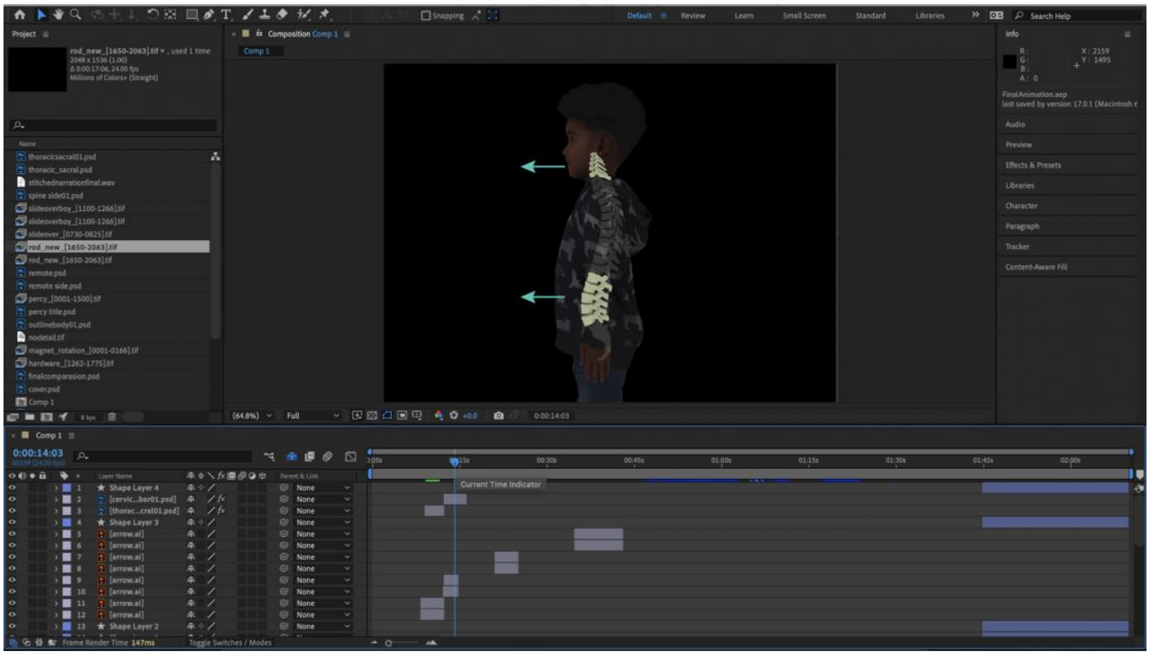

Figure 20. Highlighted cervical and lumbar curves

The models of the patient and spine are then rotated back towards the posterior view, so the spine slowly curves to the left in a lateral curve while the alignment of patients shoulders are adjusted to give an accurate depiction of the effects of scoliosis. I also used arrows in this scene to show that a scoliosis curve can develop in either direction.

