Procedures for Assembly, Disassembly, and Inspection (PADI) of the Flexible Pedestrian Legform Impactor (FlexPLI)

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1. Introduction

This document was prepared for the National Highway Traffic Safety Administration (NHTSA) under the title "Procedures for Assembly, Disassembly, and Inspection (PADI) of the Flexible Pedestrian Legform Impactor (FlexPLI)."

1.1. Purpose

This document contains the procedures for assembly and disassembly of the flexible pedestrian legform impactor (FlexPLI) for the purpose of inspection and preparation for testing. Certification tests are specified in a UNECE Addendum 126 Regulation Number 127 Revision 1 Annex 6 Section 1. The details of this test are also specified in the NHTSA companion document "Qualification Procedures for Pedestrian Test Devices December 2019." The FlexPLI user will periodically perform the qualification tests to assure that the legform is maintained at the specified performance levels.

1.2. Part Numbers

All part numbers in this document refer to the drawing package entitled "Flexible Pedestrian Legform Impactor Drawing Package December 2019".

1.3. Abbreviations

The abbreviations for threaded fasteners used throughout the PADI are listed in Table 1.

Table 1. Abbreviations for threaded fasteners

Abbreviation	Description
SHCS	Socket Head Cap Screw
BHCS	Button Head Cap Screw
FHCS	Flat Head Cap Screw
SHSS	Socket Head Shoulder Screw
MSSFP	Metric Socket Setscrew Flat Point

1.4. Torque Specifications

The torque requirements for the assembly of the FlexPLI are listed in Table 2.

Table 2. Assembly torque requirements

Description	Torque (Nm)
Leg attachment to knee front M8 BHCS	8
Leg attachment to knee rear M8 MSSFP	8
All segment M6 BHCS	3
Shoulder link screws M10	3

2. Construction

Some of the design highlights of the Flexible Pedestrian Legform Impactor (FlexPLI) include:

- Biomechanically based femur, tibia, and knee design
- Biofidelic bending characteristics
- Knee ligaments that are represented according to human anthropometry
- Flesh system of neoprene and rubber sheets
- Symmetric design to represent either a left or right leg
- Standard 12 channels of instrumentation with an option of 24 channels

3. Clothing

The FlexPLI utilizes several layers of neoprene and rubber sheets and is described in more detail in the leg assembly section 5.4.1.

4. Available Instrumentation

Standard instrumentation of the FlexPLI includes 12 channels to measure tibia and femur bending moments, knee ligament elongations, and acceleration of the bottom of the knee in the direction of impact. The standard instrumentation channels are listed in Table 3 below. The channels that are used for injury assessment include: four tibia bending moments, knee Medial Collateral Ligament (MCL) elongation, Anterior Cruciate Ligament (ACL) elongation, and Posterior Cruciate Ligament (PCL) elongation. Femur bending moments, the Lateral Collateral Ligament (LCL) elongation, and the knee bottom acceleration are used as a check to make sure the leg is functioning properly.

Table 3. Standard instrumentation channels

Instrumentation Channel	Purpose	Number
Femur Moment	Leg Performance	3
Tibia Moment	Injury Assessment	4
Knee Bottom Acceleration	Leg Performance	1
MCL Elongation	Injury Assessment	1
ACL Elongation	Injury Assessment	1
PCL Elongation	Injury Assessment	1
LCL Elongation	Leg Performance	1
	Total	**12**

There are several options for data acquisition systems (DAS). The most basic version is an off-board system in which cables from the legform are directly connected to a static laboratory DAS. The use of an off-board DAS is not recommended as the off-board cables may affect the free flight trajectory of the FlexPLI. In addition, the cables are susceptible to damage when the FlexPLI lands after rebound from the vehicle. The preferred option is the use of an onboard

DAS). Installation and use of the different onboard DAS options are described in the FlexPLI User Manual[1].

5. Procedures for Assembly, Disassembly, and Inspection

The components in Table 4 are included in the FlexPLI assembly. Figure 1 shows a drawing of the FlexPLI assembly components with parts labeled as listed in Table 4.

Table 4. FlexPLI assembly components

Part Description	Quantity	Part Number	Item #
Knee Assembly	1	133-5300	1
Tibia Assembly	1	133-5500	2
Femur Assembly	1	133-5100	3
Buffer Sheet Assembly, Leg (Not Shown)	1	133-5020	4
Cover, Inner, Femur (Not Shown)	1	133-5013	5
Cover, Outer, Femur (Not Shown)	1	133-5014	6
Cover, Inner, Tibia (Not Shown)	1	133-5015	7
Cover, Outer, Tibia (Not Shown)	1	133-5016	8
Cover, Leg (Not Shown)	1	133-5017	9
Velcro Bundle Tie (Not Shown)	6	133-5019	10

[1] Humanetics Innovative Solutions. 133-9900 User Manual FLEX PLI GTR Rev H. 2015. Various onboard DAS installations are also described in UNECE working document GTR9-9-07e version of user manual located at https://wiki.unece.org/display/trans/GTR9-2+9th+session.

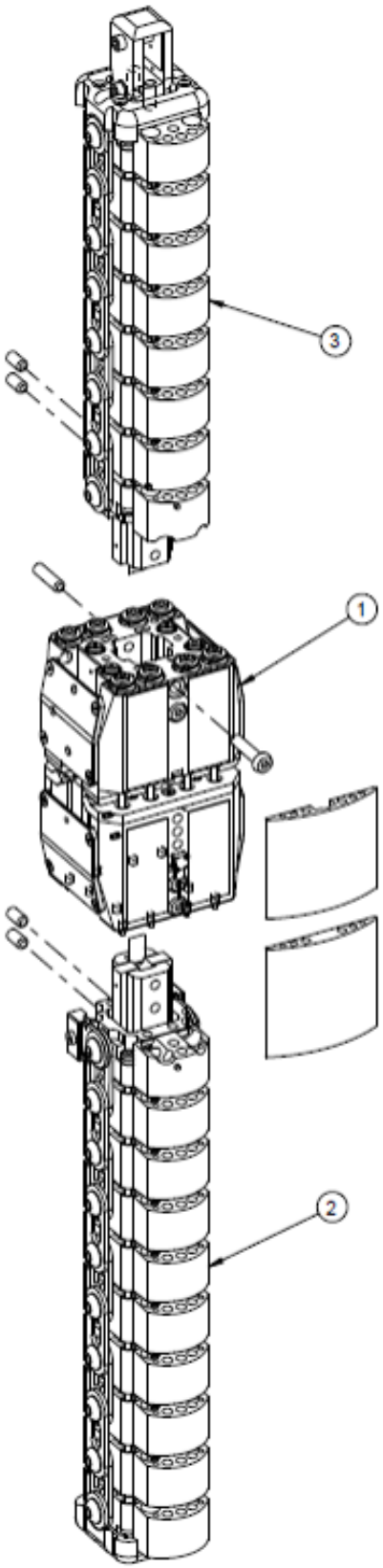

Figure 1. FlexPLI assembly components

5.1. Femur

The components in Table 5 are included in the femur assembly. Figure 2 shows a drawing of the femur assembly components with parts labeled as listed in Table 5.

Table 5. Femur assembly components

Part Description	Quantity	Part Number	Item #
Femur Bone Assembly Tested & Certified	1	133-5165	1
Bone Clamp Thin, Knee	1	133-5508	2
Bone Clamp, Thin, Femur/Tibia	1	133-5503	3
Bone Clamp Thick, Knee	1	133-5506	4
Bone Clamp Thick, Femur/Tibia	1	133-5502	5
Spacer, Bone Contact, Thick	5	133-5505	6
Shim, Bone Clamp (0.4 Thick) Optional	1	133-5504	7
Rubber Buffer, Femur/Tibia End	1	133-5510	8
Spacer, bone Contact, Thin	5	133-5507	9
Shim (0.4 Thick) Optional	5	133-5509	10
Inner Segment, Knee	1	133-5514	11
Inner Segment Assembly Closest To Knee	1	133-5535	12
Inner Segment Assembly	5	133-5534	13
Screw, BHCS M6 x 1 x 18	28	5000848	14
Link	14	133-5515	15
Segment Top, Femur	1	133-5108	16
Plate, Top	1	133-5102	17
Launch Guide	1	133-5103	18
Washer, 12 ID x 26 OD x 3	4	133-5104	19
Shoulder Bolt	16	133-5106	20
Washer, Flat M6 (6.7 ID x 12.5 OD x 1.0 Thick)	2	5000094	21
Screw, SHCS M6 x 1 x 14	2	5000847	22
Screw, SHCS M6 x 1 x 30	1	5000849	23
Roller	1	133-5107	24
Washer, Cable	8	133-5521	25
Cable Assembly, Femur	4	133-5110	26
Hex Nut, M5 x 0.8 Nylok	4	5000522	27
End Cover	1	133-5516	28
Screw, BHCS M6 x 1 x 16	6	5000072	29
Screw, BHCS M5 x 0.8 x 8	4	5000845	30
Screw, SHCS M3 x 0.5 x 6	4	5000843	31
Screw, MSSFP M8 x 16	2	5000769	32
Tape, Impact Segment (Not Shown)	6	133-5025	33
Tape, End Cover, 12 x 24 (Not Shown)	1	133-5028	34
Tape, End Cover, 10 x 12 (Not Shown)	4	133-5027	35
Tape, End Cover, 12 x 16 (Not Shown)	2	133-5026	36
Cover, End Impact	1	133-5518	37
Cover, End Impact (Knee End)	1	133-5519	38
Impact Segment	6	133-5517	39
Shim, (T0-5) Optional (Not Shown)	5	133-5001	40
Shim, Bone Clamp (T0-05) Optional (Not Shown)	2	133-5002	41
Shim, Bone Clamp (T0-5) Optional (Not Shown)	2	133-5003	42
Shim, Bone Clamp (T0-6) Optional (Not Shown)	2	133-5004	43
Shim, (T0-6) Optional (Not Shown)	5	133-5005	44
Shim, (.05) Optional (Not Shown)	15	133-5012	45

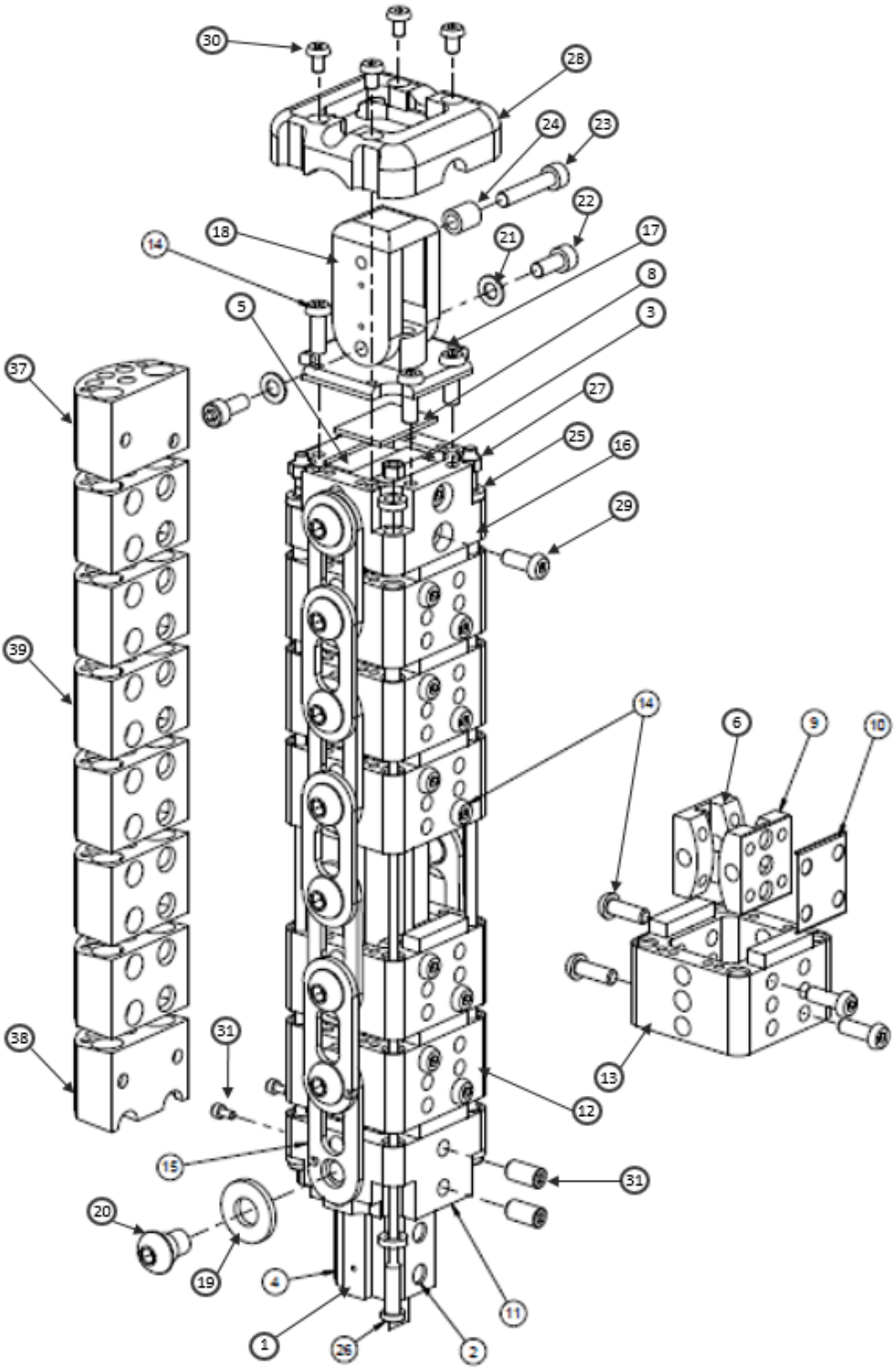

Figure 2. Femur assembly components

5.1.1. Femur Assembly

Start the femur assembly from the knee end of the bone.

Place bone clamp 133-5506 inside the tibia/femur base tool 133-8129 (used for assembly purposes and removed later) with the curved end upwards and the grooved side inwards. Loosely tighten with two M8 x 20 fasteners – as shown in Figure 3.

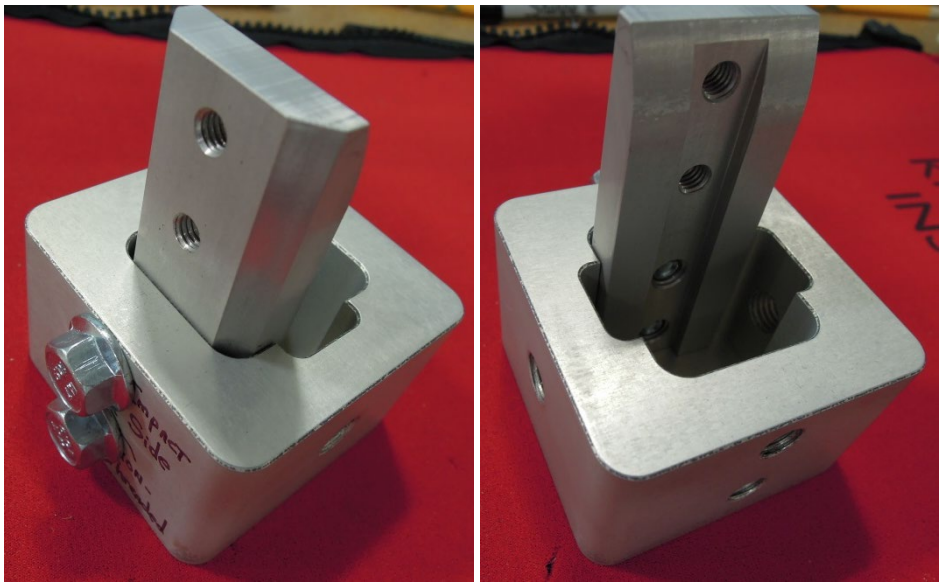

Figure 3. Tibia/femur base tool fitted with bone clamp

Place the inner knee segment 133-5514 over the clamp and loosely tighten with two M6 x 16 BHCS – as shown in Figure 4.

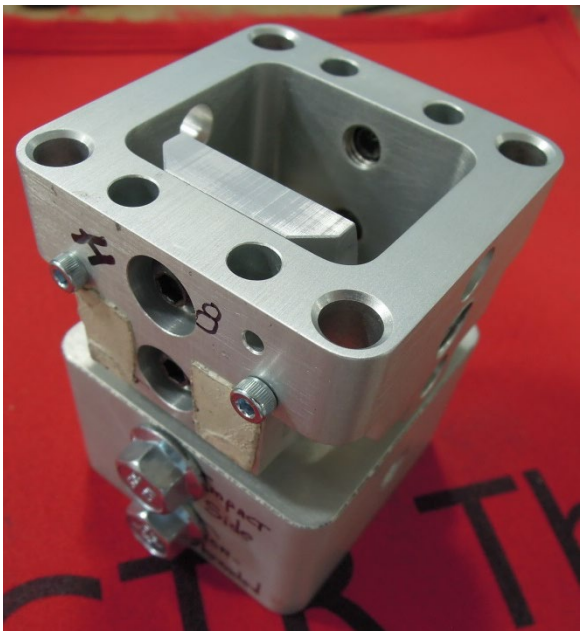

Figure 4. Tibia/femur base tool with inner knee segment

Place bone clamp 133-5508 over the bone (on the rear, non-impact side of the leg) with the curved end upwards – as shown in Figure 5.

