Oxford Foot Model 1.4 Release Notes

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Introduction

The Oxford Foot Model was developed and validated by the Nuffield Orthopaedic Centre in collaboration with Oxford University. The Vicon implementation of the Oxford Foot Model provides users with an easy-to-use plug-in which can be included in the processing pipelines of either Vicon Nexus 1.x or Vicon Workstation 5.x. The Oxford Foot Model Plug-in is designed to fit straight into the pipeline with the usual gait plug-ins such as the Woltring Filter, Gait Cycle event detection, and Plug-in Gait.

Important This document assumes that you are familiar with standard motion capture and data processing performed in either Vicon Nexus or Vicon Workstation. If you are not, please see the documentation supplied with your Vicon software for details on its features and functionality.

This document does not explain the scientific basis for the foot model, nor does it explain how to interpret the results. For details on published papers which support validation, please see ***Foot Model References*** below.

Before using the Oxford Foot Model Plug-in, you are advised to read the following ***Disclaimer***.

Requirements

The Oxford Foot Model is compatible with and fully supported under the Windows 7 64-bit operating system. Installation, software operation, and required third-party drivers are tested under the Windows 7 operating system. Although the Oxford Foot Model may install and function under other Microsoft Windows operating systems, this combination is not officially supported or recommended by Vicon.

In addition, you will require the appropriate Vicon software in order to run the Oxford Foot Model Plug-in; either Vicon Workstation or Vicon Nexus.

Disclaimer

Vicon Motion Systems takes no responsibility for the clinical accuracy or validity of the Oxford Foot Model. The Oxford Foot Model Plug-in described in this document is a direct implementation of the Oxford Foot Model as developed and validated by the Nuffield Orthopaedic Centre and Oxford University, and has not been independently verified by Vicon. Prior to using the model clinically, you are advised to consult the published papers listed below, and to conduct your own tests. Any clinical decision based on the Oxford Foot Model as implemented by Vicon is the sole responsibility of the end user.

Foot Model References

1. Stebbins,J., Harrington,M., Thompson,N., Zavatsky,A. & Theologis,T. Repeatability of a model for measuring multi-segment foot kinematics in children. *Gait & Posture* **23**, 401-410 (2006).

2. Carson,M.C., Harrington,M.E., Thompson,N., O'Connor,J.J. & Theologis,T.N. Kinematic analysis of a multi-segment foot model for research and clinical applications: a repeatability analysis. *Journal of Biomechanics* **34**, 1299-1307 (2001).

3. Theologis,T.N., Harrington,M.E., Thompson,N. & Benson,M.K. Dynamic foot movement in children treated for congenital talipes equinovarus. *J. Bone Joint Surg. Br.* **85**, 572-577 (2003).

Installing the Oxford Foot Model

The Oxford Foot Model Plug-in is available to install with Vicon Workstation and Vicon Nexus. You must have installed the appropriate Vicon software prior to installing the Oxford Foot Model Plug-in.

To download the Oxford Foot Model Plug-in:

1. In your web browser, navigate to the Vicon Support website: http://www.vicon.com/support/.
2. Log in using your VOS details and navigate to **Support** | **Downloads** | **Life Sciences** | **Example Data**, **Plug-ins, VSTs, and Models** | **Plug-ins**
3. Select the **OxfordFootModel 1.4 Installer** and download to an appropriate location.

After you have downloaded the Oxford Foot Model Plug-in installer file, install it as described below.

To install the Oxford Foot Model Plug-in:

1. Navigate to the folder where you downloaded the installer, and double click the *OxfordFootModel 1.4.56655 Installer.msi* file.
2. Follow the setup wizard to install the Oxford Foot Model:

Locating the Installed Files

The Oxford Foot Model installs the necessary files to the following locations (Windows 7):

- Vicon Skeleton templates (*.vst*) files, listed in ***Table 1*** on page 3:

  C:\Program Files (x86)\Vicon\Nexus\ModelTemplates

- The VOxfordFoot Vicon plug in (*.vpi*) file in the location:

  C:\Program Files (x86)\Vicon\Nexus\WorkstationPlugins

Processing with the Oxford Foot Model Plug-in

The Oxford Foot Model Plug-in is an extension to the standard Conventional Gait Model (Plug-in-Gait) marker set. For more information on Plug-in Gait, please refer to the *Product Guide Foundation notes* available from the **Downloads** section of Vicon Online Support. With the additional markers attached to either the left, right or both lower limbs, the model will calculate a range of extra output variables which can be used for later analysis. For a full description of the kinematic structure of the model, and for more explanations on the various kinematic output variables, see ***Foot Model References*** on page 1.