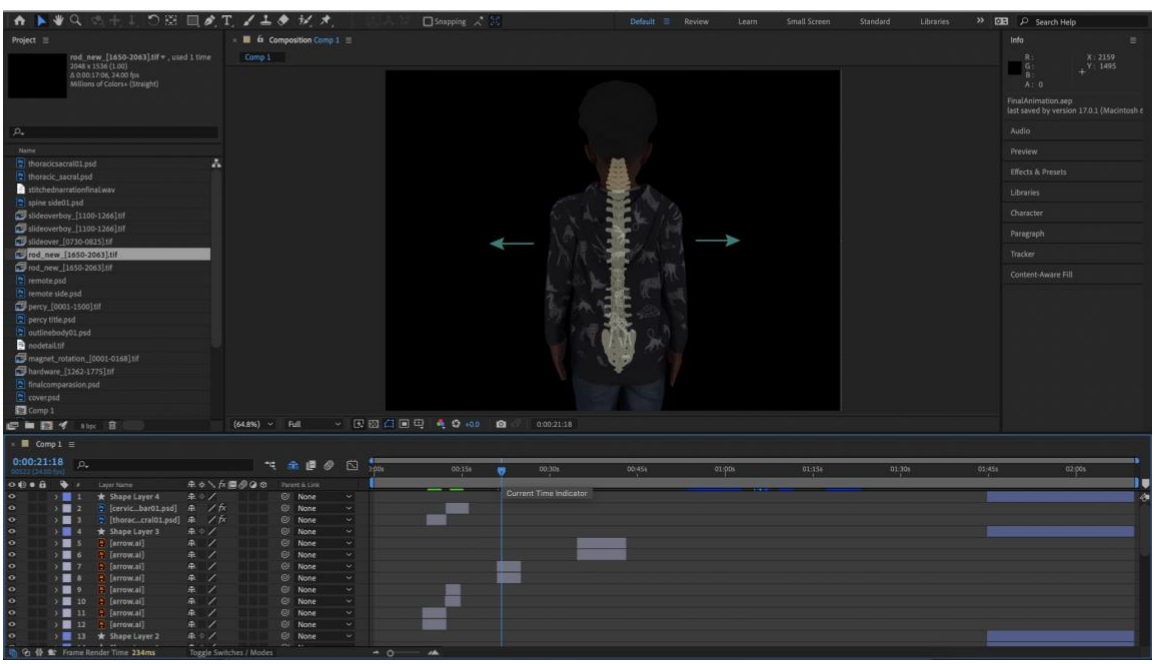

Figure 21. Normal spine with arrows highlighting direct of scoliosis curves

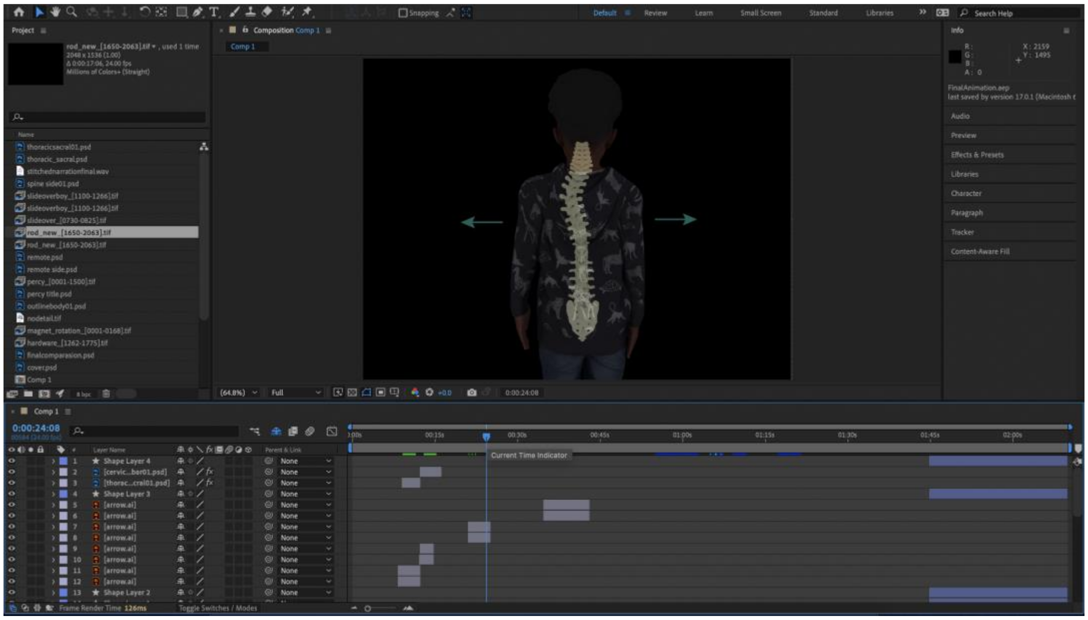

Figure 22. Slowly curving spine with arrows highlighting direct of scoliosis curves

The next scene is an explanation of the surgical treatment of scoliosis using magnetic rods. I used the model of the rods to create a slight movement with arrows along the side to show how the lengthening functions.