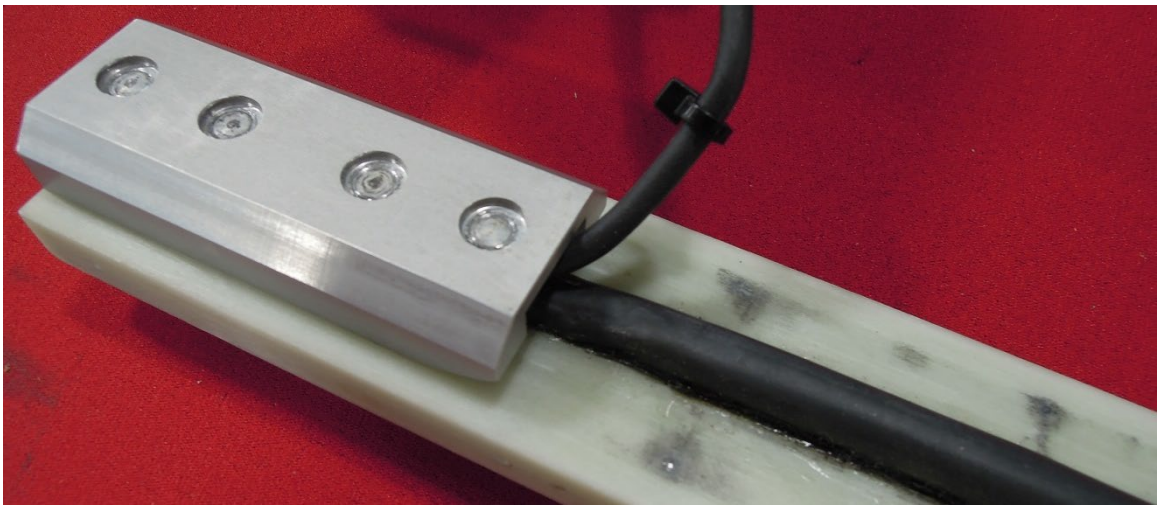

Figure 5. Bone clamp over the rear bone

Insert the bone and clamp into the base. Place two M8 x 12 SSFP fasteners into the fixture base and two M8 x 16 SSFP fasteners into segment 133-5514. Then tighten all fasteners to 3 Nm – as shown in Figure 6. Lay the strain gage exit wire to the side.

Figure 6. Insertion of bone and clamp into the base

Place a thick bone contact spacer 133-5505 to segment 133-5535 (blue segment with rubber buffers on both sides) and secure using two M6 x 18 BHCS fasteners – as shown in Figure 7.

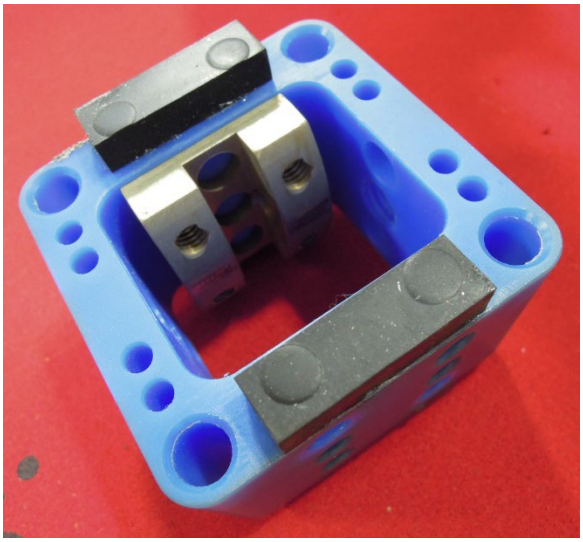

Figure 7. Blue segment with thick bone contact spacer

Slide the segment over the bone with the thick spacer on the impact side. Do not damage the black strain gage cover running down the center of the bone – as shown in Figure 8.

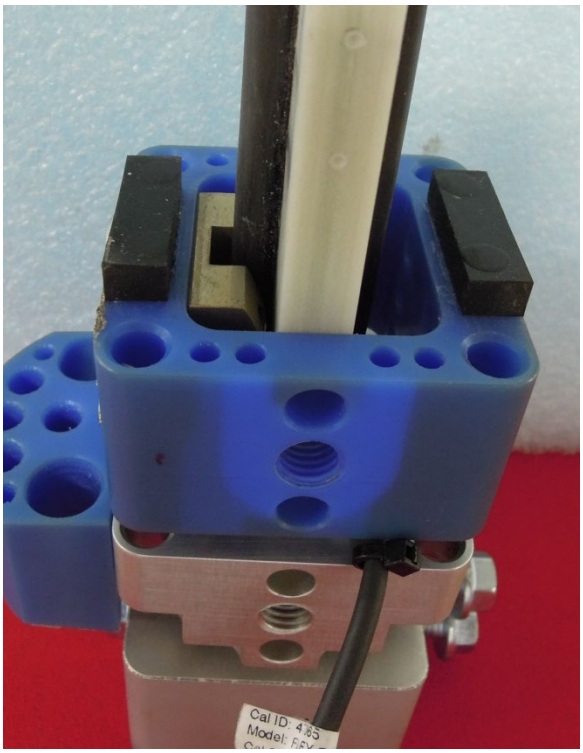

Figure 8. First blue segment over the bone with a thick spacer on the impact side

Place a thin bone contact spacer 133-5507 and thin shim 133-5012 into the gap between the bone and the blue bone segment on the non-impact side – as shown in Figure 9.

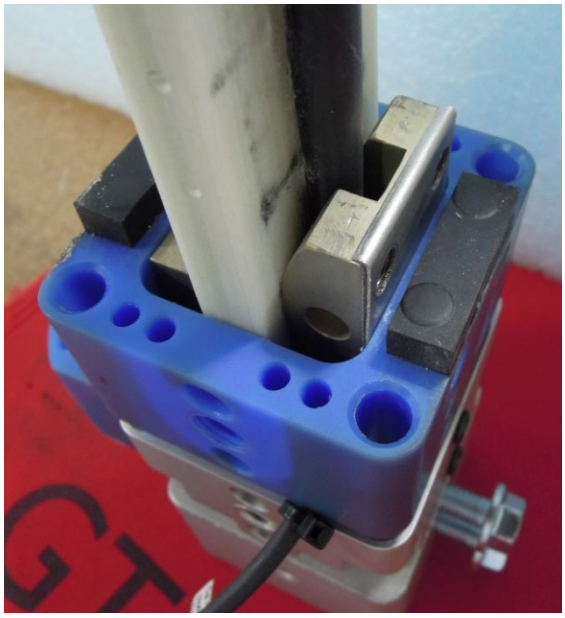

Figure 9. Fitting a thin bone spacer and shims into the first blue segment

When fitting the spacer-shim assembly, push down on top of the assembly using thumb force only. The user should feel high resistance when pushing the spacer-shim assembly in – as shown in Figure 10.

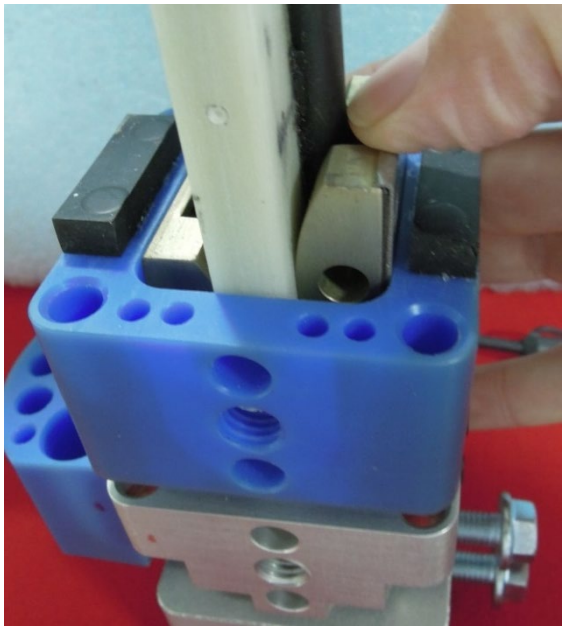

Figure 10. Fitting the spacer-shim assembly using thumb force

Check for fit by rotating the blue segment about the bone z-axis. If there is any play, change the shim configuration by adding additional thin shims, using thicker shims (133-5029 or 133-5030), or by using any combination of shims. When the spacer-shim assembly fits as tight as possible with thumb pressure, align the screw holes and tighten both the front and rear fasteners with two M6 x 18 BHCS to 3 Nm – as shown in Figure 11.

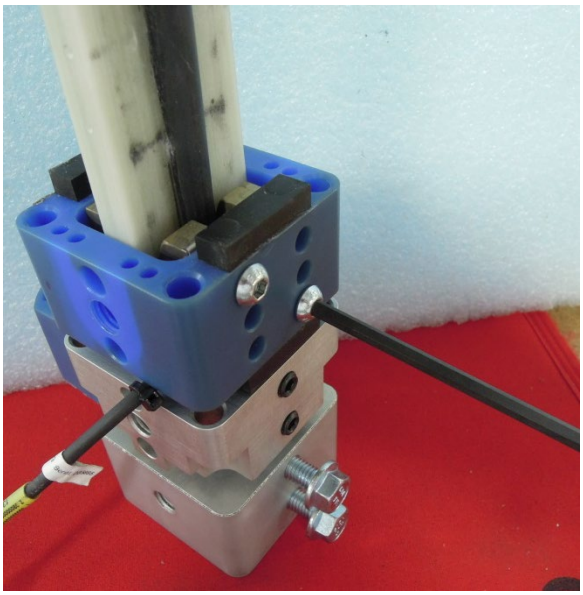

Figure 11. Tightening the segment fasteners to 3 Nm

For the next segment, attach a thick bone contact spacer 133-5505 to a blue bone segment 133-5534 using two M6 x 18 BHCS as per the previous segment. Slide this segment over the bone with the rubber buffer on the top side and the thick spacer on the impact side. Try using the same spacer-shim configuration as the previous segment. Adjust the spacer-shim configuration if loose. Align the screw holes and tighten both front and rear fasteners with two M6 x 18 BHCS to 3 Nm. Repeat for the next three segments. Figure 12 shows the Femur assembly with the tibia/femur base tool, inner knee segment, and five blue segments.

Figure 12. Femur assembly with the inner knee segment and five blue segments

For the last two segments, on the impact side, place a thick bone clamp 133-5502 to the last blue segment 133-5534 and to the top femur (aluminum) segment 133-5108 using two M6 x 18 BHCS for the blue segment and two M6 x 16 BHCS for the top aluminum segment – as shown in Figure 13.

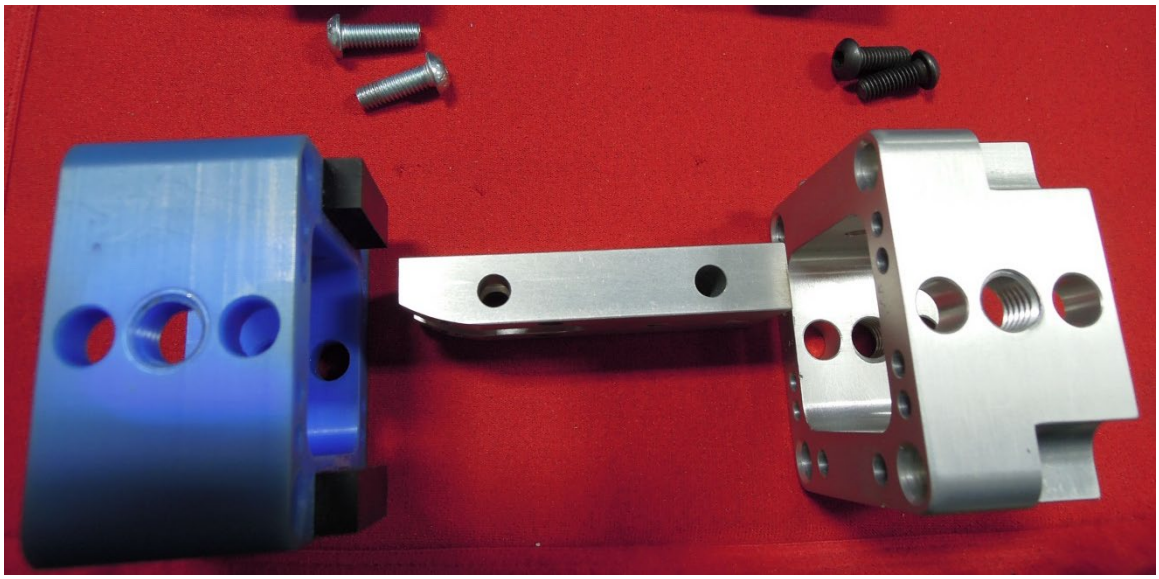

Figure 13. Last blue segment, top femur segment, and thick bone clamp

On the non-impact side of the last two segments, fix a thin bone clamp 133-5503 using two M6 x 18 BHCS for the blue segment and two M6 x 16 BHCS for the top aluminum segment – as shown in Figure 14.

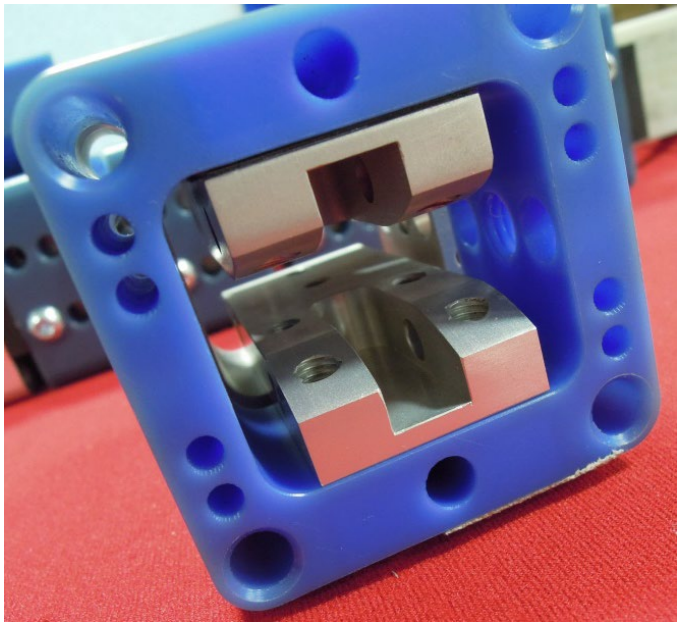

Figure 14. Thick and thin bone clamps fitted into the last blue segment

Slide and push the last two segments over the top of the bone as shown in Figure 15 below.

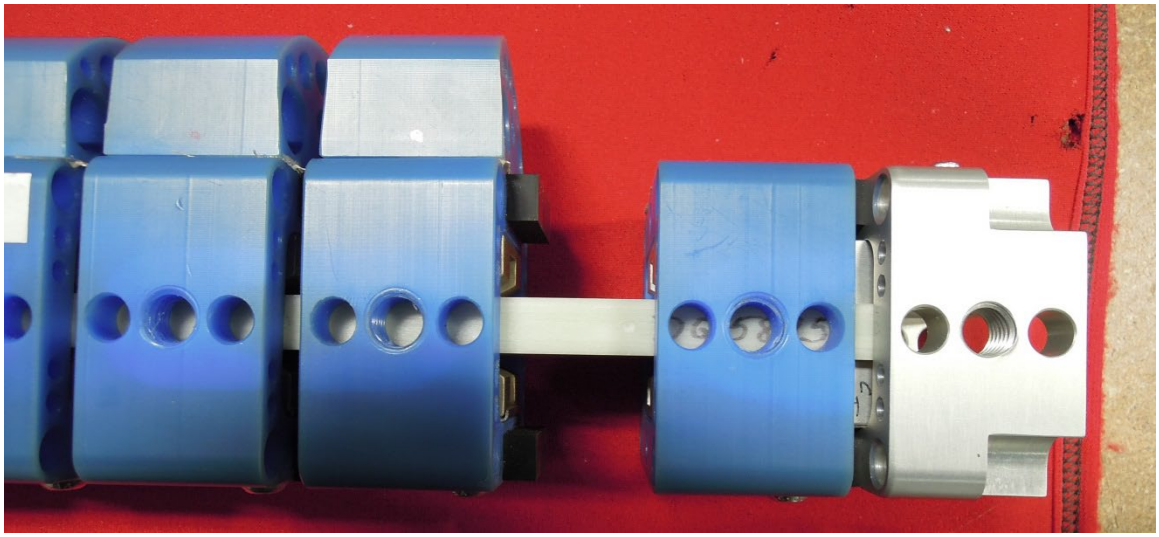

Figure 15. Sliding the last two segments over the bone

If the fit is loose, add 0.05 mm shims (133-5012) until the fit is tight as shown in Figure 16. Once the fit is tight, tighten all fasteners to 3 Nm.

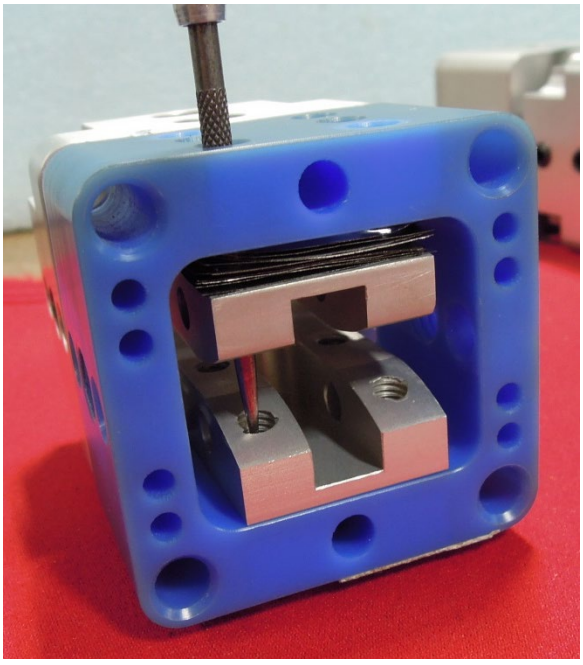

Figure 16. Addition of 0.05 mm shims to the non-impact side bone clamp

The distance from the top of the bone to the top of the aluminum segment should be between 1.5 mm and 2 mm and should match the small rubber buffer glued to the underside of the top plate 133-5102 – as shown in Figure 17.