Important To use the Oxford Foot Model and the Conventional Gait Model simultaneously, your Vicon motion capture system must be capable of reliably capturing the additional markers on the feet. Ensure your system is capable of capturing small and closely positioned markers by conducting experiments *prior* to collecting clinical data.

Processing with the Oxford Foot Model Plug-in involves the following stages:

1. ***Attaching the Marker Set to the Subject*** (Plug-in Gait AND Oxford Foot Model)
2. ***Capturing and Processing a Static Trial***
3. ***Capturing and Processing a Dynamic Trial***

Attaching the Marker Set to the Subject

The first stage in using the Oxford Foot Model is to attach markers to the subject. The markers for the Oxford Foot Model are applied in addition to the standard lower body makers required for Plug-in-Gait. For a description of the Oxford Foot Model Marker placement and Oxford Foot Model and Lower Body Marker sets required, see ***Figure 1*** on page 4 and ***Table 2*** on page 5 respectively.

To subsequently label the markers within Vicon Nexus, the appropriate model needs to be attached to the subject within the application software.

Depending on the markers applied and subsequent workflow, attach one of the following models:

Table 1: Marker and Template Files

Vicon Workstation	Vicon Nexus
OxfordFootModel BILATERAL KAD.mkr	OxfordFootModel BILATERAL KAD.vst
OxfordFootModel_BILATERAL.mkr	OxfordFootModel_BILATERAL.vst
OxfordFootModel_LEFT.mkr	OxfordFootModel_LEFT.vst
OxfordFootModel_RIGHT.mkr	OxfordFootModel_RIGHT.vst

These files will contain all the markers required for the lower body Plug-in-Gait plus those required for the Oxford Foot Model.