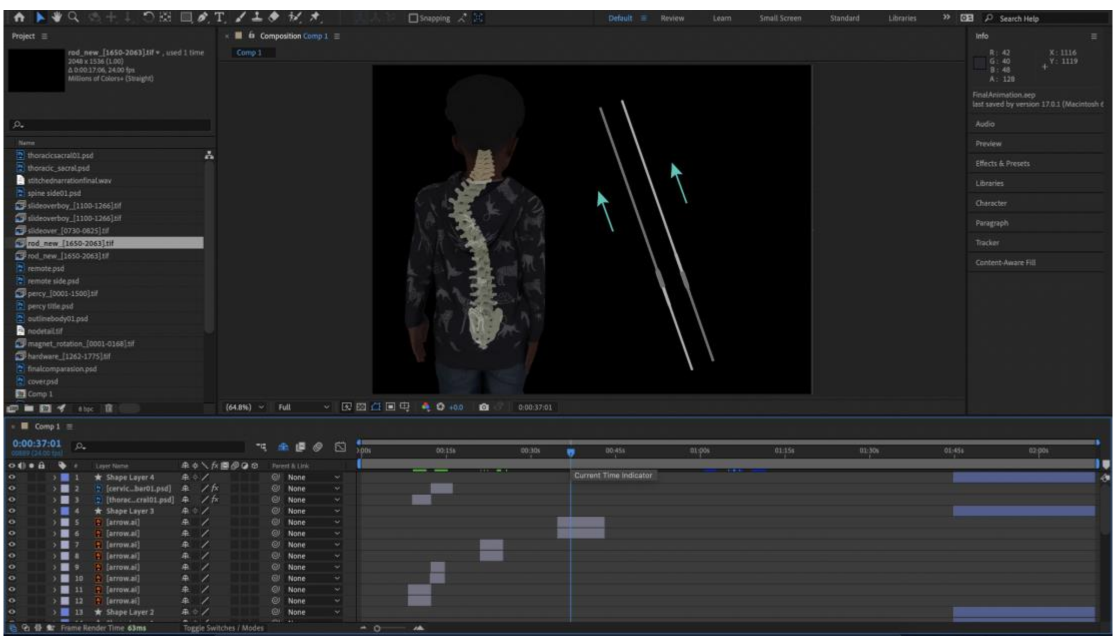

Figure 23. "Percy" and growing rods

At this point in the animation, I begin to illustrate the steps in the surgical process. I replaced the detailed model of the patient with a light blue silhouette of a similarly built child to make the visuals more patient-friendly. To indicate the incision sites at the top and bottom of the spine, I created circular masks that subtracted sections of the patient model to provide visual access to the spine.