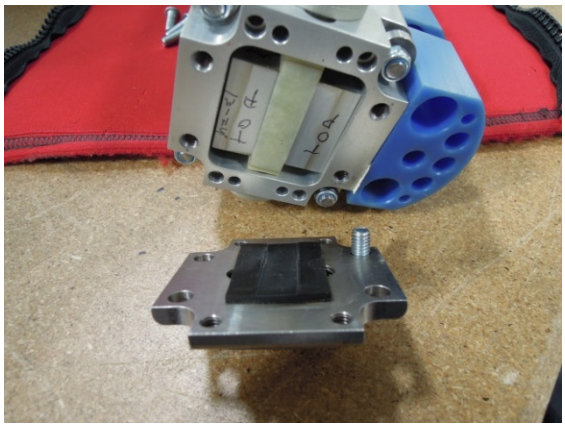

Figure 17. Top plate with underside rubber buffer

Tighten the top plate with four M6 x 18 BHCS – as shown in Figure 18.

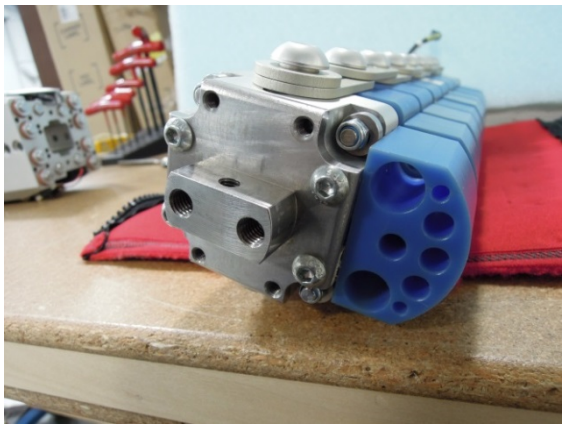

Figure 18. Attachment of the femur top plate

Pass the bone strain gage wire through a side link 133-5515. Starting from the knee, tighten all 14 links 133-5515 and four end washers 133-5104 using the shoulder bolts 133-5106. Torque all shoulder bolts to 3 Nm – as shown in Figure 19.

Figure 19. Installation of femur side links

Remove the base tool 133-8129. Place a washer 133-5521 over each of the four stainless steel cables 133-5110. Starting at the knee end, feed each of the cables through the corner holes of the leg segments. Place a washer 133-5521 over the threaded fitting of each of the cables and fit four M5 Nylok nuts 5000522 – as shown in Figure 20.

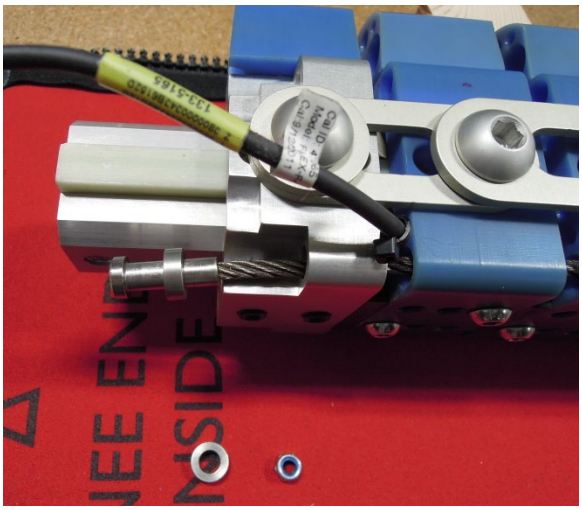

Figure 20. Insertion of stainless steel cable, washers, and Nylok nut

Set the gap between the Nylok nut and washer to 9.1 mm using the spacer tool 133-5112 – as shown in Figure 21.

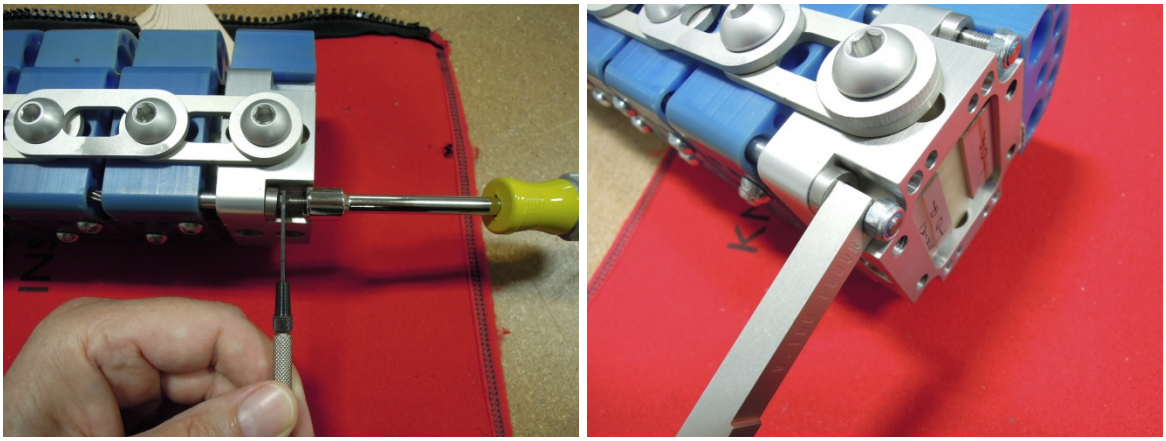

Figure 21. Setting the gap and tightening the Nylok nut

Clean and degrease the fronts of the six middle femur segments and fit with the six double sided tape profiles 133-5025. Fit the impact covers 133-5517 to the middle segments by locating them over the two BHCS. Clean and degrease the fronts of the two aluminum end segments and fit with double sided tape profiles 133-5026, 133-5027, and 133-5028 according to Figure 2. Fix four M3 x 8 SHCS to the front of the two aluminum end segments. Fit impact cover 133-5519 to the knee-end aluminum segment and impact cover 133-5518 to the opposite end aluminum segment.

At the knee-end of the femur, where the bone strain gage wire comes out through the link, attach two cable ties, one on the link and another on the wire as shown in Figure 22 to provide strain relief to the wire.

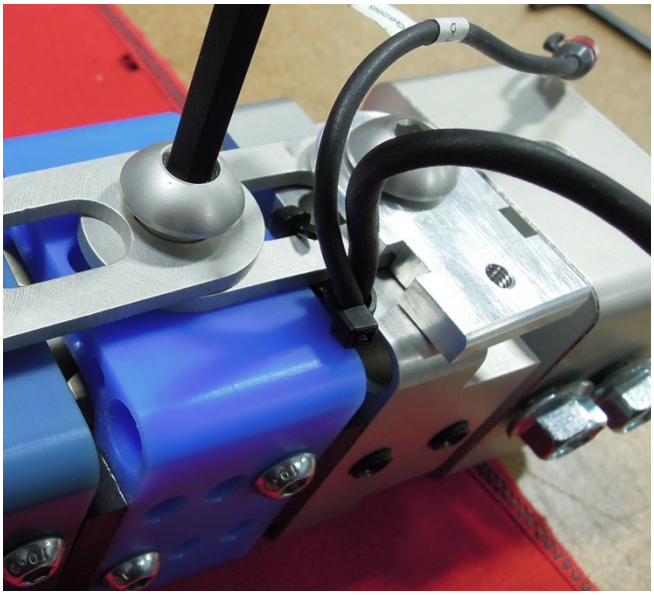

Figure 22. Bone wire strain relief

5.1.2. Femur Disassembly

To disassemble the Femur, reverse the process described in section 5.1.1.

5.2. Tibia

The components in Table 6 are included in the tibia assembly. Figure 23 shows a drawing of the tibia assembly components with parts labeled as listed in Table 6.

Table 6. Tibia assembly components

Part Description	Quantity	Part Number	Item #
Tibia Bone Assembly Tested & Certified	1	133-5565	1
Bone Clamp Thick, Femur/Tibia (Not Shown)	1	133-5502	2
Bone Clamp Thin, Femur/Tibia (Not Shown)	1	133-5503	3
Shim, Bone Clamp (0.4 Thick) (Not Shown)	1	133-5504	4
Spacer, Bone Contact, Thick	7	133-5505	5
Bone Clamp Thick, Knee	1	133-5506	6
Spacer, Bone Contact, Thin	7	133-5507	7
Bone Clamp Thin, Knee	1	133-5508	8
Shim (0.4 Thick)	7	133-5509	9
Rubber Buffer, Femur/Tibia End (Not Shown)	1	133-5510	10
Segment Bottom, Tibia	1	133-5511	11
Inner Segment Assembly	7	133-5534	12
Inner Segment Assembly Closest To Knee	1	133-5535	13
Inner Segment, Knee	1	133-5514	14
Link	18	133-5515	15
Washer, 12 ID x 26 OD x 3	4	133-5104	16
Shoulder Bolt	20	133-5106	17
Washer, Cable	8	133-5521	18
Cable Assembly, Tibia	4	133-5530	19
Screw, BHCS M6 x 1 x 18	32	5000848	20
Hex Nut, M5 x 0.8 Nylok	4	5000522	21
End Cover	1	133-5516	22
Screw, BHCS M6 x 1 x 16	6	5000072	23
Screw, BHCS M5 x 0.8 x 8	4	5000845	24
Screw, SHCS M3 x 0.5 x 6	4	5000843	25
Screw, MSSFP M8 x 16	2	5000769	26
Tape, Impact Segment (Not Shown)	8	133-5025	27
Tape, End Cover, 12 x 24 (Not Shown)	1	133-5028	28
Tape, End Cover, 10 x 12 (Not Shown)	4	133-5027	29
Tape, End Cover, 12 x 16 (Not Shown)	2	133-5026	30
Cover, End Impact, Knee End	1	133-5519	31
Impact Segment	8	133-5517	32
Cover, End Impact	1	133-5518	33
Shim (T0-5) Optional (Not Shown)	7	133-5001	34
Shim, Bone Clamp (T0-05) Optional (Not Shown)	2	133-5002	35
Shim, Bone Clamp (T0-5) Optional (Not Shown)	2	133-5003	36
Shim, Bone Clamp (T0-6) Optional (Not Shown)	2	133-5004	37
Shim (T0-6) Optional (Not Shown)	7	133-5005	38
Shim (0.05) Optional (Not Shown)	21	133-5012	39
Wire Exit Base	2	133-5522	40
Wire Exit Clamp	2	133-5523	41
Screw, BHCS M5 x 0.8 x 12	2	5000846	42

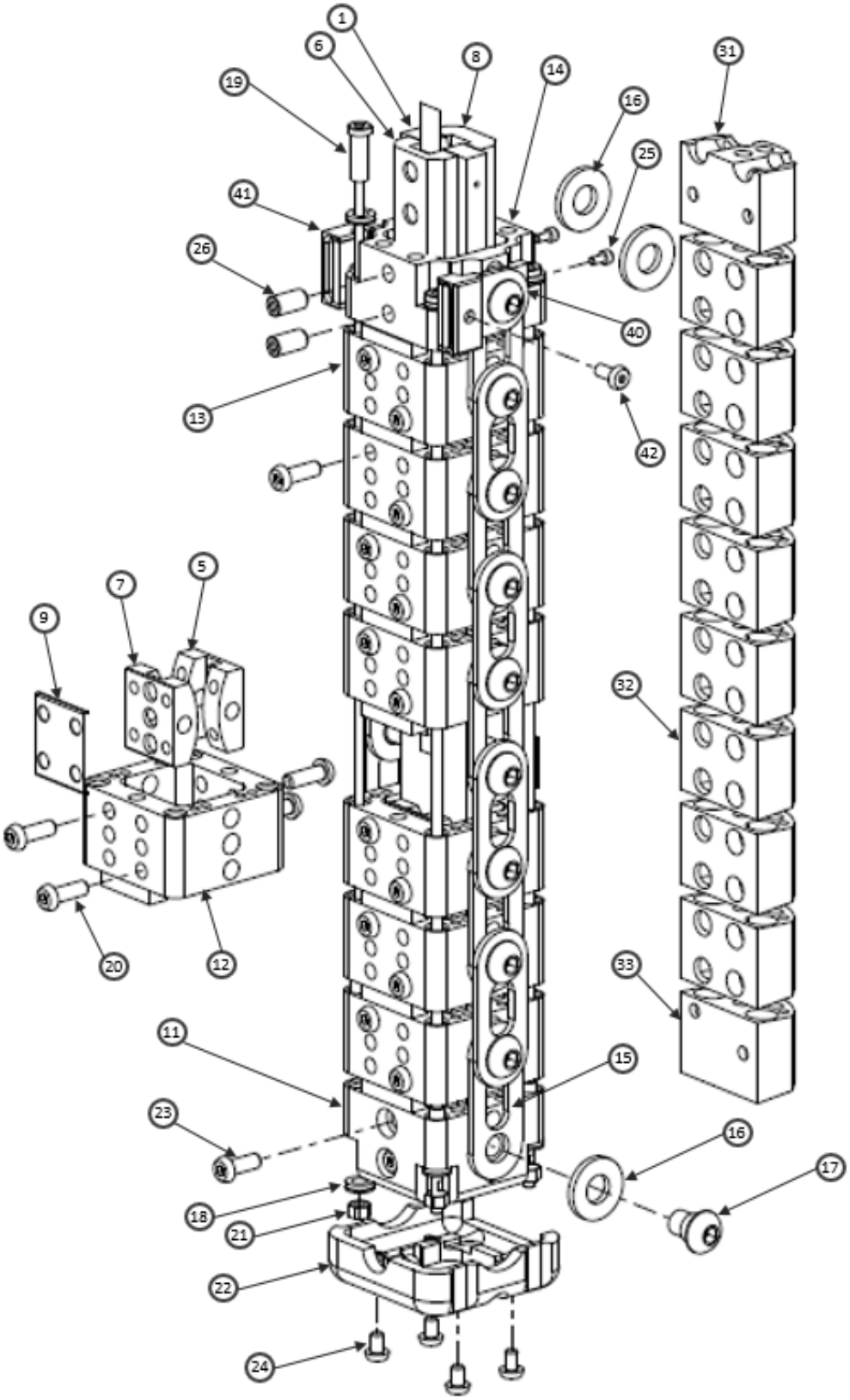

Figure 23. Tibia assembly components

5.2.1. Tibia Assembly

Start the assembly from the knee end of the bone.

Place bone clamp 133-5506 inside the tibia/femur base tool 133-8129 with the curved end upwards and the grooved side inwards. Loosely tighten with two M8 x 20 fasteners – as shown in Figure 24.

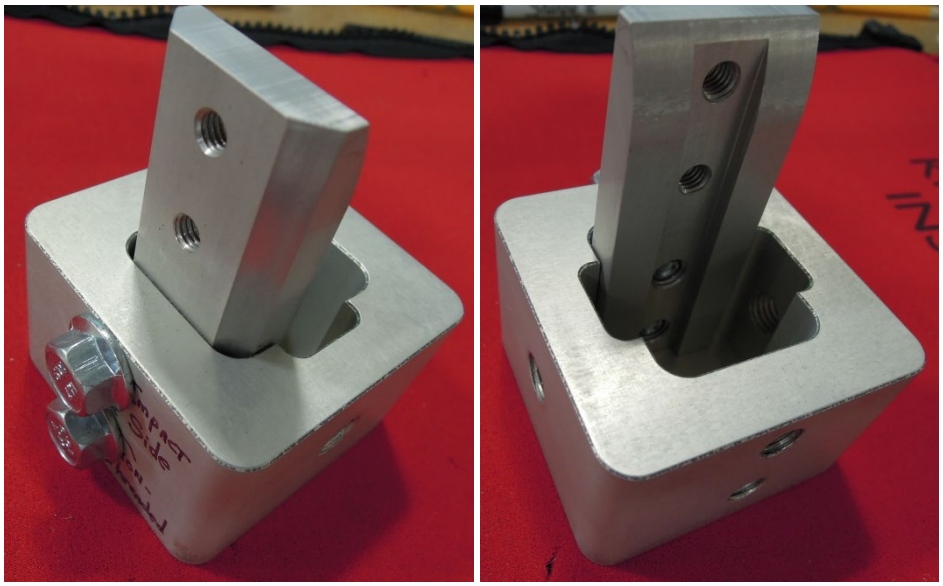

Figure 24. Tibia/femur base tool fitted with bone clamp

Place the knee inner segment 133-5514 over the bone clamp and loosely tighten with two M6 x 16 BHCS – as shown in Figure 25.

