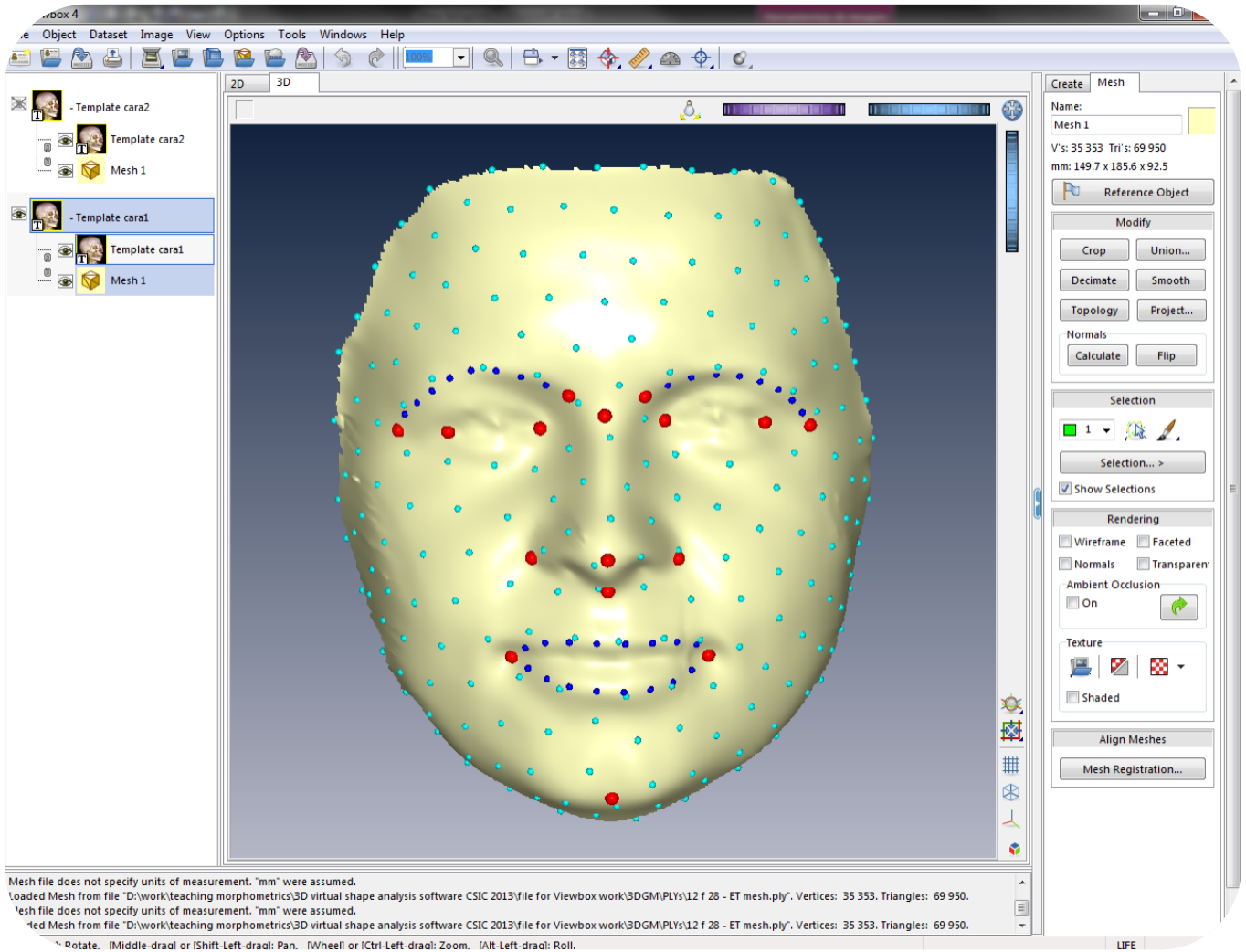
How to create a template for digitisation in Viewbox