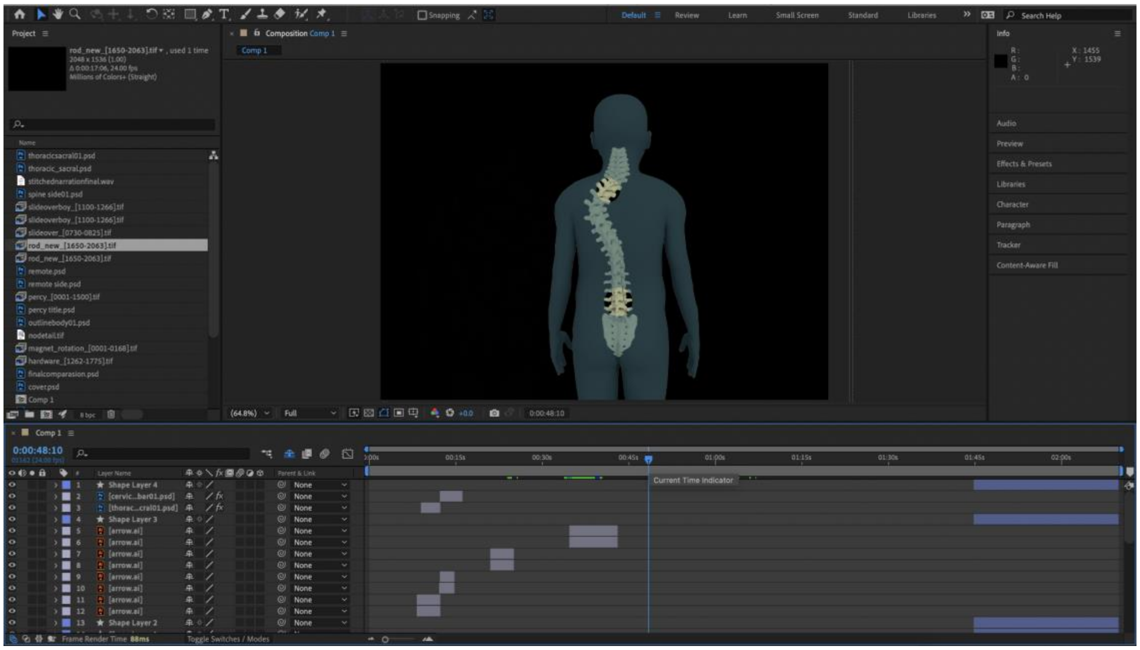

Figure 24. Nonspecific child model with incisions

To create a clearer view of the placement of the surgical hardware on the spine, I zoomed in on the attachment points and removed the silhouette of the patient. First, I focused on the superior attachment site where supralaminar hooks are placed. Then, the view pans down to the inferior attachment site where the pedicle screws are inserted. I made the hardware enter the scene and mimic the movement that would be used to correctly place them in the body (i.e., the rotation of the screws).