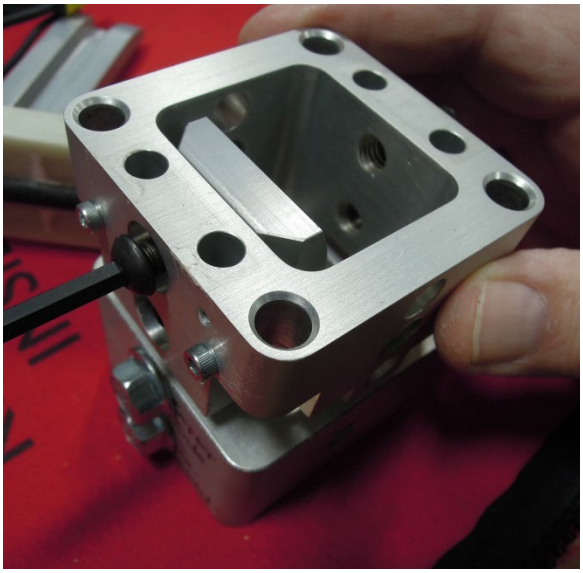

Figure 25. Tibia/femur base tool with bone clamp and inner knee segment

Place the thin bone clamp 133-5508 over the rear, non-impact side of the bone– as shown in Figure 26.

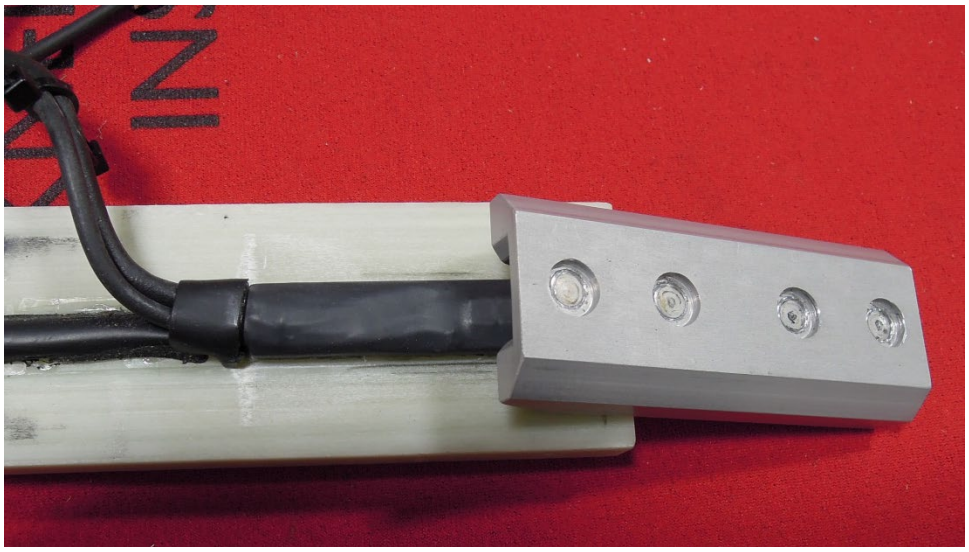

Figure 26. Thin bone clamp being placed over the rear, non-impact side of the bone

Insert the bone and clamp together into the base, making sure that it is on the non-impact side of the leg. Place two M8 x 12 MSSFP fasteners into the fixture base and two M8 x 16 MSSFP fasteners into segment 133-5514. Tighten all fasteners to 3 Nm – as shown in Figure 27. Lay the strain gage exit wire to the side.

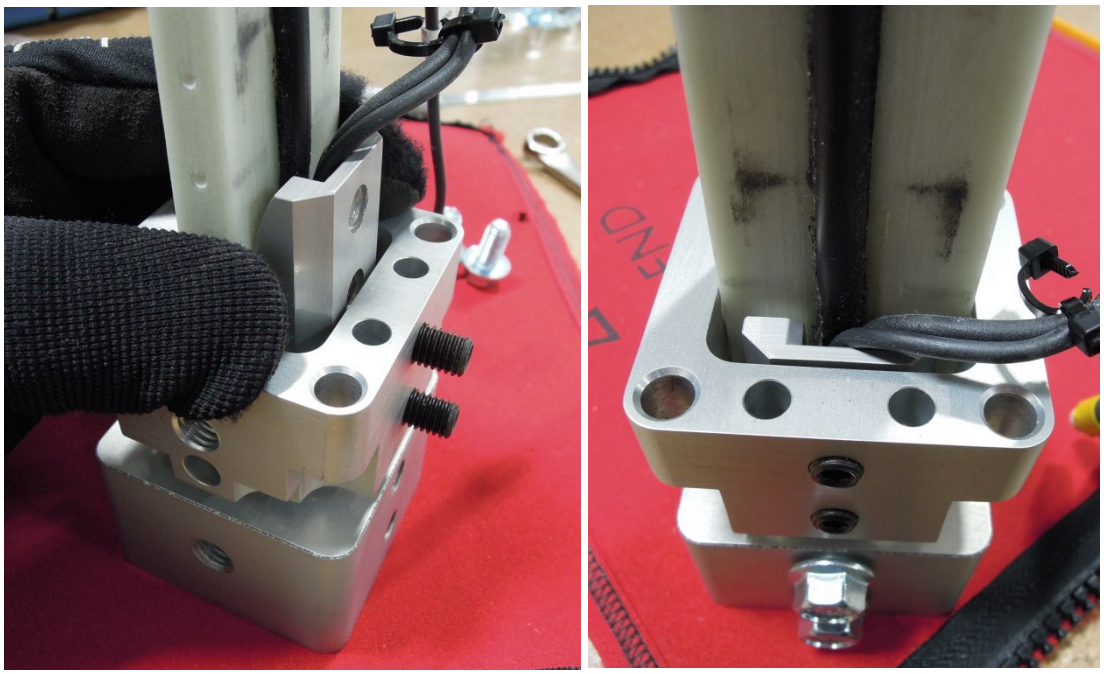

Figure 27. Insertion of the thin bone clamp and bone into the tibia base

Place a thick bone contact spacer 133-5505 into segment 133-5535 (blue segment with rubber buffers on both sides) and tighten with two M6 x 18 BHCS fasteners – as shown in Figure 28.

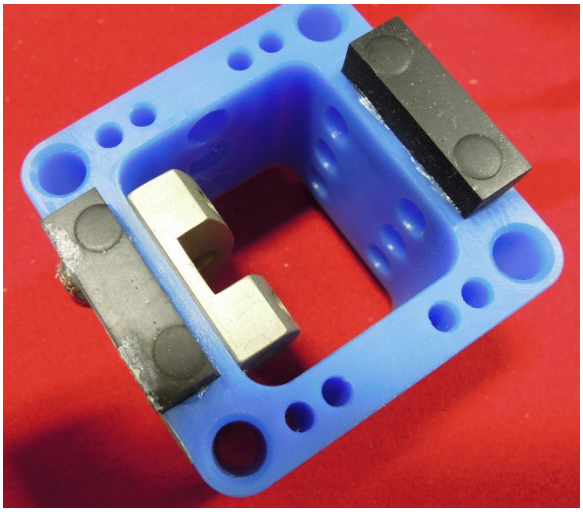

Figure 28. Thick bone contact spacer in the first blue segment of the tibia

Slide the segment over the bone with the thick spacer on the impact side. Be careful not to damage the black strain gage cover running down the center of the bone – as shown in Figure 29.

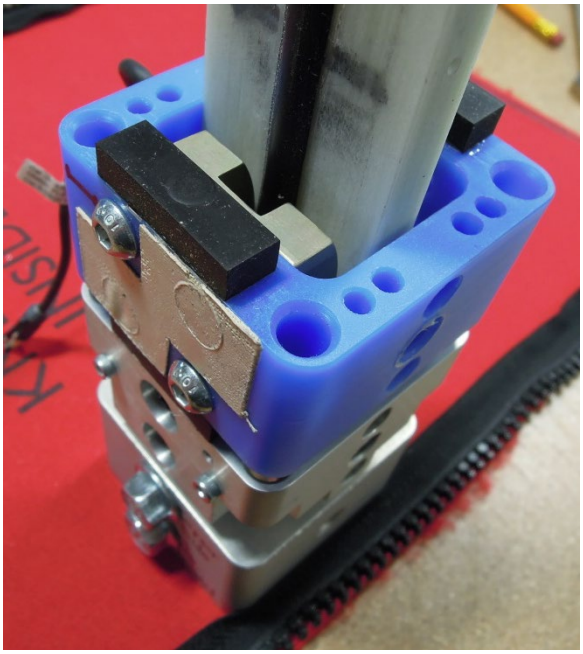

Figure 29. Fitting of the first blue segment over the tibia bone

Insert a thin bone contact spacer 133-5507 and thin shim 133-5012 (as shown in Figure 30) into the gap between the bone and the blue bone segment on the non-impact side.

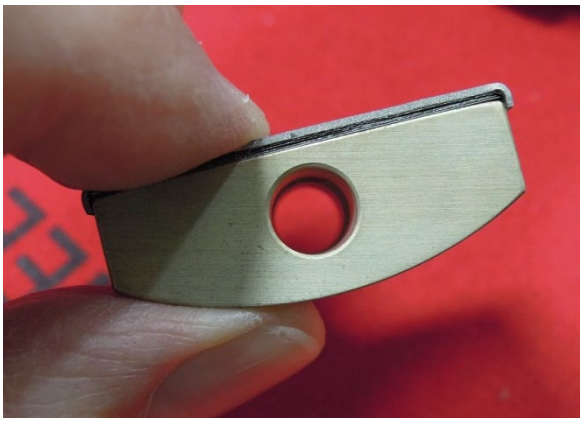

Figure 30. Thin bone contact spacer and shims for non-impact side

When fitting the spacer-shim assembly, push down on top of the assembly using thumb force only. The user should feel high resistance when pushing in the spacer-shim assembly – as shown in Figure 31.

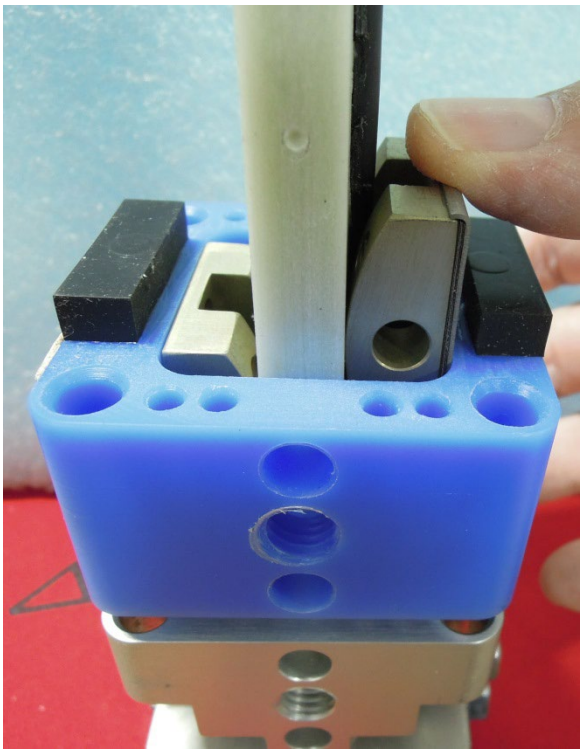

Figure 31. Fitting the spacer-shim assembly to the non-impact side

Check for fit by rotating the blue segment about the bone z-axis. If the fit is loose, change the shim configuration by adding additional thin shims, using thicker shims (133-5029 or 133-5030), or by using any combination of shims. When the spacer-shim assembly fits as tight as possible with thumb pressure, align the screw holes and tighten both the front and rear fasteners to 3 Nm with two M6 x 18 BHCS – as shown in Figure 32.

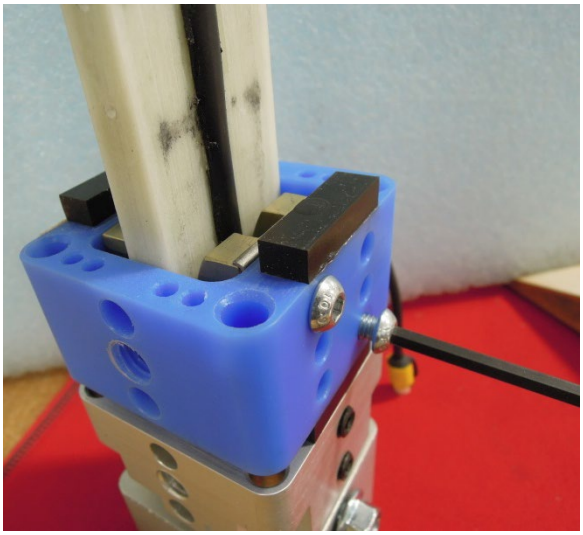

Figure 32. Tightening of the first tibia blue segment

For the next segment, attach a thick bone contact spacer 133-5505 to a blue bone segment 133-5534 using two M6 x 18 BHCS fitted diagonally as per the previous segment. Slide over the bone with the rubber buffer on the top side and the thick spacer on the impact side. Try using the same spacer-shim configuration as the previous segment. Adjust the spacer-shim configuration if loose. Align the screw holes and tighten both front and rear fasteners to 3 Nm with two M6 x 18 BHCS. Repeat for the next five segments. Figure 33 shows the Tibia assembly with the tibia/femur base tool, inner knee segment, and seven blue segments.

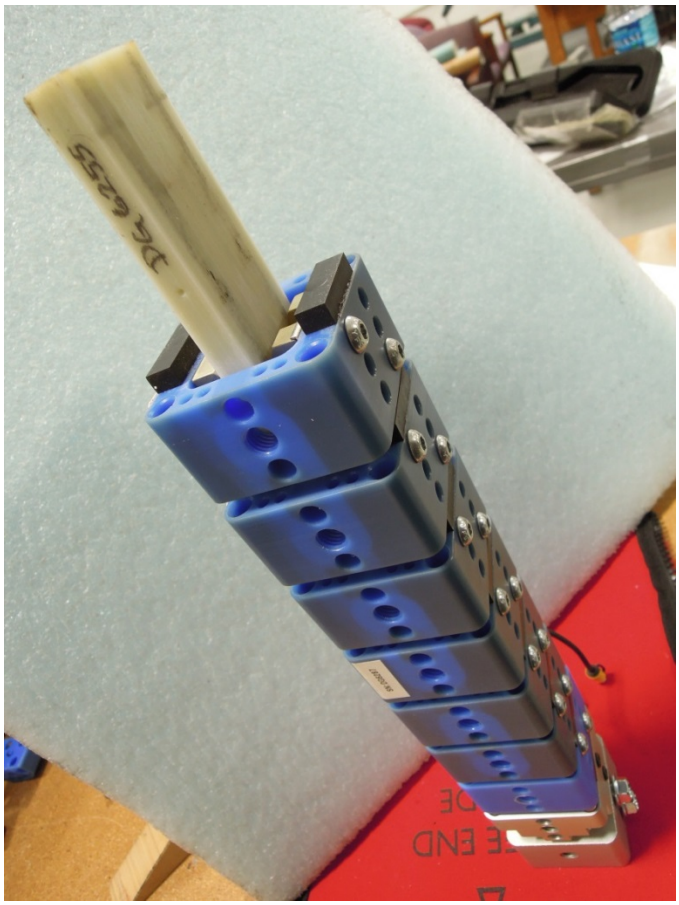

Figure 33. Tibia assembly with the tibia/femur base tool, inner knee segment, and seven blue segments

Look inside the bottom tibia segment 133-5511 and ensure that the rubber buffer is still bonded inside the bottom of the part – as shown in Figure 34. If not, the rubber buffer will need to be located and re-bonded to prevent loose fit at the end of the bone. Additional "packing" may be needed to prevent the bone from moving.

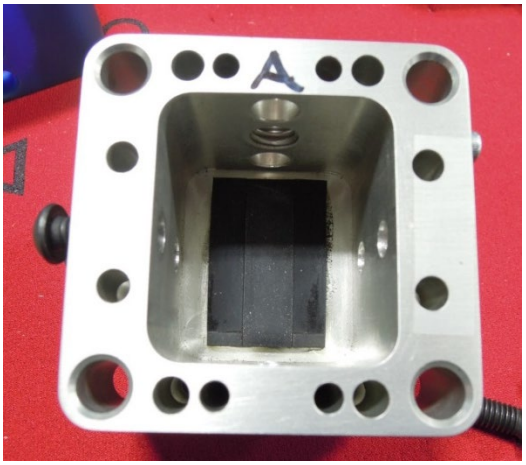

Figure 34. Rubber buffer inside the aluminum tibia bottom segment

Place a thick bone clamp 133-5502 on the impact side of both the last blue segment 133-5534 and the bottom tibia segment 133-5511 and tighten with two M6 x 18 BHCS for the blue segment and two M6 x 16 BHCS for the bottom aluminum segment – as shown in Figure 35.

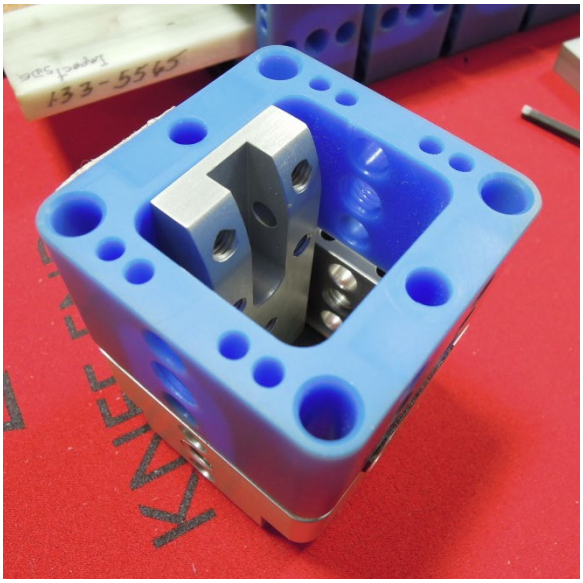

Figure 35. Thick bone clamp fitted to the last blue segment and bottom tibia segment

On the non-impact side of the same two segments, tighten a thin bone clamp 133-5503 using two M6 x 18 BHCS for the blue segment and two M6 x 16 BHCS for the bottom aluminum segment – as shown in Figure 36.