Figure 1: Oxford Foot Model Marker Placement

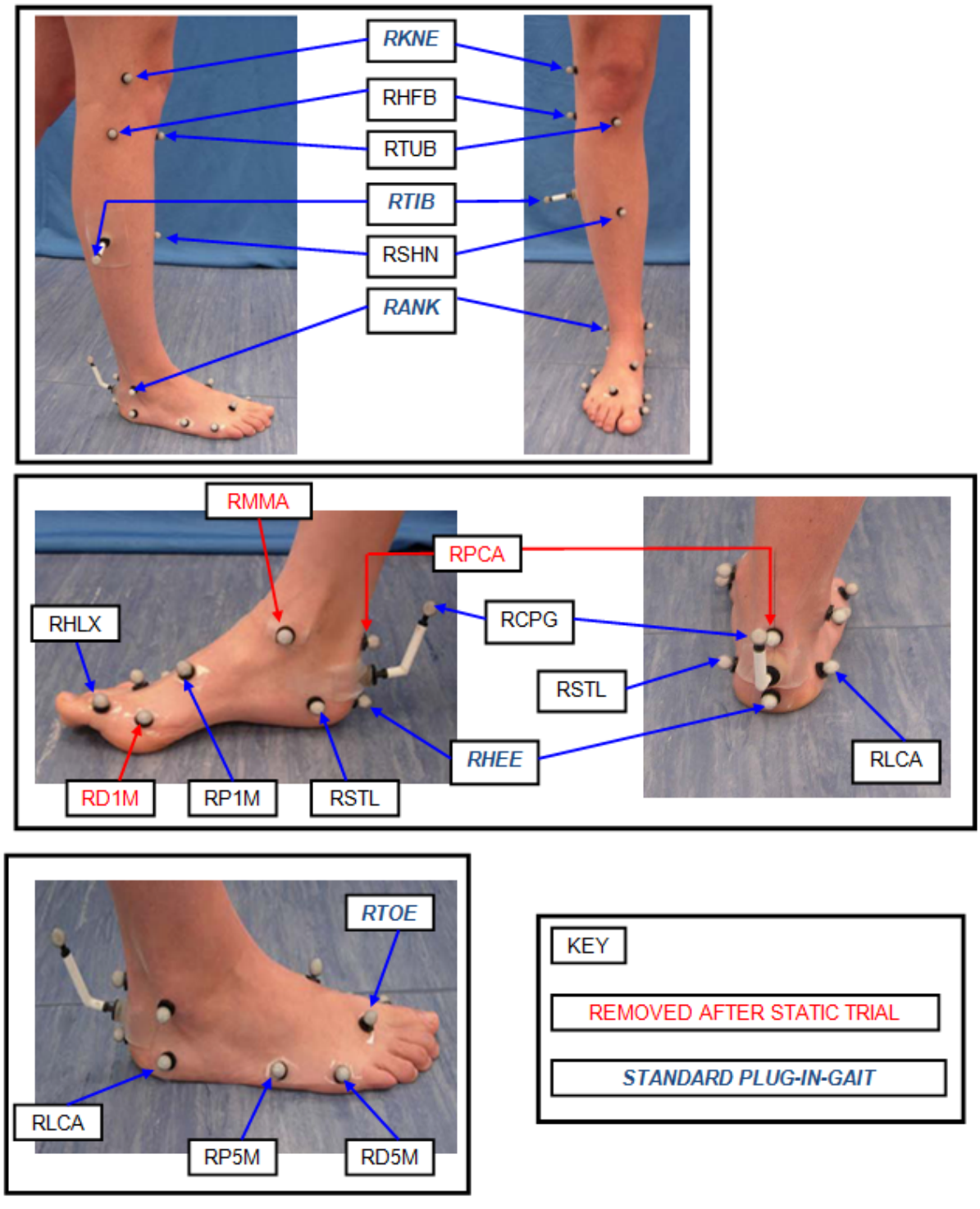


Table 2 below also details the markers required. Markers prefixed with **L** indicate Left side, and those prefixed with **R** indicate Right side. The table identifies the markers required for standard Plug-in-Gait and Oxford Foot Model, and identifies the markers required for **Static Trial only** when using the Oxford Foot Model.

Table 2: Lower Body and Oxford Foot Model Marker Description

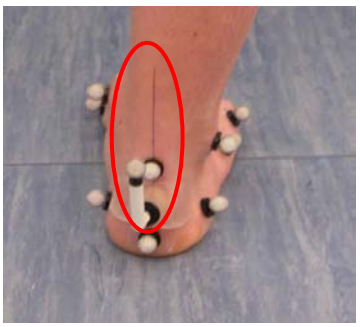
Marker	Description - Position	Notes
LASI RASI	Anterior Superior Iliac Spine	Conventional Plug-in-Gait model
LPSIS RPSIS	Posterior Superior Iliac Spine	Conventional Plug-in-Gait model
SACR	Sacral marker – midway between the posterior superior iliac spines	Conventional Plug-in-Gait model
LTHI RTHI	Thigh marker	Conventional Plug-in-Gait model
LKNE RKNE	Standard lateral knee	Conventional Plug-in-Gait model
LTIB RTIB	Tibial marker	Conventional Plug-in-Gait model
LHFB RHFB	Lateral head of fibula	
LTUB RTUB	Tibial tuberosity	
LSHN RSHN	Anterior aspect of the shin	
LANK RANK	Ankle	Conventional Plug-in-Gait model
LMMA RMMA	*Medial Malleoli*	*Static trial only – remove for dynamic*
LCPG RCPG	Peg marker – Posterior end of the calcaneus	
LHEE RHEE	Heel	Conventional Plug-in-Gait model See ***Additional Information*** on page 6.
LPCA RPCA	*Posterior calcaneus proximal*	*Static trial only – remove for dynamic*
RLCA RLCA	Lateral calcaneus	
LSTL RSTL	Sustaniculum Tali	
LP1M RP1M	1st metatarsal, proximal dorsal	
LD1M RD1M	1st metatarsal, distal medial	*Static trial only – remove for dynamic*
LP5M RP5M	5th metatarsal, proximal lateral	
LD5M RD5M	5th metatarsal, distal lateral	
LTOE RTOE	Toe	Conventional Plug-in-Gait model
LHLX RHLX	Hallux Proximal end of 1st Distal phalanx *or* Distal end of 1st medial phalanx	

Additional Information for the Placement of the Oxford Foot Model Markers

Hindfoot

Start by drawing a line with a soft pencil, for example eye liner, which bisects the calcaneus. Palpate the lateral borders of the calcaneus and mark the midpoint at different heights up the calcaneus. Connect the midpoints using, for example, a straight edged flexible rule. Extend the line proximally beyond the calcaneus (see ***Figure 2***).