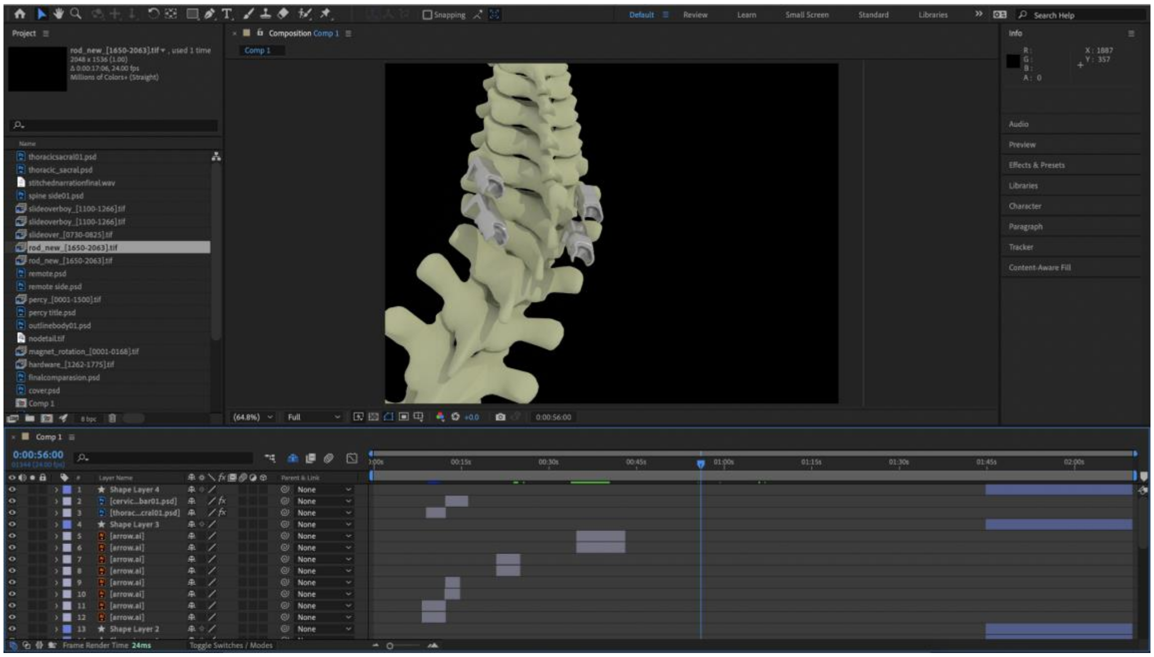

Figure 25. Supralaminar hook placement

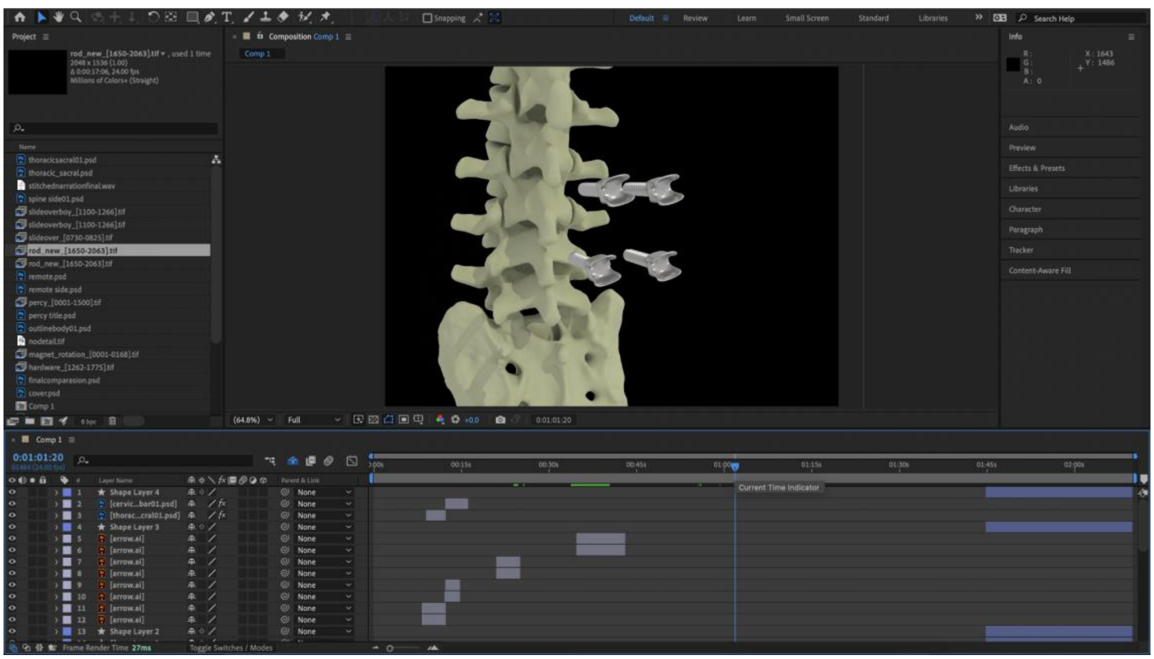

Figure 26. Pedicle screw placement

The view zoomed back out to show the spine and patient silhouette with the incision sites. The rods are then shown being shaped and threaded through the incisions to be placed under the skin and attached to the hooks and screws. Once they are placed, the incision sites are closed.

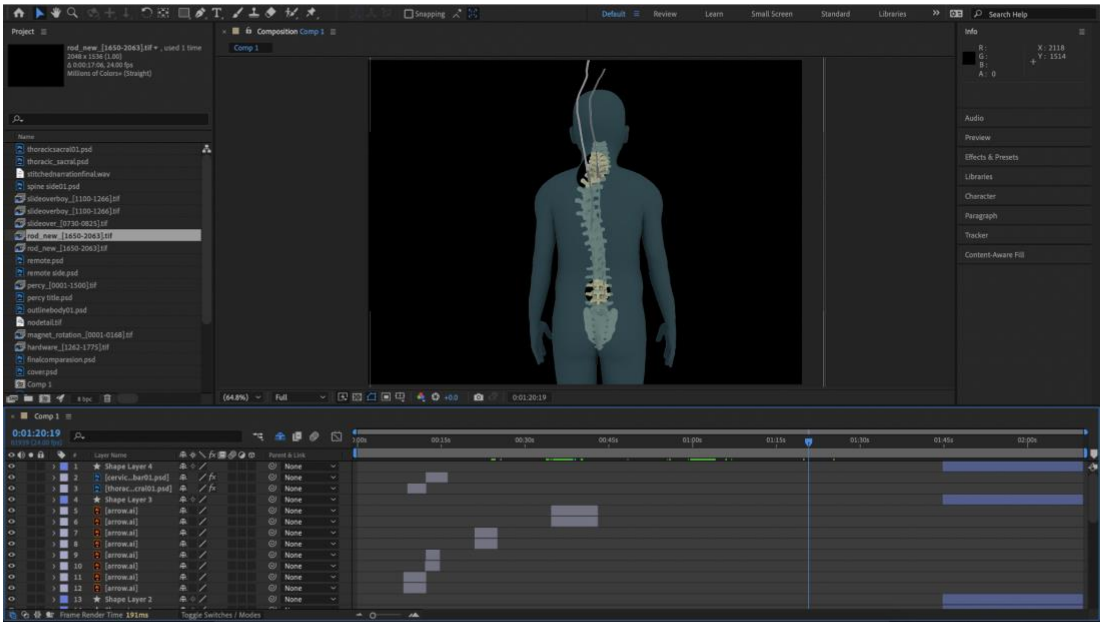
Figure 27. Rods are threaded through incision sites to be placed on each side of the spine

The next step of the animation was used to show the lengthening process of the rods. This was to highlight that the lengthening is done with a magnetic remote control and does not require additional surgery. The model is moved into a prone position and the remote is placed above the actuator of the rods. A callout magnifying the section of the rod where the extension takes place appears in the top corner to give a clearer view of the motion.