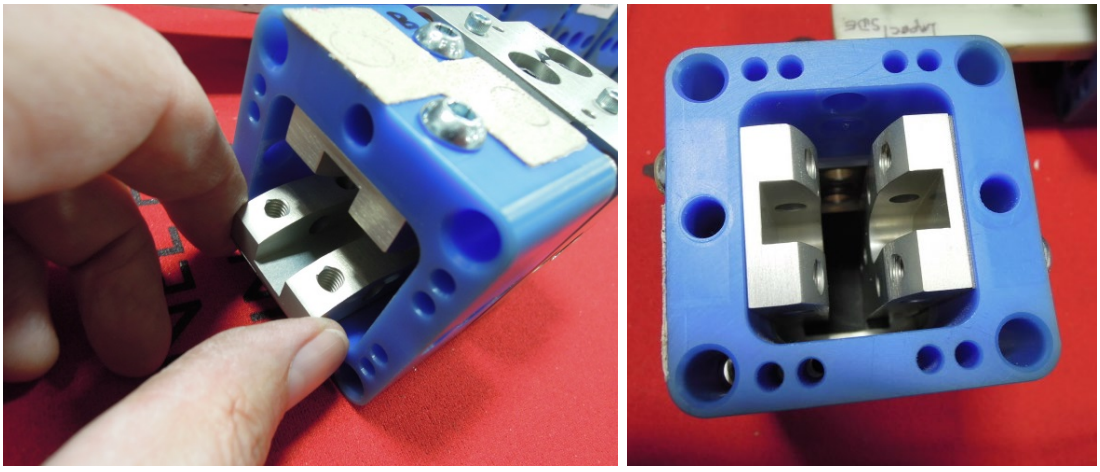

Figure 36. Fitting of the thin bone clamp to the bottom two segments

Slide and push the last two segments over the top of the bone – as shown in Figure 37 below.

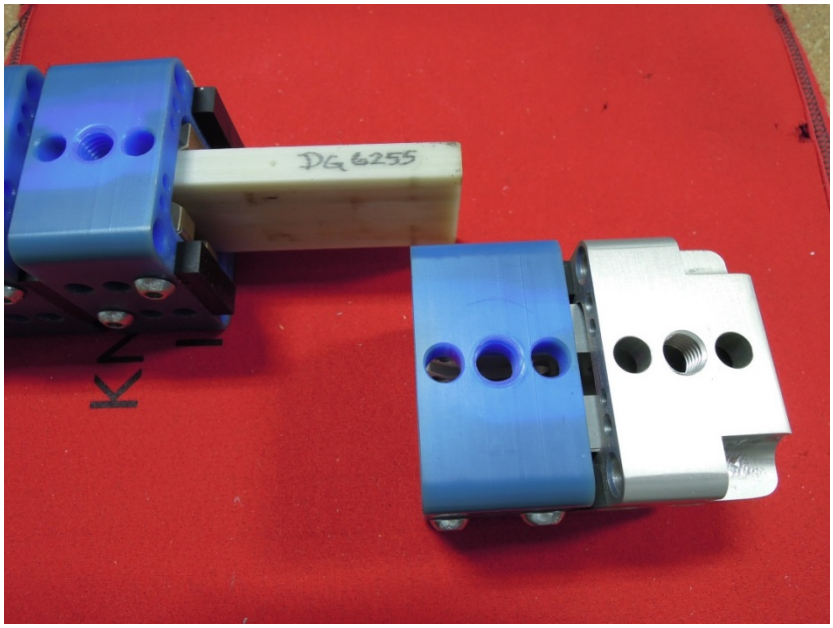

Figure 37. Orientation and installation of the last two tibia segments

Check that there is no gap between the bone and the rubber buffer inside the bottom aluminum segment by looking through the holes in the side of the aluminum segment. If there is a gap, this should be packed so that there is no loose fitting at the end of the bone.

If the fit is loose over either of the last two segments, add 0.05 mm shims (133-5012) until the fit is tight as shown in Figure 38. Once the fit is tight, tighten all fasteners to 3 Nm.

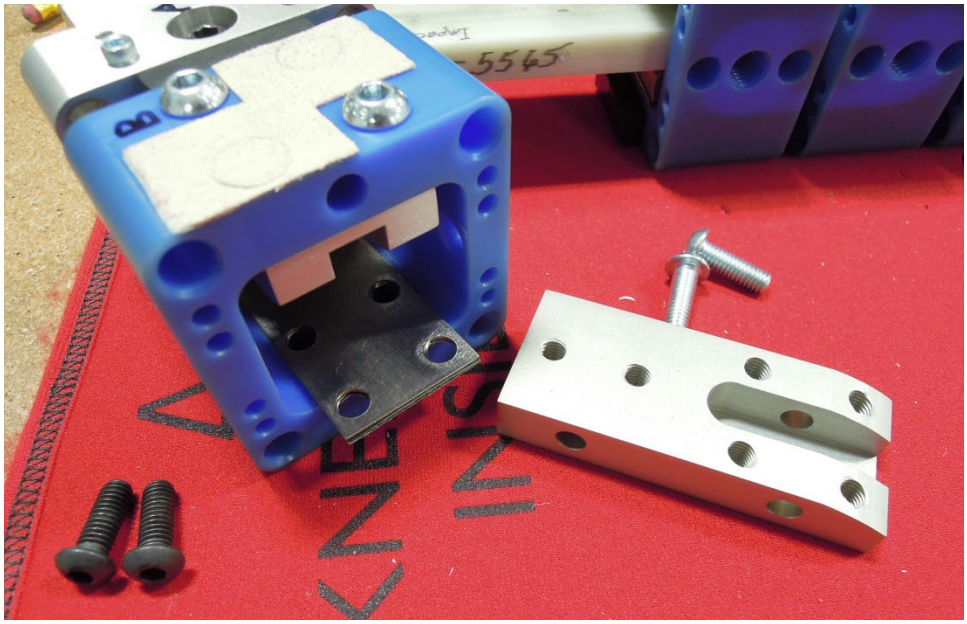

Figure 38. Thin bone clamp and shim combination to tighten the fit of the last two tibia segments

Pass the bone strain gage wire through a side link 133-5515. Starting from the knee, fix all 14 links 133-5515 and four end washers 133-5104 using the shoulder bolts 133-5106. Torque all shoulder bolts to 3 Nm – as shown in Figure 39.

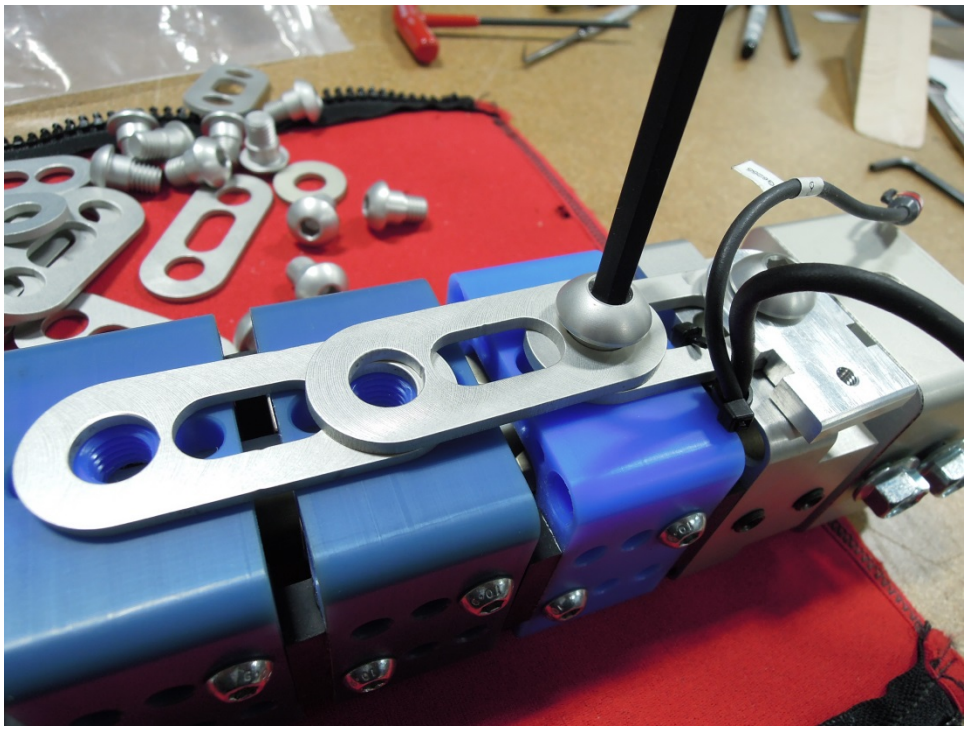

Figure 39. Installation of the tibia side links

Remove the base tool 133-8129. Place a washer 133-5521 over each of the four stainless steel cables 133-5110. Starting at the knee end, feed each of the cables through the corner holes of the leg segments. Place a washer 133-5521 over the threaded fitting of each of the cables and fit four M5 Nylok nuts 5000522. See Figure 40.

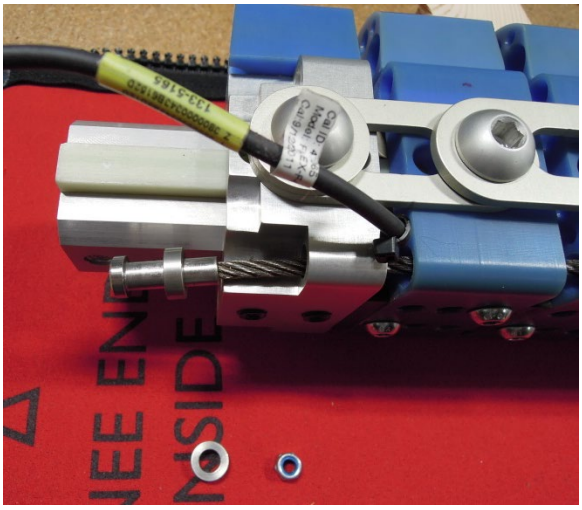

Figure 40. Insertion of stainless steel cable, washers, and Nylok nut

Set the gap between the Nylok nut and washer to 10.3 mm using the spacer tool 133-5112 – as shown in Figure 41.

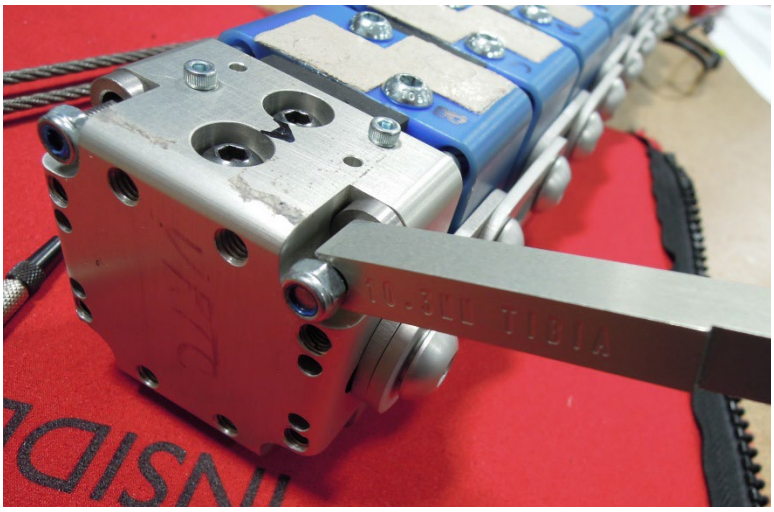

Figure 41. Setting the 10.3 mm gap between the Nylok nut and washer using the spacer tool

Clean and degrease the fronts of the middle six segments and fit with the six double sided tape profiles 133-5025. Place the impact covers 133-5517 to the middle segments locating them over the two BHCS. Clean and degrease the fronts of the two aluminum end segments and fit with double sided tape profiles 133-5026, 133-5027, and 133-5028 according to Figure 23. Fix four M3 x 8 SHCS to the front of the two aluminum end segments. Fit impact cover 133-5519 to the knee-end aluminum segment and impact cover 133-5518 to the opposite end aluminum segment.

5.2.2. Tibia Disassembly

To disassemble the Tibia, reverse the process described in section 5.2.1.

5.3. Knee

The components in Table 7 are included in the knee assembly. Figure 42 shows a drawing of the knee assembly components with parts labeled as listed in Table 7.

Table 7. Knee assembly components

Part Description	Quantity	Part Number	Item #
Knee Block, Tibia	1	133-5330	1
Meniscus Assembly	1	133-5313	2
Screw, SHCS M5 x 0.8 x 10, Lowhead (Not Shown)	4	5000774	3
Knee Block, Femur	1	133-5320	4
Attachment Plate, String Pot (Not Shown)	1	133-5302	5
Spring, 12 x 40	8	9003159	6
Spring, 18 x 80	16	9003158	7
Spring Cap Knee Block, Tibia	8	133-5318	8
Cable Washer	8	133-5311	9
Spring Cap Knee Block, Femur	8	133-5310	10
Cable Assembly, Knee ML	8	133-5350	11
Screw, FHCS M3 x 0.5 x 10 (Not Shown)	2	5000203	12
Cover, Knee, Femur Right Side	1	133-5315	13
Cover, Knee	2	133-5306	14
Cover, Knee, Tibia Left Side	1	133-5314	15
Screw, FHCS M4 x 0.7 x 8, Zinc	16	5000844	16
AP Cable Assembly	4	133-5360	17
Hex Nut, M5 x 0.8 Nylok	12	5000522	18
Screw, MSSFP M8 x 30	4	5000770	19
Screw, BHCS M8 x 1.25 x 35, Zinc	4	5000850	20
Tape, Front Cover	4	133-5018	21
Cover, Upper Knee	1	133-5304	22
Cover, Lower Knee	1	133-5305	23
String Potentiometer RH (Not Shown)	2	61-503-05-01-00	
String Potentiometer LH (Not Shown)	2	61-507-05-01-00	

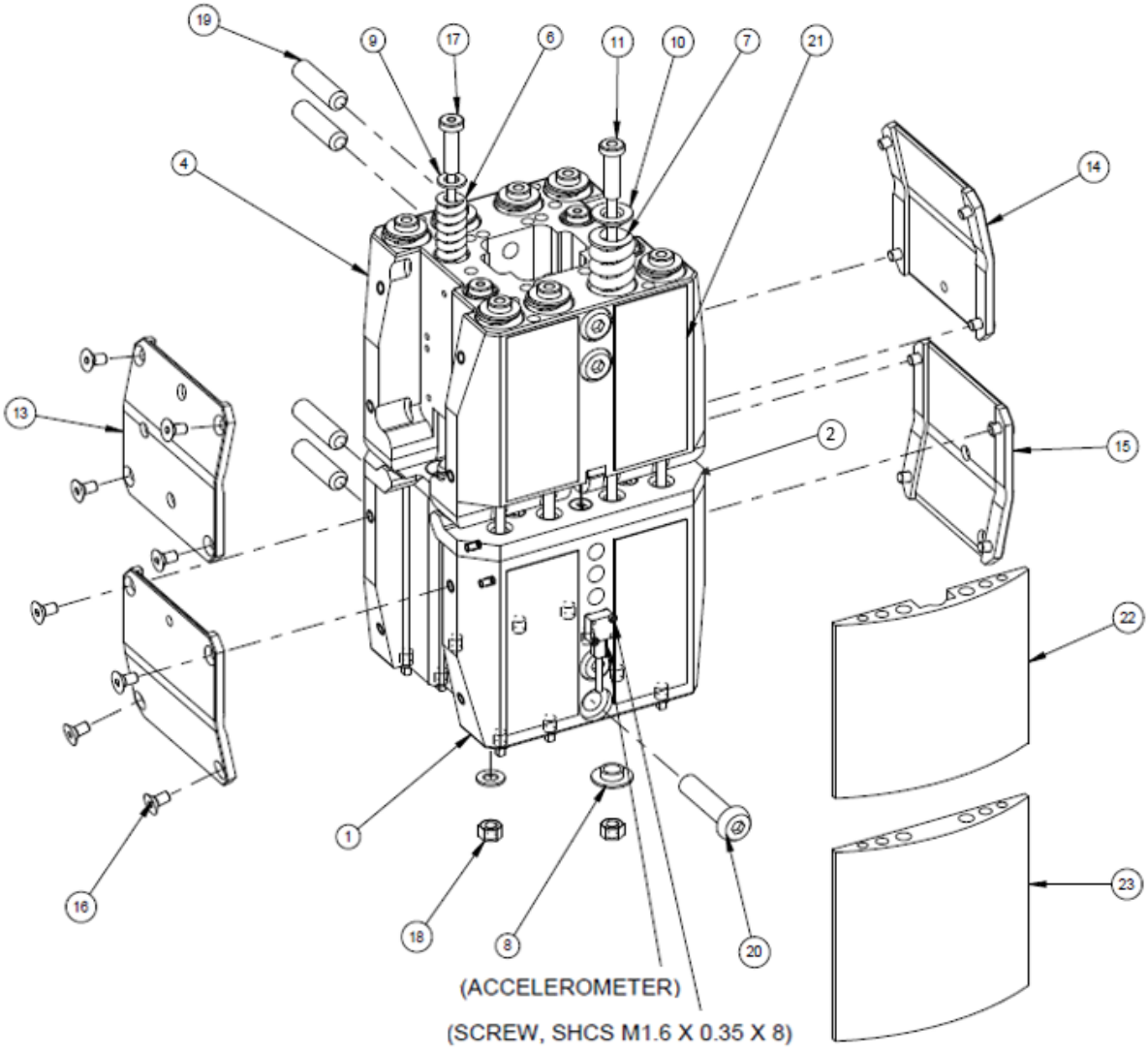

Figure 42. Knee assembly components

5.3.1. Knee Assembly

Make a note of the string pot serial numbers and their ligament positions. Right hand pull (RH) and left-hand pull (LH) string potentiometers can be identified by their serial number – the RH has an "R" at the end of the number and the LH has an "L".