Figure 2: Line Bisecting Calcaneus



- Place the **HEE** marker on this line, as far down the calcaneus as is feasible when considering dynamic trials. This marker also needs to be the same height from the plantar surface of the foot as the P5M marker (if using the hindfoot NOT flat option). *Consider the gait of the patient in the placement of this marker i.e. the chances of the marker being removed if contact is made with the heel.*
- Place the **CPG** marker on this line, above the HEE marker. The base of the marker should be on the line and the marker should reflect the varus/valgus alignment of the heel.
- Place the **PCA** marker on the same line, above the base of the CPG marker. This marker does not have to be on the calcaneus, and is **removed after static trials**.
- Place the **LCA** and **STL** markers on the lateral and medial aspects of the calcaneus respectively, ensuring these are equidistant from the HEE marker.
- Place the **MMA** marker on the medial malleoli. This marker is **removed after static trials**

Forefoot

- Place the **D1M** marker on the head of the 1st metatarsal, **D5M** marker on the head of the 5th metatarsal, ensuring they are the same distance from the plantar surface of the foot. Marker D1M is **removed after static trials**
- Place the **P5M** marker on the base of the 5th metatarsal, at the same height from the plantar surface of the foot as the markers on the metatarsal heads.
- Place the **P1M** marker on the base of the 1st metatarsal. Palpate the EHL tendon whilst the patient dorsiflexes the big toe, and place the marker medially of the EHL. The line connecting the mid-point of the markers on the base of the 1st and 5th metatarsals and the TOE marker represents the Ab/Adduction alignment of the forefoot.
- Place the **HLX** marker on the hallux, at the same height as the D1M marker, on the proximal end of the distal phalanx, *or* the distal end of the medial phalanx.

Tibia

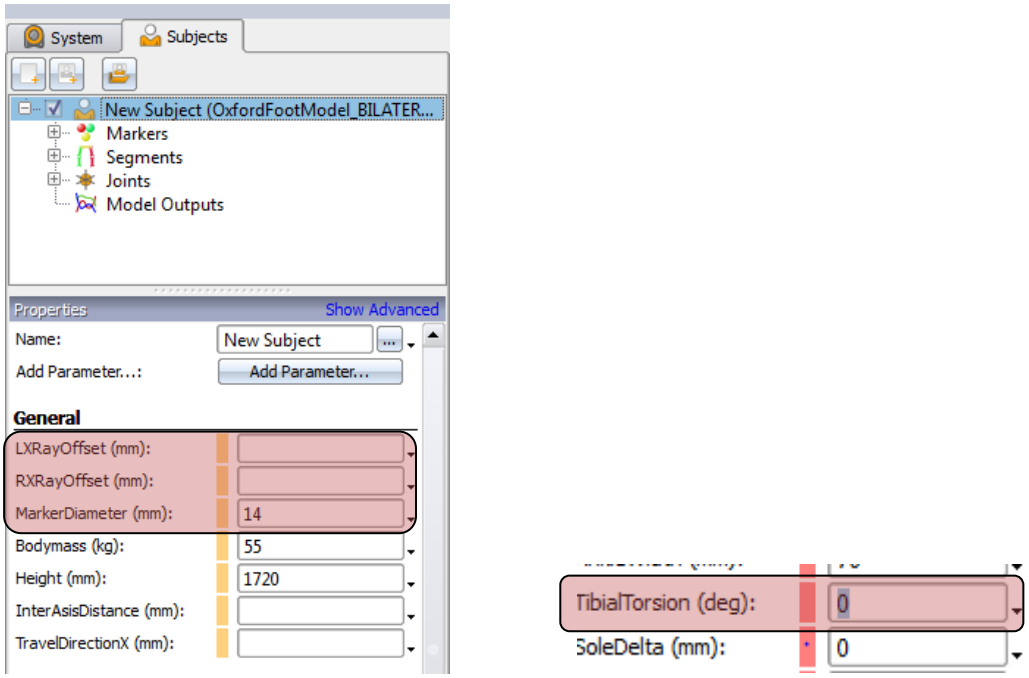
- Place the **TUB** marker on the tibial tuberosity, palpating the patient as they flex the knee if possible.
- Place the **HFB** marker on the head of the fibula, palpating the landmark from inferior to superior.
- Place the **SHN** marker on the anterior crest of the tibia.