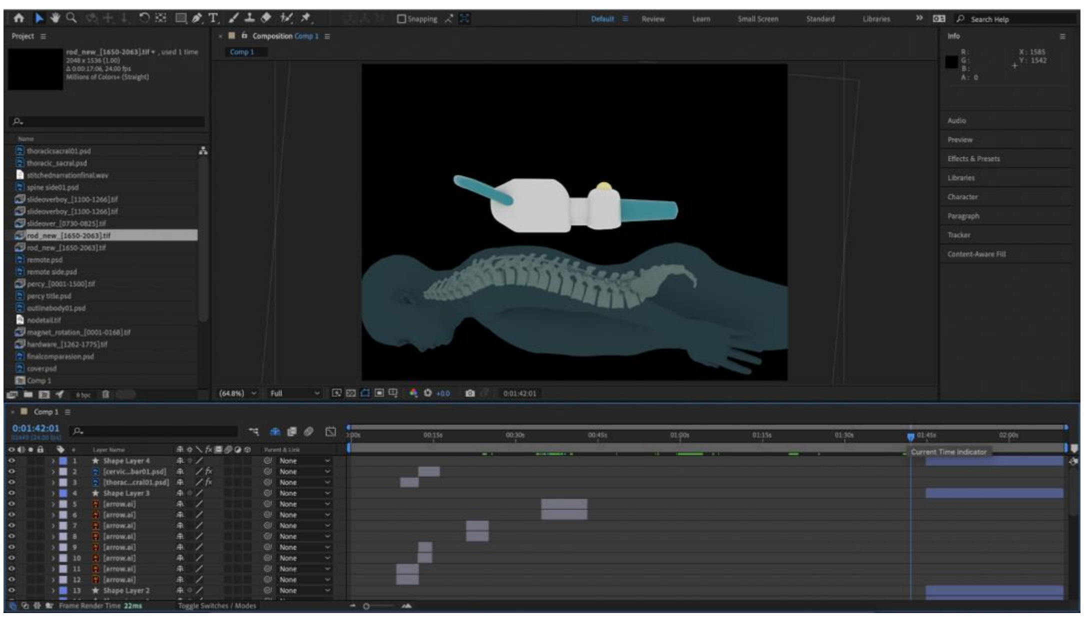
Figure 28. Magnetic remote held over placed rods