Feed the cable connector of one of the right-hand pull string potentiometers (61-503-05-01-00) through the inner side of one of the central holes of the meniscus assembly 133-5313 – as shown in Figure 43 below. Attach the string pot with the #2-56 x ¼ long cap head screws and ensure that the pull wire is directed towards the outer bushing. Feed the cable connector of the other RH pull string potentiometer through the inner side of the opposite central hole. Fit and attach this RH pull string potentiometer in the same way, on the opposite side. The two RH pull string potentiometers should be positioned closest to the main flange of the meniscus. Attach the LH pull string potentiometers (61-507-05-01-00) above the RH pull string potentiometers following

a similar procedure. The pull wires of the LH pull string potentiometers, however, will be oriented directly in line with the two inner bushes. Feed the pull wires through their respective bushings. Figures 43-44 show the orientation of the string potentiometers with the meniscus assembly.

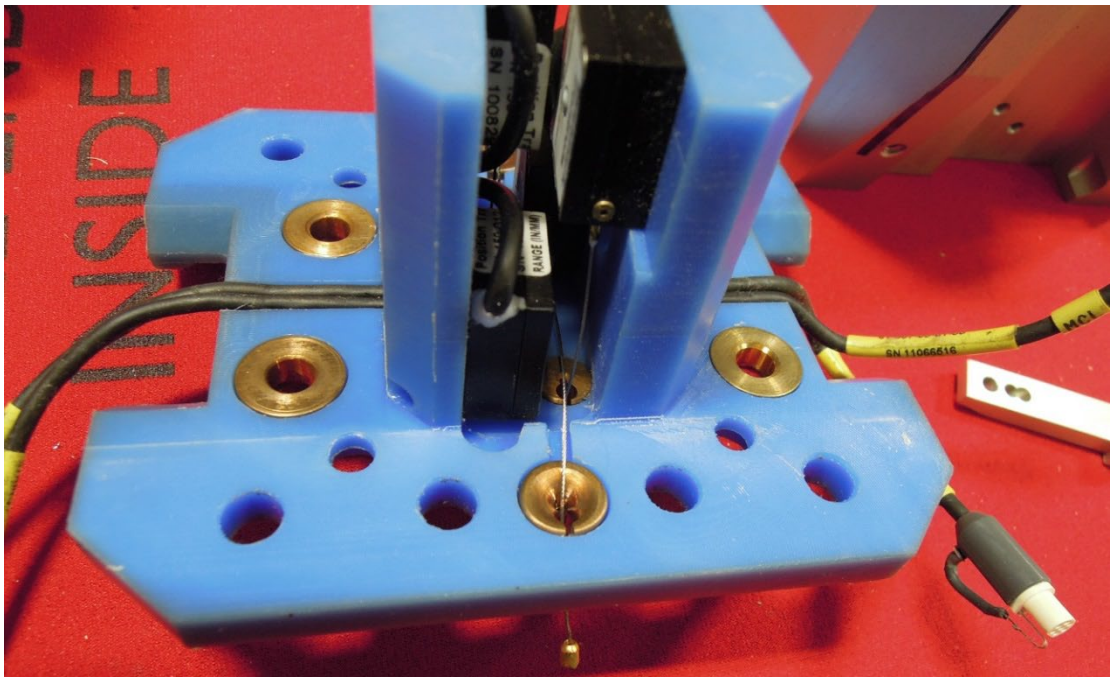

Figure 43. Installation of the string potentiometers onto the meniscus assembly

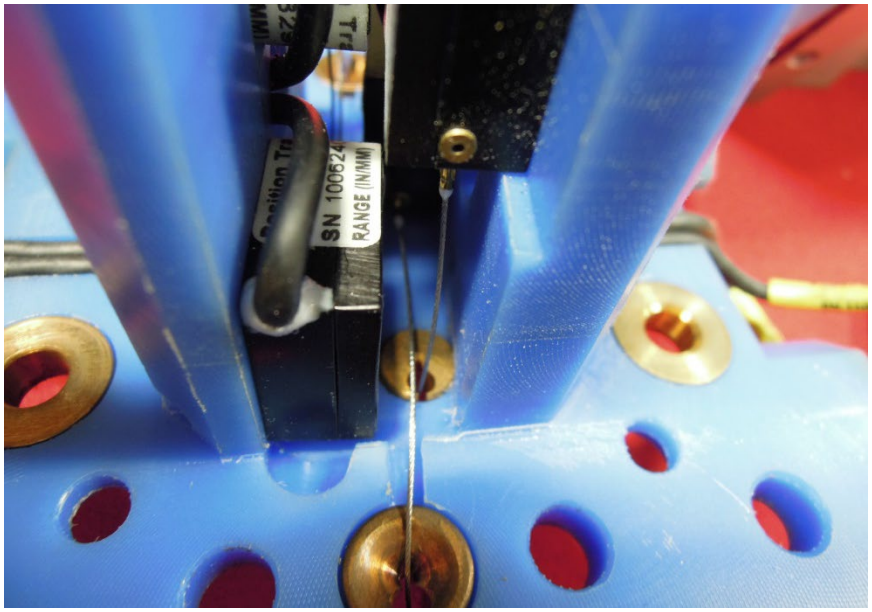

Figure 44. Close up view of the string potentiometer orientation and pull wire routing

Make sure that all electrical cables are inside the cavity as much as possible. Run the cables through the channels on either side of the meniscus and clamp with the retaining plates – as shown in Figure 45.

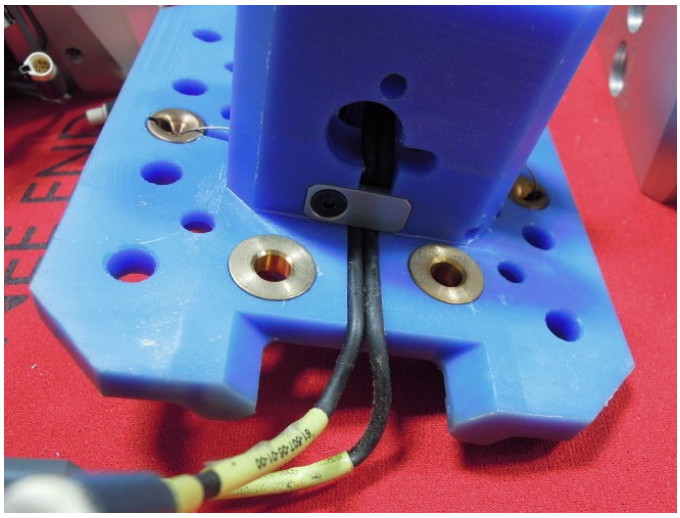

Figure 45. Electrical cable routing through a central hole and retaining plate

Place the meniscus assembly over the tibia knee block 133-5330 and make sure that the potentiometer pull wires are in their grooves – as shown in Figure 46.

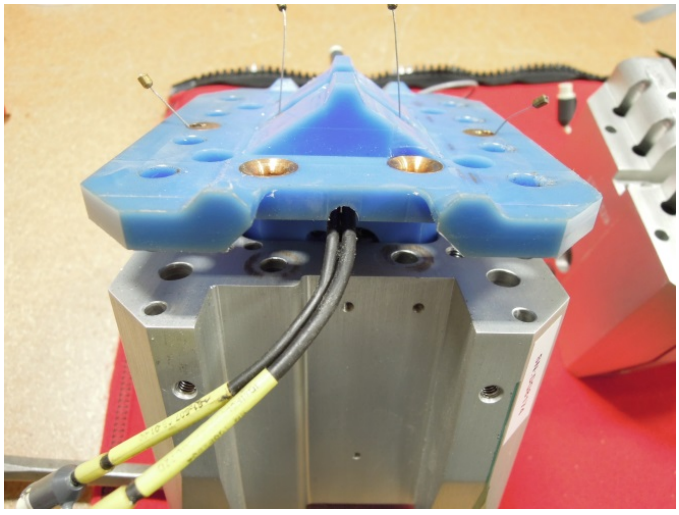

Figure 46. Fitting the meniscus assembly over the tibia knee block

Attach the meniscus assembly to the tibia knee block using four M5 x 10 low head cap screws. Low strength thread lock will need to be applied to these cap screws to prevent loosening – as shown in Figure 47.

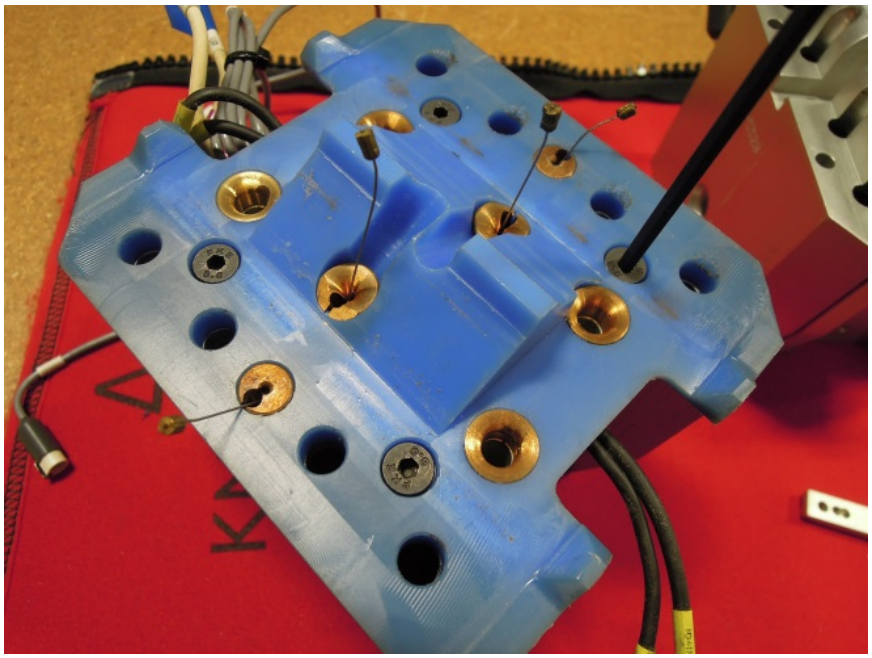

Figure 47. Attachment of the meniscus assembly to the tibia knee block

With the tibia knee block on the bottom and the meniscus on the top, pass the four ball crimps from the four string potentiometers through the attachment plate 133-5302. Place the two spacers 133-5113 between the attachment plate and the meniscus – as shown in Figure 48.

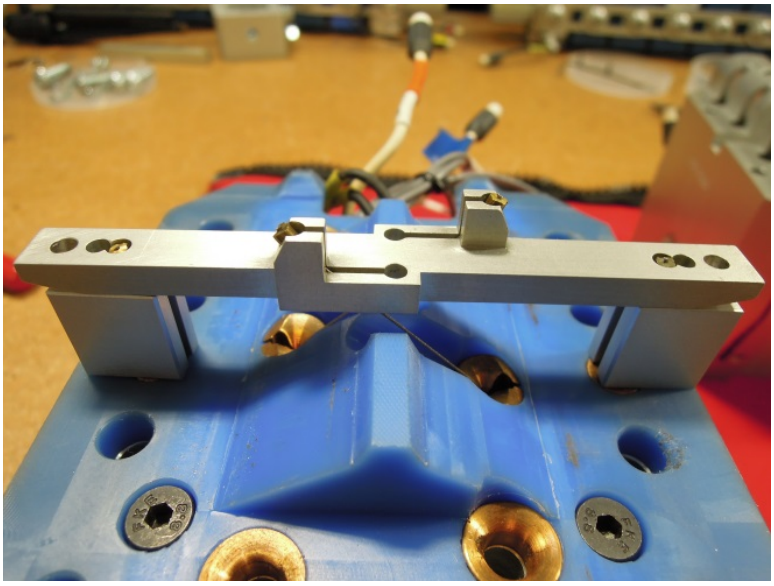

Figure 48. String potentiometer attachment plate with spacers

Place four of the smaller 12 x 40 springs (9003159) into the femur knee block 133-5320. Place washer 133-5311 on top of each of the springs. Insert wires 133-5360 through the washers and springs – as shown in. See Figure 49.

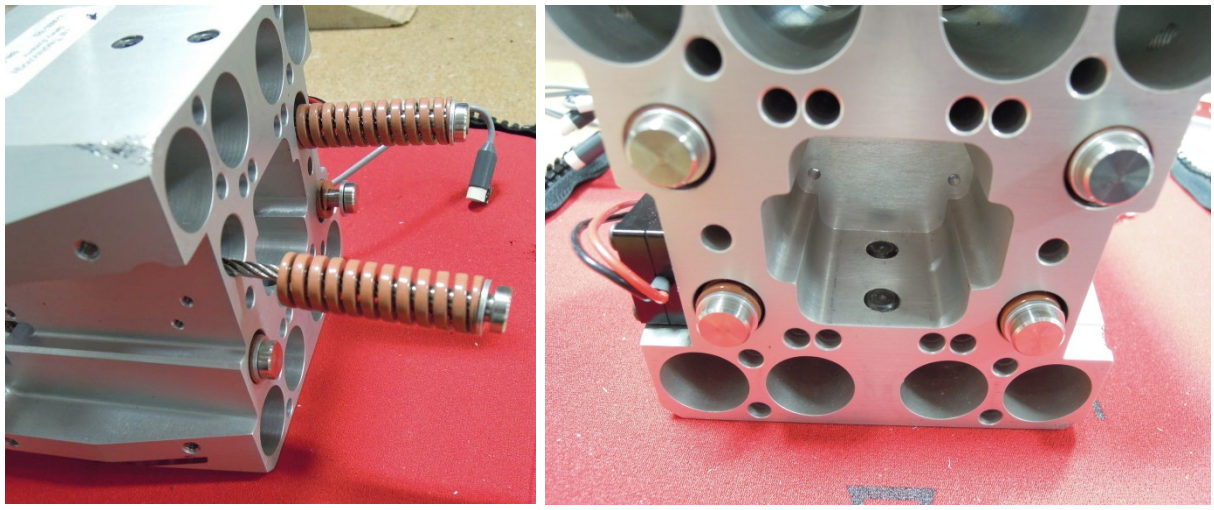

Figure 49. Springs, washers, and wires inserted into the femur knee block

Make sure that the femur knee and tibia knee blocks are oriented correctly. Take the femur knee block assembly and carefully lower it over the tibia knee block, then position it over the attachment plate and guide the wires across to their designated holes. Make sure that the wires are in their correct aligned holes and not crossed over – as shown in Figures 50-51.

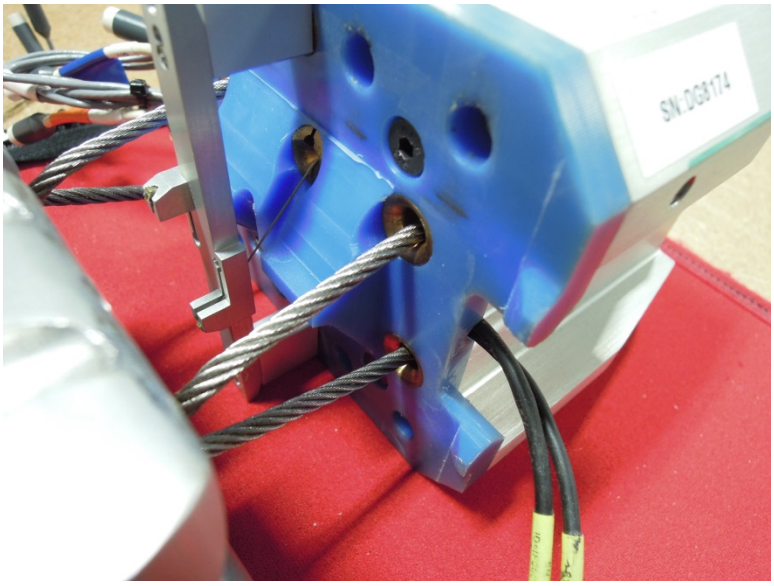

Figure 50. Joining of the femur and tibia knee block

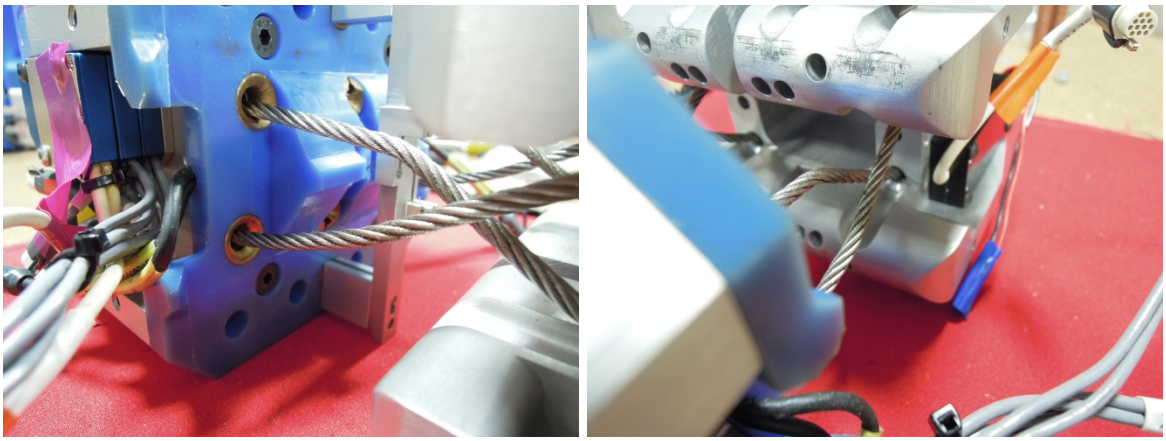

Figure 51. Wire alignment across the knee

Carefully turn the whole assembly onto its side and insert the remaining 12 x 40 springs over the wires. Insert a washer 133-5311 and Nylok nut over each of the springs. Tighten the nuts down using 8 mm and 1/8" wrenches until the washers are exactly flush with the femur knee block – as shown in Figure 52.