Subject Measurements

In addition to the standard subject measurements required for Plug-in Gait, specify, if required, the additional subject measurements for the Oxford Foot Model, **XRayOffset** (see ***Figure 3***). This is an optional measurement, obtained from X-Rays if available, and is the absolute offset of the hindfoot, referred to as Calcaneal Pitch. If no radiographic information is available, enter 0 (zero) here. Please also ensure the correct Marker Diameter is entered in the relevant box (Figure 3).

In addition, a value for Tibial Torsion should either be entered or calculated (i.e. from medial malleoli markers and BodyBuilder script).

Figure 3: Additional Measurements for Oxford Foot Model

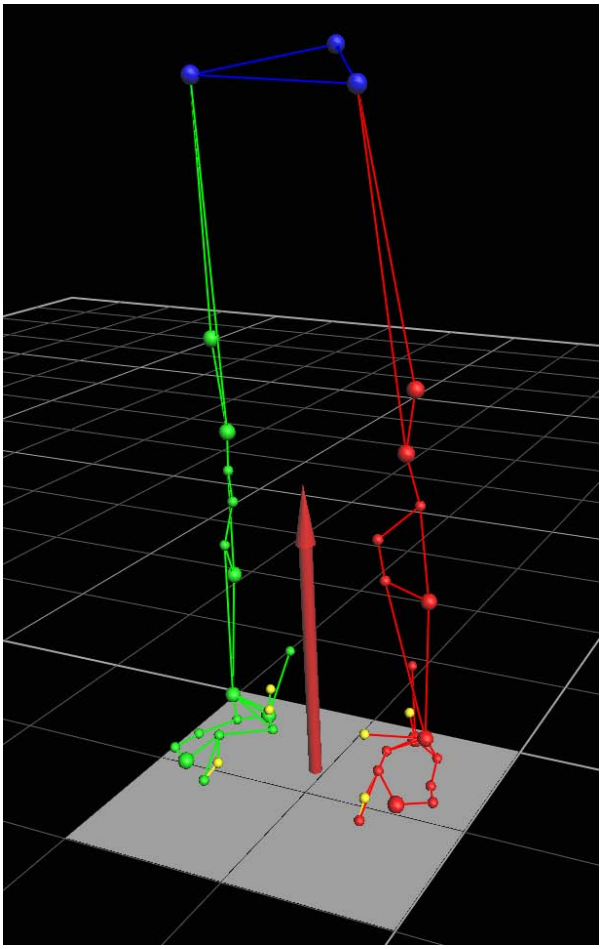


Capturing and Processing a Static Trial

The next stage is to capture a static trial with the subject in a stationary position. The markers then require labelling according to the marker file. The static trial enables the Vicon software to associate captured markers with known positions or labels. Once you have captured and fully labelled the static trial (see ***Figure 4***), follow the steps beginning on page 9 to process the static trial.

Important If markers are missing or labelled incorrectly, processing the static model will either fail or produce erroneous results.

Figure 4: Static Trial Labelled

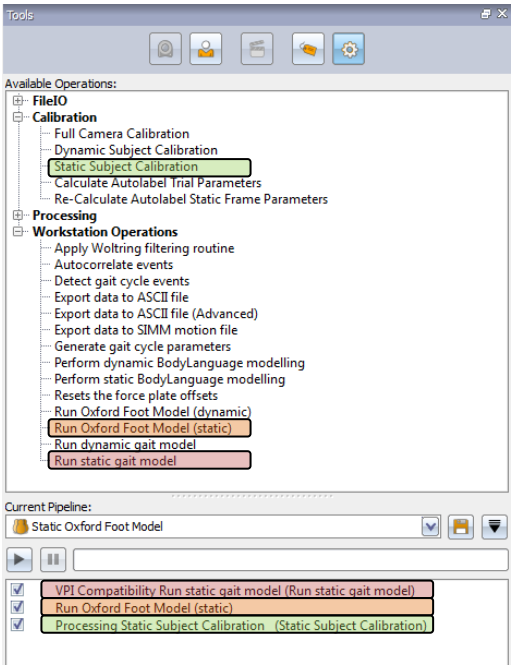


To process a static trial:

1. Create a pipeline with the following operations in the order as shown in ***Figure 5***:

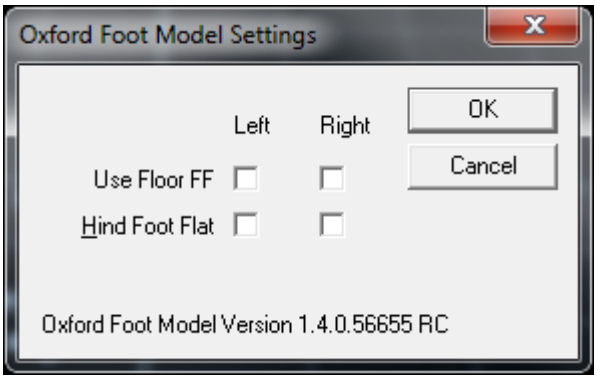
   - **VPI Compatibility Run static gait model (Run Static Gait Model)** – Under Workstation Operations
   - **Run Oxford Foot Model (static)** - Under Workstation Operations
   - **Processing Static Subject Calibration (Static Subject Calibration)** - under Calibration

   Figure 5: Pipeline Operations Required for Static Oxford Foot Model



2. When running the static model, click the **Options** of the **Run Oxford Foot Model (Static)** operation to display the **Oxford Foot Model Settings** dialog box, shown in ***Figure 6***:

   Figure 6: Oxford Foot Model Settings Dialog Box



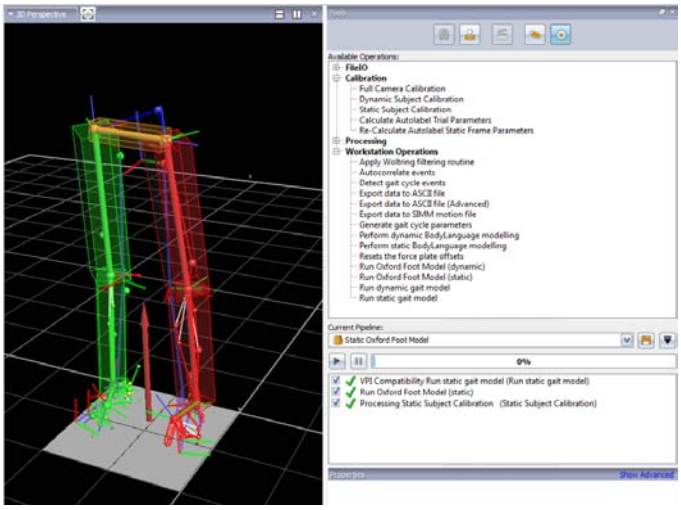
3. Specify the following settings in the **Oxford Foot Model Settings** dialog box to match the ability of the patient for the static trial:

   - **Use Floor FF**: Selecting this option forces the z component of the 3 markers that define the forefoot plane (D1M, P5M and D5M) to be the same, thus parallel to the floor. Leave this option clear to determine this plane based on marker positions, in for example foot deformity such as varus.

- **Hind Foot Flat**: Leave this option blank if the hindfoot is not flat on the floor (i.e. if the patient is standing in equinus). The z components of the HEE and P5M markers are then used to define the anterior/posterior axis. In addition, a VIRTUAL HEE marker is created, mid-way between the original HEE and PCA markers. This is purely for Plug-in-Gait, as the HEE marker is too low for Conventional Plug-in-Gait otherwise. Therefore Plug-in-Gait static model needs to be run AGAIN after the foot model static, to incorporate the new HEE marker position.

4. Process the static trial by running a pipeline containing the operations described previously.

Figure 7: Static Trial after Running Static Plug-in Gait and Static Oxford Foot Model



5. Save the trial.

You are now ready to capture and process dynamic trials using the Oxford Foot Model.

Capturing and Processing a Dynamic Trial

To successfully capture and process dynamic trials, you must have first successfully processed and saved the static trial.