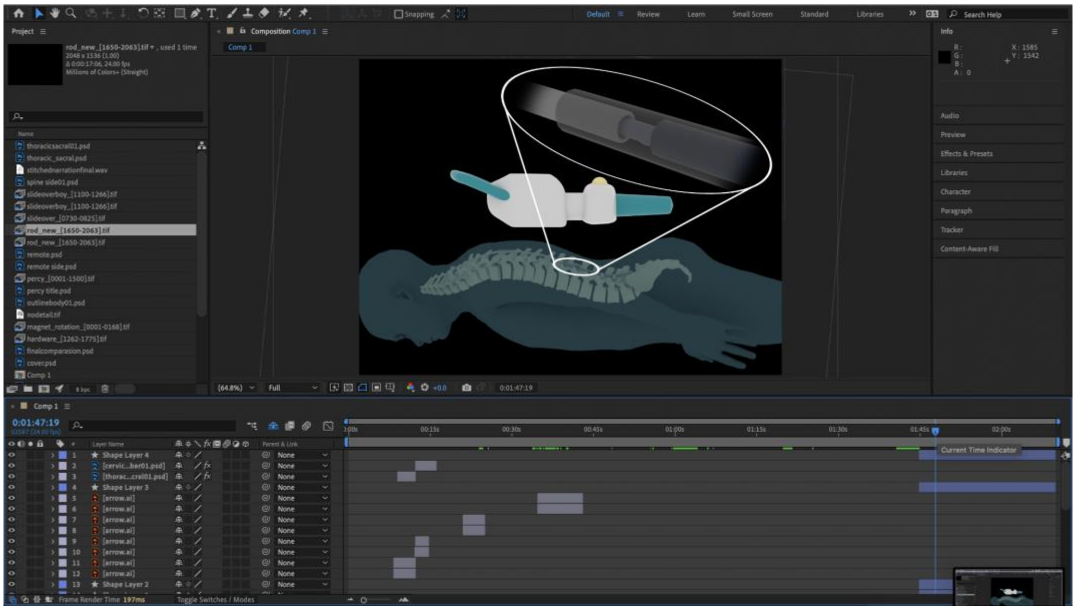

Figure 29. Highlight of rod lengthening mechanism

The final scene of the animation compared the untreated 60-degree lateral curve to the post-surgical curve with the growing rods in place. The main goal of this scene was to call attention to the fact that the surgery will not result in completely straightening the spine, but will improve the curve and prevent it from getting worse. Patients and caregivers are also instructed to speak with their healthcare professional if they have any additional questions.

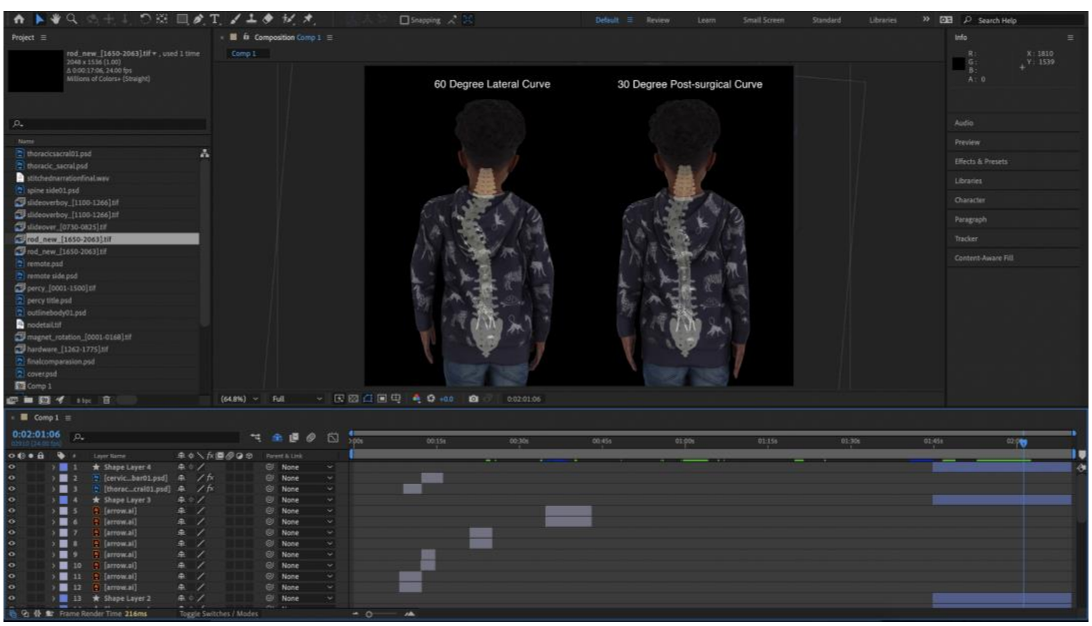

Figure 30. Final comparison of untreated scoliosis spine and post surgical spine.