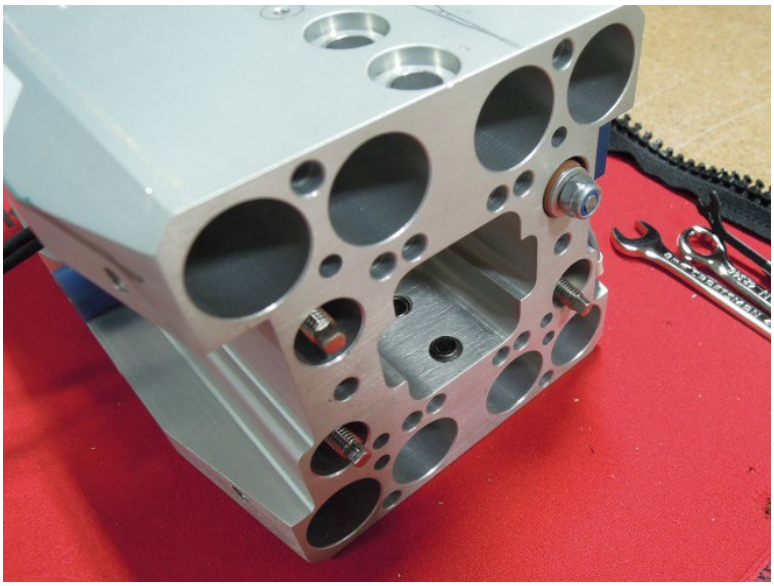

Figure 52. Installation of the springs, washers, and nuts into the tibia knee block

Tighten the attachment plate with two M3 x 8 countersunk screws and remove the spacer blocks. It may be necessary to remove a spacer block to access the screw – as shown in Figure 53.

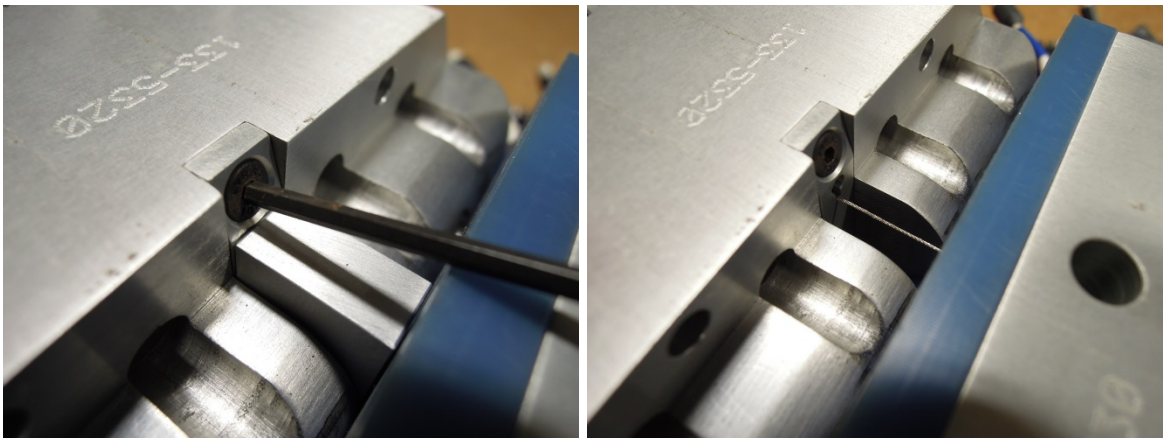

Figure 53. Fixing the string potentiometer attachment plate and removal of the spacer

Place eight 18 x 80 springs 9003158 into the femur knee block counter bores. Place a washer 133-5310 on top of each of the springs then feed a wire 133-5350 through each of the eight springs. Turn the knee assembly over and insert the remaining eight 18 x 80 springs into their counter bores and over each of the wires. Place a washer 133-5318 and M5 Nylok nut over each of the springs – as shown in Figure 54.

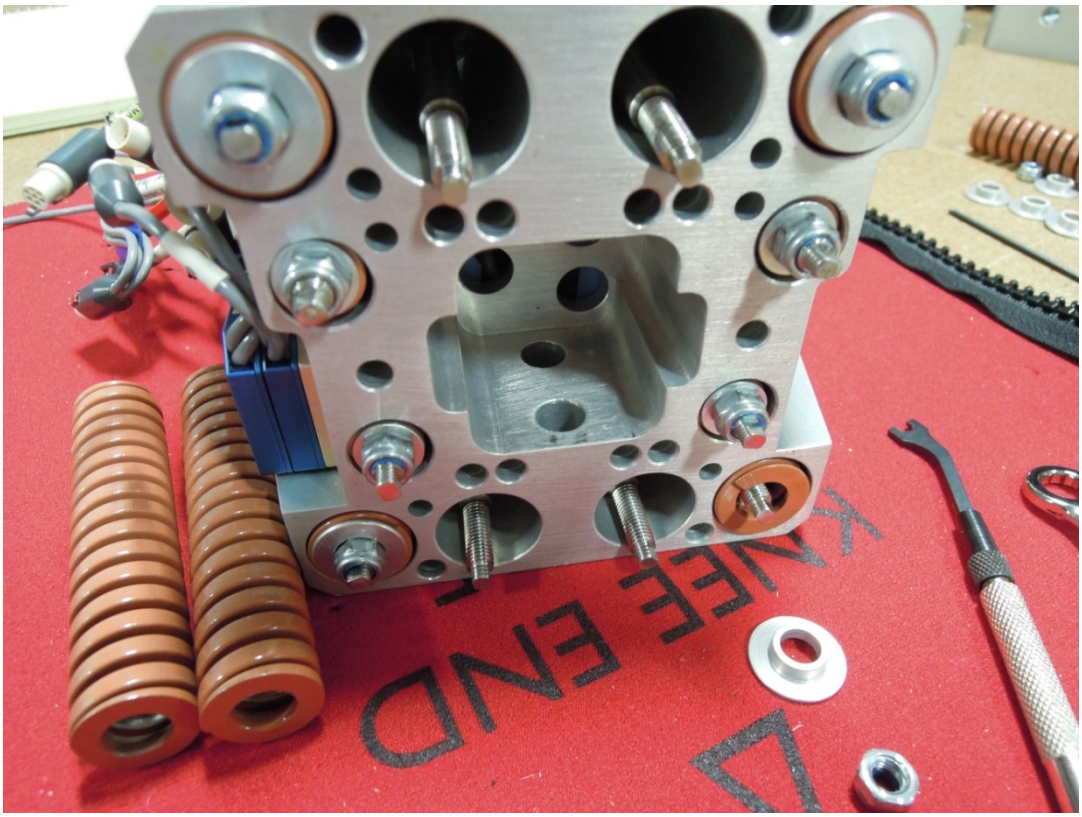

Figure 54. Installation of the 18 x 80 springs into the tibia knee block

Tighten all nuts until all washers are flush with the tibia knee block. Spring protrusion on the femur knee block should be 3 mm – as shown in Figure 55.

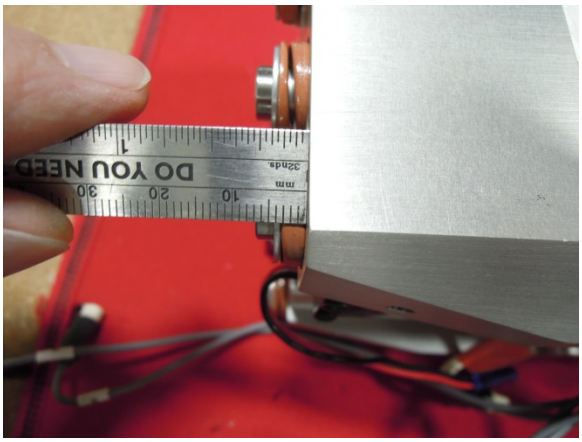

Figure 55. Spring protrusion on the femur knee block should be 3 mm

5.4. Leg Assembly

Insert the femur assembly into the femur knee block making sure that the orientation is correct. Insert two M8 x 35 BHCS into the femur knee block impact side counter bored holes. Insert two M8 x 30 set screws into the non-impact side. Tighten all M8 fasteners to 8 Nm – as shown in Figure 56.

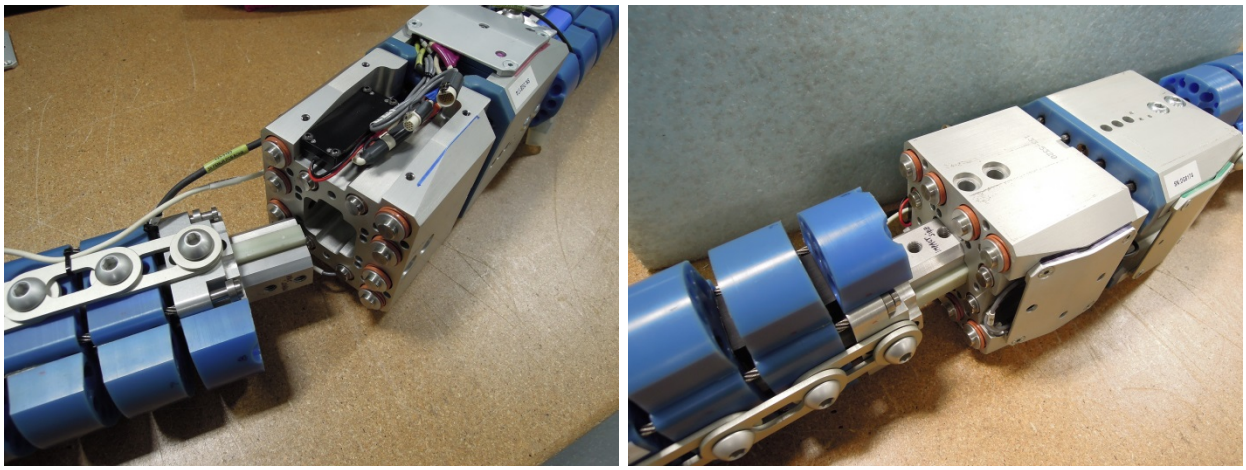

Figure 56. Insertion of the femur assembly into the femur knee block

Insert the tibia assembly into the tibia knee block and make sure that the orientation is correct. Insert two M8 x 35 BHCS into the tibia knee block impact side counter bored holes. Insert two M8 x 30 set screws into the non-impact side. Tighten all M8 fasteners to 8 Nm.

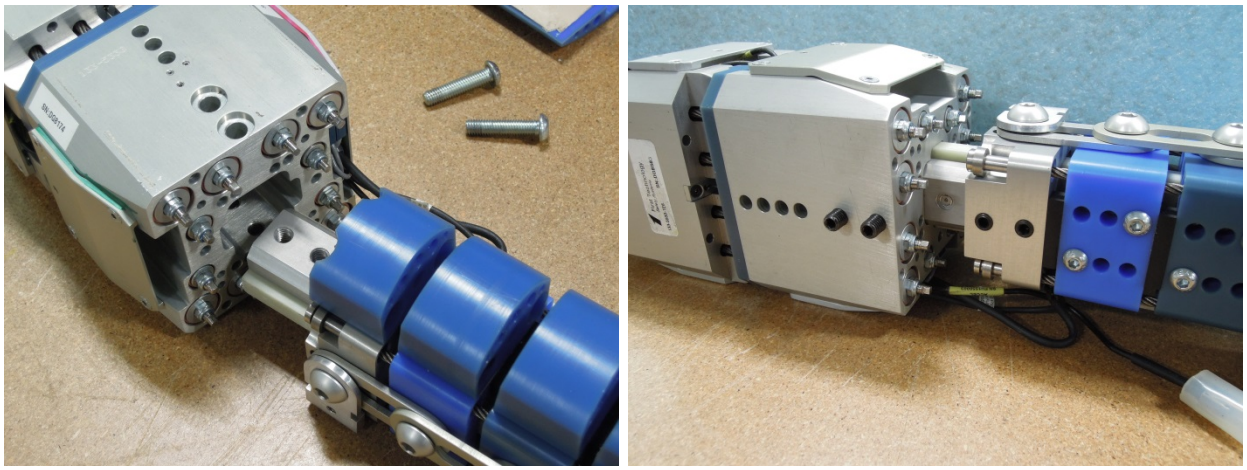

Figure 57. Insertion of the tibia assembly into the tibia knee block

Connect all the sensors to the DAS – as shown in Figure 58.

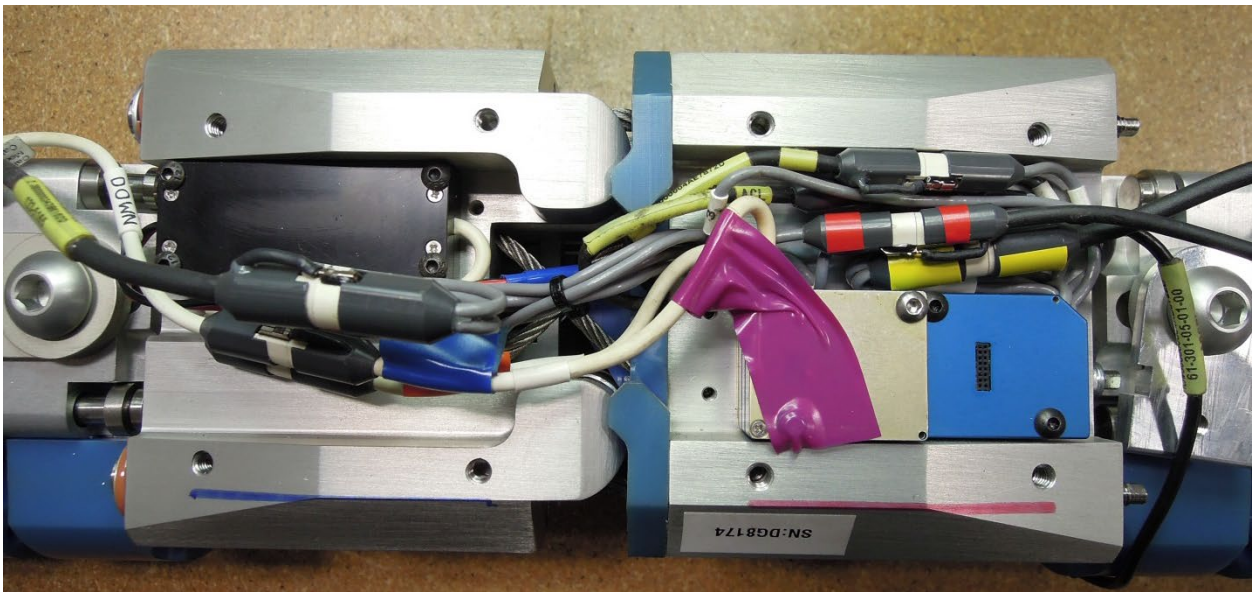

Figure 58. DAS and sensor connections within the knee

Install four aluminum side covers and tighten with M4 FHCS. Make sure that the instrumentation wires are not crushed and are free to move when the knee is flexed – as shown in Figure 59.

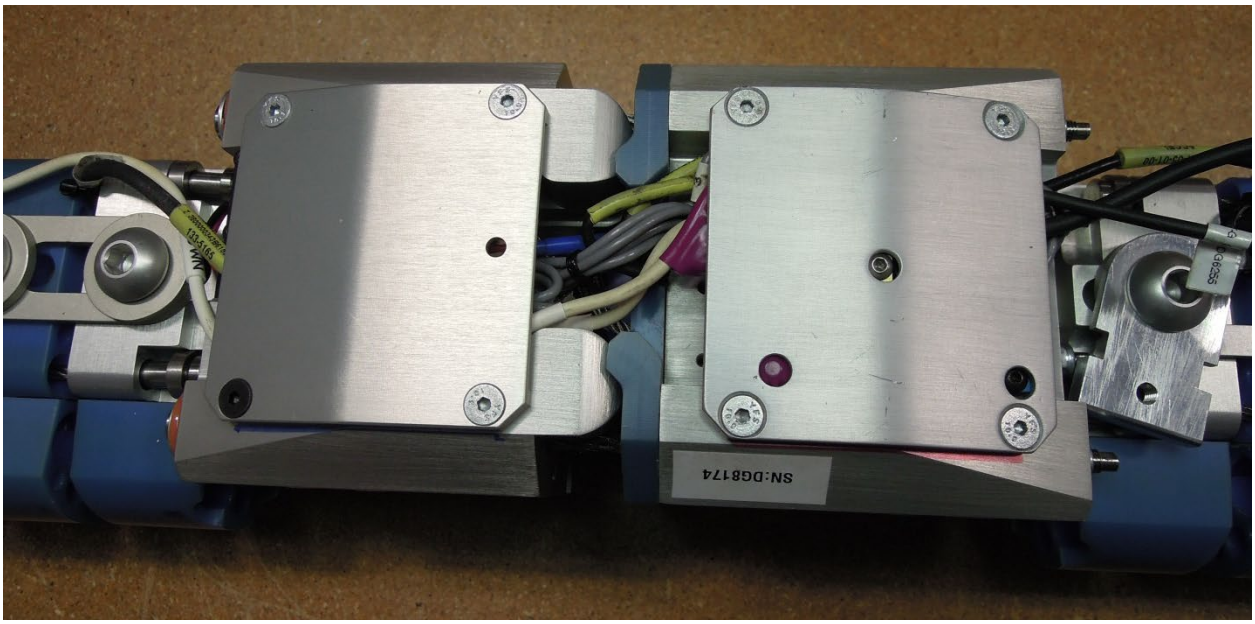

Figure 59. Aluminum side covers to protect instrumentation wires inside the knee

Install the accelerometer to the impact side of the tibia knee block, connect its wire to the DAS, and route the cable safely – as shown in Figure 60.