To capture and process a dynamic trial:

1. After collecting the required static trials, remove the following markers, on both (L) and (R) sides, prior to dynamic trials:

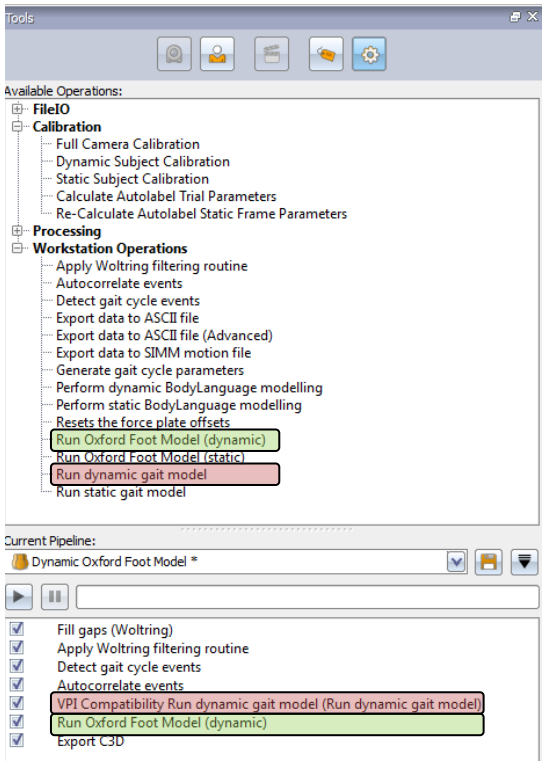
   - MMA
   - PCA
   - D1M

   Important You must leave the LHEE/RHEE markers attached for the dynamic trials, even if you would normally remove these when running the Conventional Gait Model.

2. Create a pipeline containing the following, in the order shown below and in ***Figure 8***:

   - Run Dynamic Gait Model
   - Run Oxford Foot Model (Dynamic)

   Figure 8: Pipeline Operations Required for Dynamic Oxford Foot Model



3. Capture the required number of trials for your purposes.

4. Process the required dynamic trial(s) ensuring that the operation **Run Dynamic Gait Model** and **Run Oxford Foot Model (Dynamic)** operations are selected within the pipeline, and then running the pipeline.

   The Oxford Foot Model outputs kinematic data for the trial(s), as described in ***Data Outputs*** on page 13.

Default Pipelines Loaded with the Installer

The installer loads pipelines with Oxford Foot Model operations to the following locations by default. If you wish to use these pipelines, you must move them to another location before amending them.

To view the pipelines in the Pipeline window:

1. **Copy** the pipeline files from:

   C:\Program Files (x86)\Vicon\Nexus\Configurations\Pipelines

2. **Paste** them into the following location:

   C:\ProgramData\Vicon\Nexus\Configurations\Pipelines

Changes to Static Pipeline

Amend this pipeline to reflect the sequence of operations as per ***Figure 5*** on page 9:

- **VPI Compatibility Run static gait model (Run Static Gait Model)** – Under Workstation Operations
- **Run Oxford Foot Model (static)** - Under Workstation Operations
- **Processing Static Subject Calibration (Static Subject Calibration)** - under Calibration

Changes to Dynamic Pipeline

Amend the Dynamic Oxford Foot Model pipeline to reflect the sequence of operations as per ***Figure 8*** on page 11:

- **Run Dynamic Gait Model**
- **Run Oxford Foot Model (Dynamic)**

In addition, remove the **Core Processing** operation from the Dynamic Oxford Foot Model pipeline, as this will reconstruct the data and thus any previous labelling will not be retained.

Data Outputs

Once you have processed dynamic trials using the Oxford Foot Model Plug-in, a number of additional variables are added to the **Angles** and **Scalars** section of the *.c3d* file.

Output Angles

As the Oxford Foot Model calculates the same segments as Plug-in Gait for the lower body, some of the output angles are the same. These outputs are provided for quality assurance.

Table 3 describes the variables that are added to the **Angles** section in the *.c3d* file as output from a dynamic trial using the Oxford Foot Model Plug-in, with reference also to Plug-in Gait outputs.