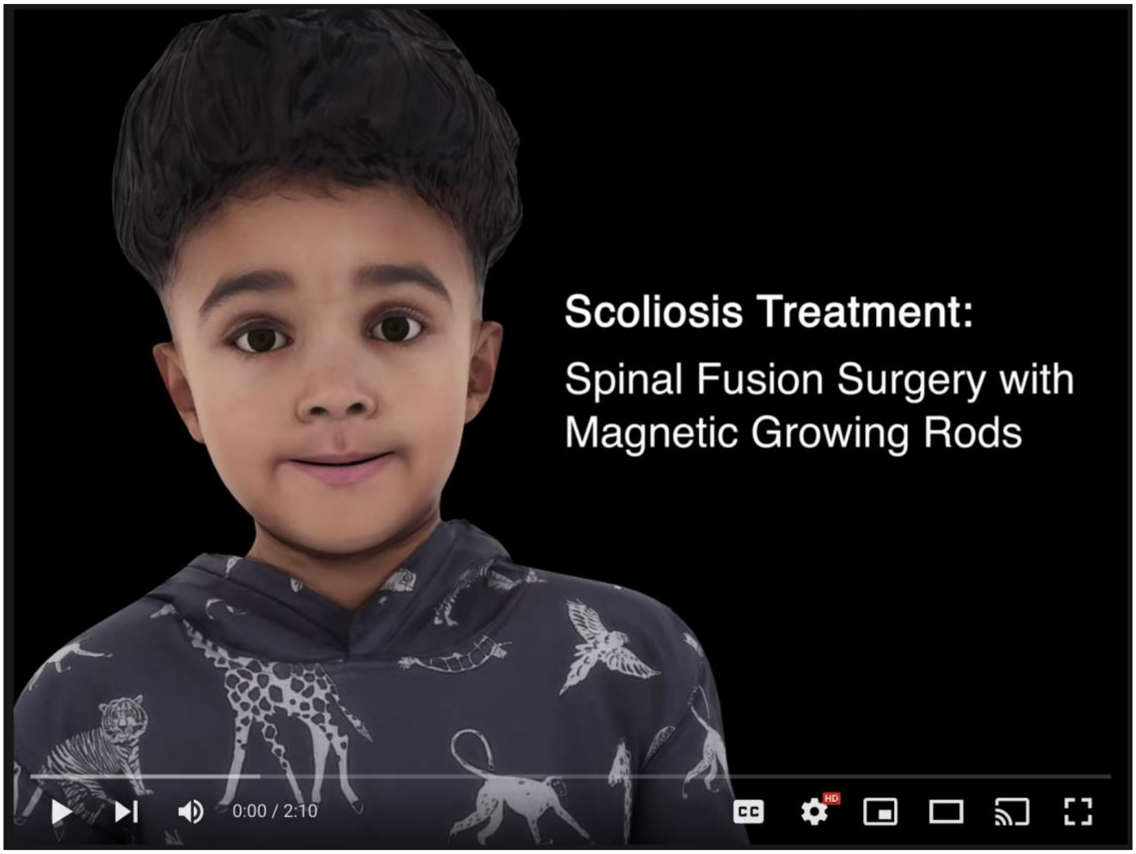

Figure 31. Title screen on YouTube (link to video: https://youtu.be/ugtvZT5PTg8)

IV. Conclusion

The main objective of the patient materials was to cultivate an understanding of scoliosis and its surgical treatment to a lay audience of young patients and their caregivers. I believe that the interactive 3D models and animation met these objectives by providing age-appropriate education that can be shared without inciting fear or anxiety. While keeping the assets I created as anatomically accurate as possible, I was able to remove some of the more graphic details such as blood, body tissue and organs that are visible in most surgical illustrations and animations and still clearly convey the effects of the disease and steps of the surgery. The secondary objective was to create a more accessible form of patient education. I met this objective by posting the 3D model comparison on SketchFab and the animation on YouTube where they can be viewed for free by the general public at any time. This objective's success is also based on how the materials are distributed and utilized by healthcare professionals. While the general public would be able to locate my work when researching scoliosis, a main goal was to provide it to patients during downtime at a doctor's appointment to have the basic explanation done and to help streamline conversation in the limited time they had with their physician.

Looking towards the future I believe that printed materials, such as a poster to hang in examination rooms or a brochure that can be distributed to patients for additional post-diagnosis and pre-surgical information, would be beneficial to the project overall. I would also like to adapt this work to make the animation more accessible to patients with disabilities, such as creating a more descriptive script or adding an audio description option. Ideally, the animation will be provided in as many languages as possible to strengthen accessibility.

This experience taught me that patient education materials for surgical processes do not generally provide a step-by-step explanation unless someone is able to locate a video of the actual surgery being performed. It is my opinion that patients should have a thorough understanding of their treatment and healthcare providers cannot be solely relied upon to provide this education. I hope to use the objectives and outcome of this project in my career as a medical illustrator to provide patient-friendly education for more procedures and surgeries, and allow everyone to have the understanding of what is happening to their own bodies that they deserve.

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