Figure 60. Knee accelerometer location on tibia knee block

Clean and degrease the impact side faces of the knee blocks. Place the upper (133-5304) and lower (133-5305) blue knee impact covers over the impact side of the knee blocks and install using double sided tape (133-5018) – as shown in Figure 61.

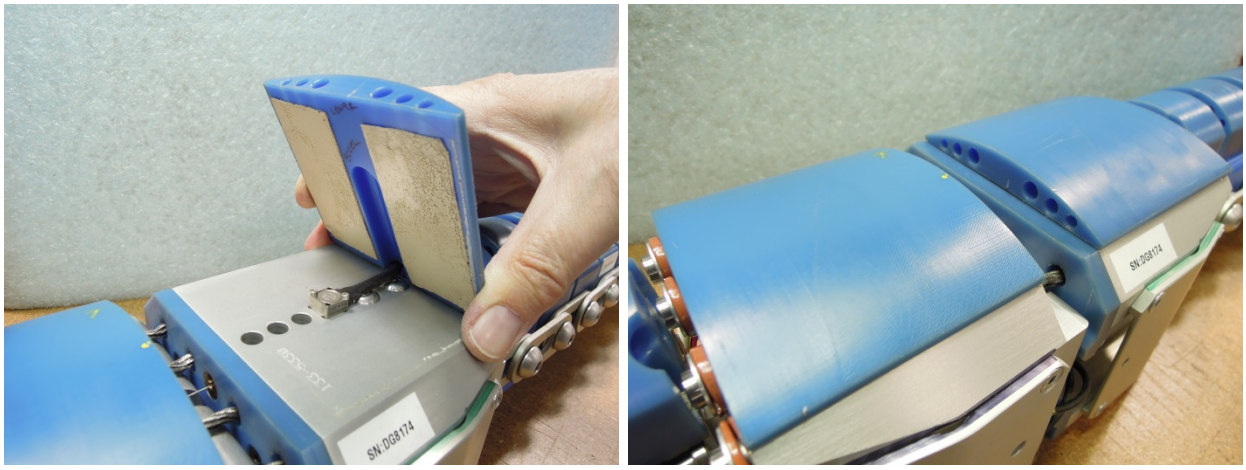

Figure 61. Installation of blue impact covers located on the knee

If an onboard DAS is used, the disconnect cable will either exit at the top of the leg or just below the knee depending on the brand of DAS. If exiting at the top, make sure that the wire is tied to the side links and has sufficient relief during femur bending – as shown in Figure 62.

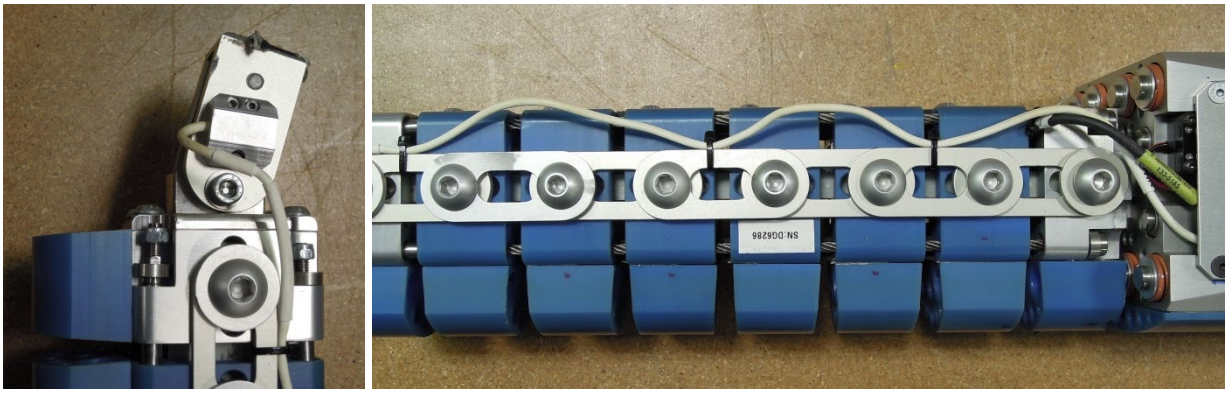

Figure 62. Routing of onboard DAS disconnect cable

5.4.1. Fitting the Flesh and Covers

Before testing, place the flesh and covers over the leg. When not in use, remove the flesh and covers from the leg to allow them to rest. The flesh system consists of one large outer neoprene cover 133-5017, two smaller neoprene covers 133-5013 and 133-5014 for the femur (labeled thigh), two smaller neoprene covers 133-5015 and 133-5016 for the tibia (labeled leg), and one rubber buffer sheet assembly 133-5020.

Place the large outer neoprene cover 133-5017 on a flat surface with lettering facing down. Lay 6 strips of Velcro tape 133-5019 on top of the neoprene cover, soft side down, and place the

rubber buffer sheet assembly 133-5020 on top. The larger portion of the rubber sheet is the top of the leg and is the opposite end of where the zipper on the outer neoprene cover starts. Adjust the Velcro strips to line up with the six marks on the rubber – as shown in Figure 63.

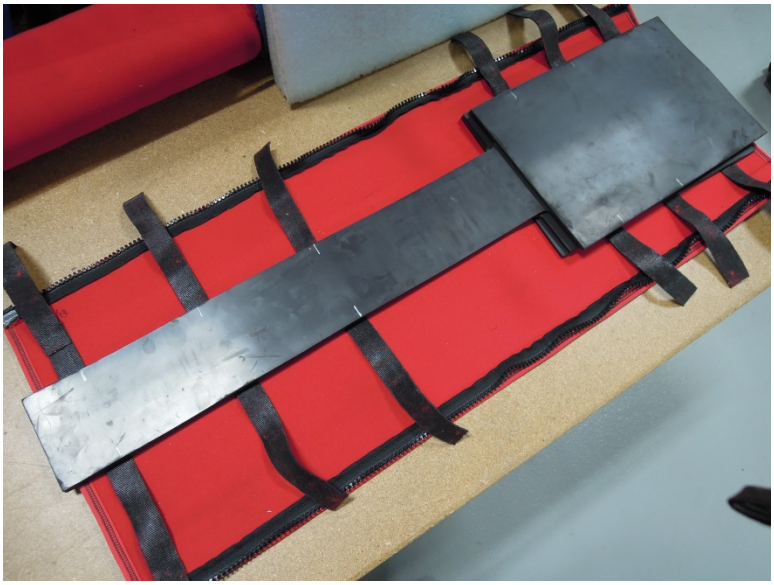

Figure 63. Outer neoprene cover, rubber buffer sheet assembly, and Velcro straps

Lay the 2 thigh covers 133-5013 and 133-5014 and the 2 leg covers 133-5015 and 133-5016 as shown in Figure 64 with the "knee end inside" arrows pointing towards each other and allowing a gap for the knee area. Offset the covers so that when zipping up, the zippers are oriented on opposite sides of the leg.

Figure 64. Positioning of thigh and leg neoprene covers

Place the leg assembly on top of the laid-out flesh covers. Position the legform and flesh covers such that the lower edge of the femur neoprene covers and the larger portion of the rubber system are aligned with the top of the femur knee block. Position the leg neoprene covers such that they are aligned with the lower end of the tibia knee block. The outer neoprene cover should be centered along the length of the leg assembly – as shown in Figure 65.

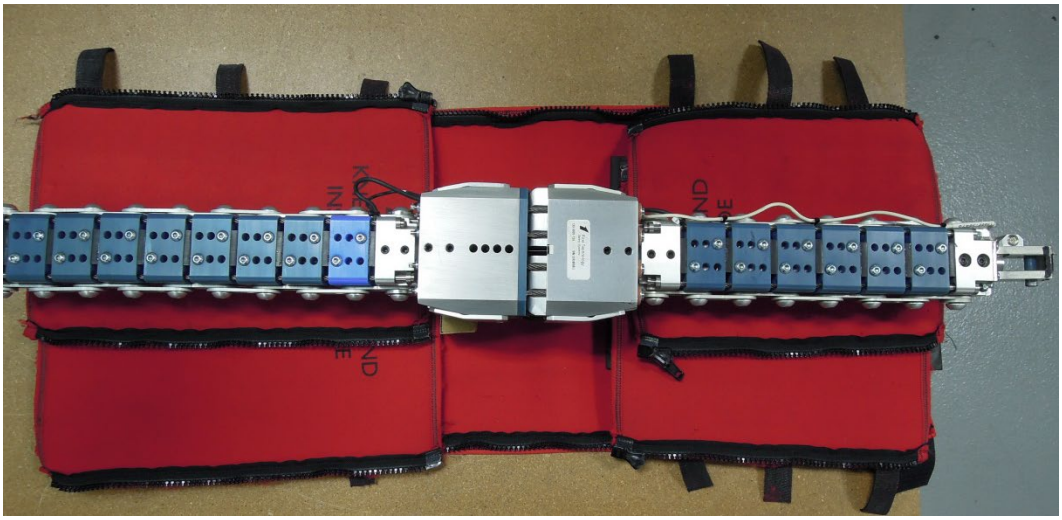

Figure 65. Orientation of leg assembly and flesh covers

Zip up the thigh and leg covers making sure that each zipper is positioned on the side of the leg near the area of the shoulder bolts. No zipper should be at the back or front of the leg as it can interfere with the flat surface of the launch plate or sustain damage upon impact – as shown in Figure 66.

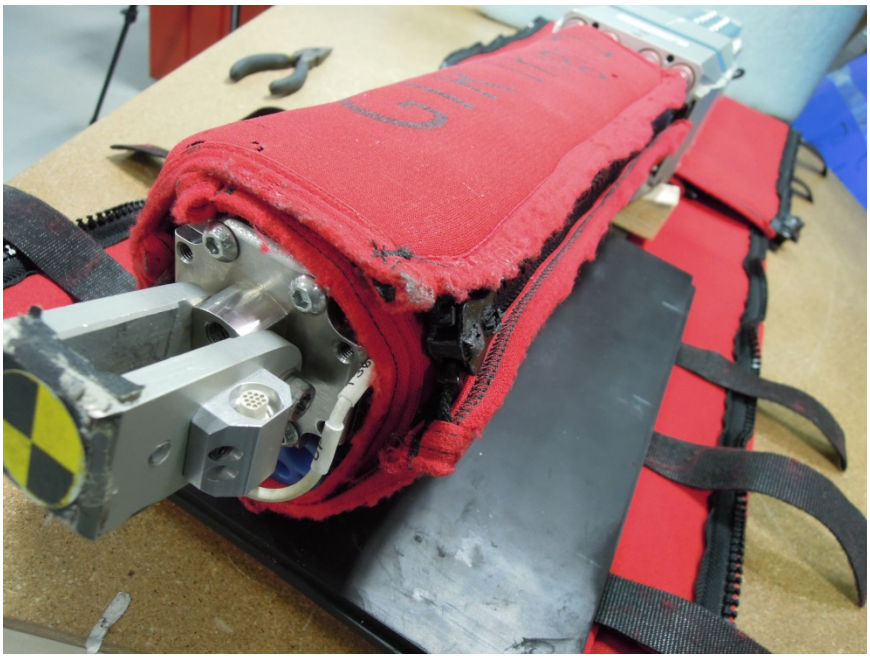

Figure 66. Zipping up the thigh and leg neoprene covers

Wrap the rubber buffer assembly around the leg using the six Velcro straps – as shown in Figure 67.

Figure 67. Securing the rubber assembly with the Velcro straps

Finally, zip up the outer neoprene cover from the bottom of the leg and make sure that the zipper is on the opposite side of the last thigh and leg zippers – as shown in Figure 68.

Figure 68. Zipping up the outer neoprene cover

6. External Dimensions

Dimensions and center of gravity locations for the femur, knee joint, and tibia are shown in Figure 69 (from ECE R127 Regulation ECE/TRANS/WP.29/2014/38).

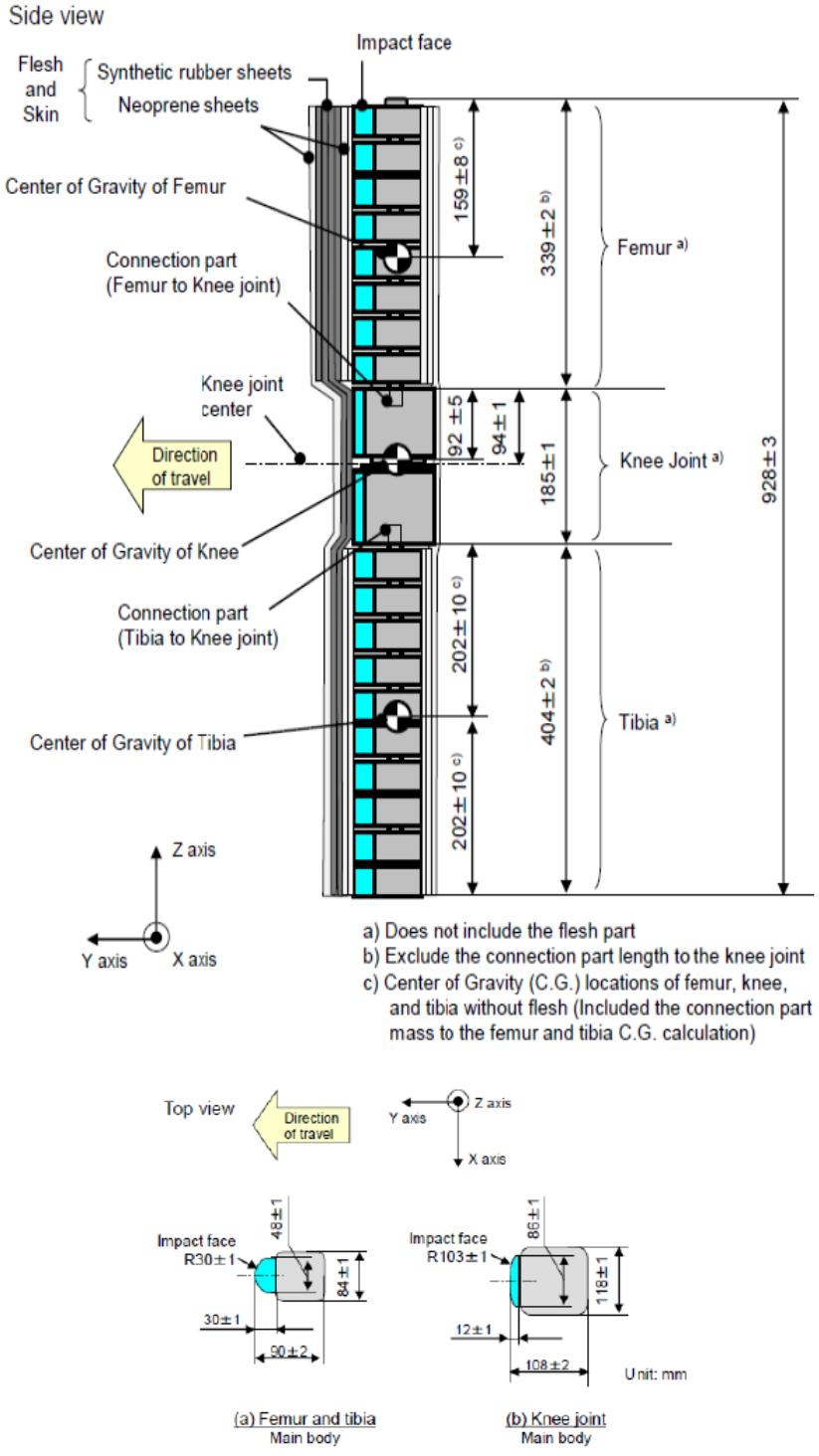

Figure 69. FlexPLI dimensions (ECE/TRANS/WP.29/2014/38)

7. Mass Specifications

FlexPLI assembly mass and tolerances are given in Table 8.

Table 8. FlexPLI mass specifications

Part	Mass (kg)
Femur	2.46 ± 0.12
Knee*	4.28 ± 0.21
Tibia	2.64 ± 0.13
Femur, Knee, & Tibia	9.38 ± 0.30
Flesh System**	3.82 ± 0.21
Total Leg Assembly	**13.2 ± 0.40**
*If off-board DAS used, 0.1 kg allocated for cables	
**Includes Velcro straps	