Table 3: Output Angles for Oxford Foot Model

Output Angle	Description	Notes
PELAng	Pelvis angles	Same as Plug-in Gait Output for reference
LANA/RANA	Ankle angles	Same as Plug-in Gait
LFETBA/RFETBA	Femur/tibia angles	Equivalent to knee angles
LFFHFA/RFFHFA	Forefoot with respect to hindfoot angles	
LFFTBA/RFFTBA	Forefoot with respect to tibia angles	
LFTA/RFTA	Foot progression angles	Same as Plug-in Gait
LHFTBA/RHFTBA	Hindfoot with respect to tibia angles	
LHFTFL/RHFTFL	Hindfoot with respect to lab	
LHPA/RHPA	Hip angles	Same as Plug-in Gait
LHXFFA/RHXFFA	Hallux with respect to forefoot, dorsiflexion only	
LKNA/RKNA	Knee angles	Same as Plug-in Gait
LTIBA/RTIBA	Tibia with respect to lab angles	

Scalars

In addition to the outputs seen in ***Table 3***, the variable Scalars is added to the .c3d file for dynamic trials modelled with the Oxford Foot Model. The **LArchHeightIndex/ RArchHeightIndex** variable is a measure of the rigidity of the forefoot segment, used as a quality measure to check the accuracy of the model's assumption of forefoot rigidity. This is also an estimate of Arch height, that is, the Normal distance of the plane of the forefoot from the P1M marker.

Troubleshooting

Some issues may be encountered and a few suggestions below may assist in troubleshooting. *Table 4* is indicative of some problems only, and is not exhaustive.

Table 4: Troubleshooting

Error	Possible solution
Labelling error	Check all markers are labelled correctly
Kinematic fit looks incorrect	Check all anthropometrics are entered in mm
No foot model outputs	Check the pipeline to include the operation **Run Oxford Foot Model (dynamic)**
Dynamic model does not run	Check static markers are removed for dynamic trials Check static trial has been processed and saved Check you are licensed to run the model
Batch processing (autolabelling) dynamic data does not run	Check calibrate labelling model has been performed on the static trial, and the trial has been saved.

Support and Further Resources

The following topics provide information on contacting Vicon, reporting errors and additional resources.

Vicon Online Support

If you are a licensed Vicon user and have a valid Vicon System Maintenance Agreement, you can access the Vicon Support knowledge base at *www.vicon.com/support*.

Tip To access Vicon Support on the web, you must have a Vicon Online Support User ID and password. If you do not have this information or need assistance with logging in to Vicon Online Support, contact Vicon Support at *support@vicon.com*, OR click the **Register** link on the Vicon Online Support page and complete the application to have a username and password emailed to you.

This section describes the support resources available from the Vicon Online Support knowledge base:

- **Downloads.** Obtain latest firmware and other software patches, models and scripts, and product documentation.
- **FAQs. Loca**te topics providing answers to frequently asked questions about Vicon hardware, software, plug-ins**,** and licensing as well as third-party software.
- **Cases.** Submit your own question or report a problem if you cannot locate the information you need in the FAQs, then track responses to your questions and updates to your problems.

To log in to Vicon Online Support:

1. From a web browser, enter the URL for Vicon Online Support: *www.vicon.com/support*. The Vicon Support + Services page is displayed.
2. In the **Log in** area, enter your Vicon Online Support **Username** and **Password**, agree to the Terms and Conditions by checking the **Agree to terms and conditions** box, and then click **Enter**. The Online Support page is displayed with your account information below the available Vicon Online Support sections on the left side of the page.
3. When you are ready to exit Vicon Online Support, click the **Logout** link.

Vicon Error Reporting

The Vicon Error Reporting system provides a quick and convenient way for you to contact Vicon in the event that your Vicon application software stops responding. It enables Vicon to investigate particular problems and to take your feedback into consideration for future product updates. For details, see the *Vicon Error Reporting Utility Product Guide*, which is available on the Vicon Online Support site. Once logged in to Vicon Online Support, follow these links: **Downloads > Life Sciences > Vicon Nexus > Documentation, Videos and Tutorials**. Click on the document link to view it.

Additional Resources

Vicon 3D motion capture and analysis systems have been applied to technologies in the fields of human movement sciences, clinical analysis, computer animation, and engineering around the world.
You can use these resources to keep up to date with Vicon developments:

- **Vicon Newsletters.** Register to receive Vicon newsletters via email for your field of interest:
- **Online:** Complete the form on the Contact page of our web site: *www.vicon.com/contact/*
- **Email:** Send a request to: *moveme@vicon.com*
- **The Standard.** You can view the latest issue of *The Standard* online or subscribe to receive a printed copy from the web site: *www.viconstandard.org/*. This publication contains articles on motion analysis in science and engineering research and application projects. Articles are contributed by practising experts and leading authorities in laboratories throughout the world.