Bastir et al., 2019 Journal of Anthropological Sciences

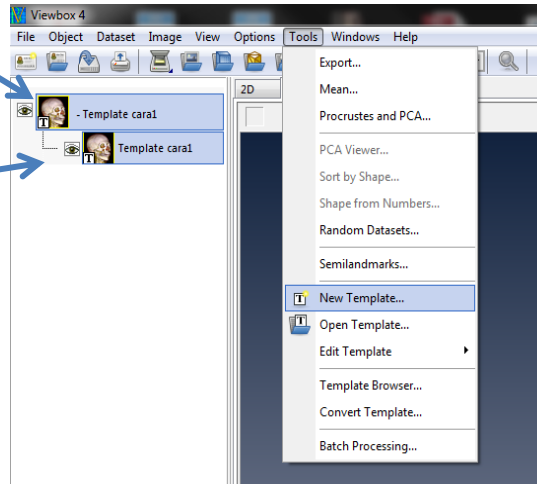
How to create a template file (.vbr format):

1) Tools → New Template
2) Give a name to the template file “cara2”.vbr
    - .vbr is the format of a template in Viewbox.
    - The template needs to be saved in the directory created during the installation.
    - Right-click on “Object” to describe “Object Properties”
    - Give it the same name as the .vbr file “Template cara2”

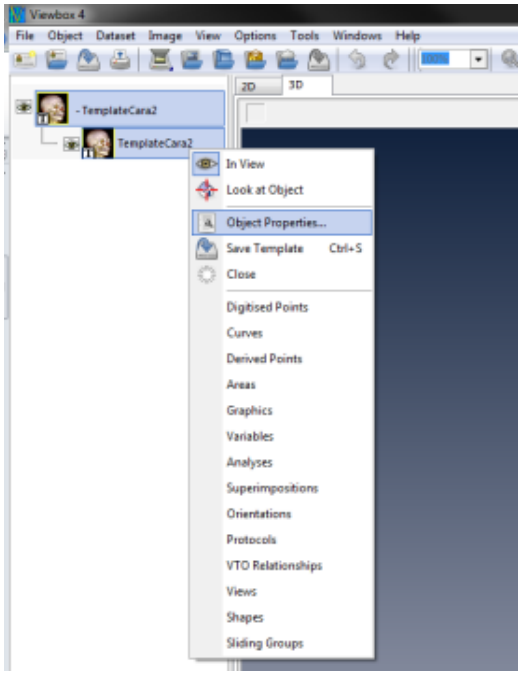
*To save: Right-click on “Patient” → “Save Template” or simply CTRL + S.

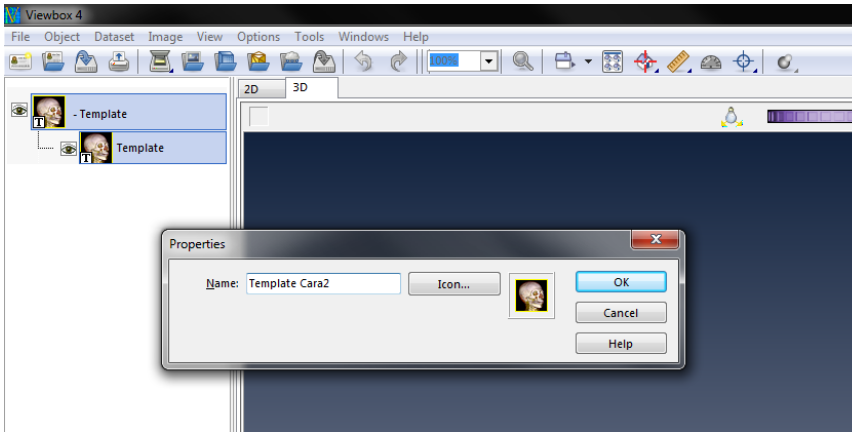
Patient/dataset

Object



2

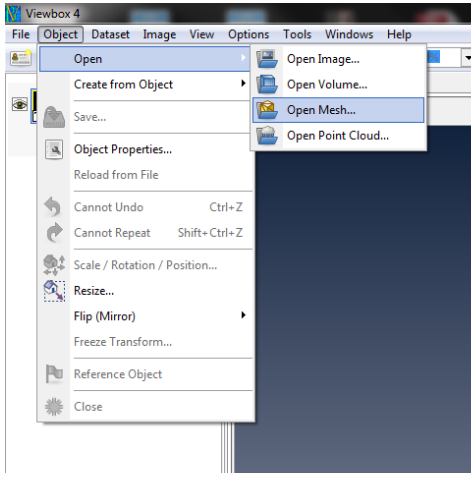




Bastir et al., 2019; Journal of Anthropological Sciences

How to import a 3D virtual model (.ply, .stl, .obj format):

3



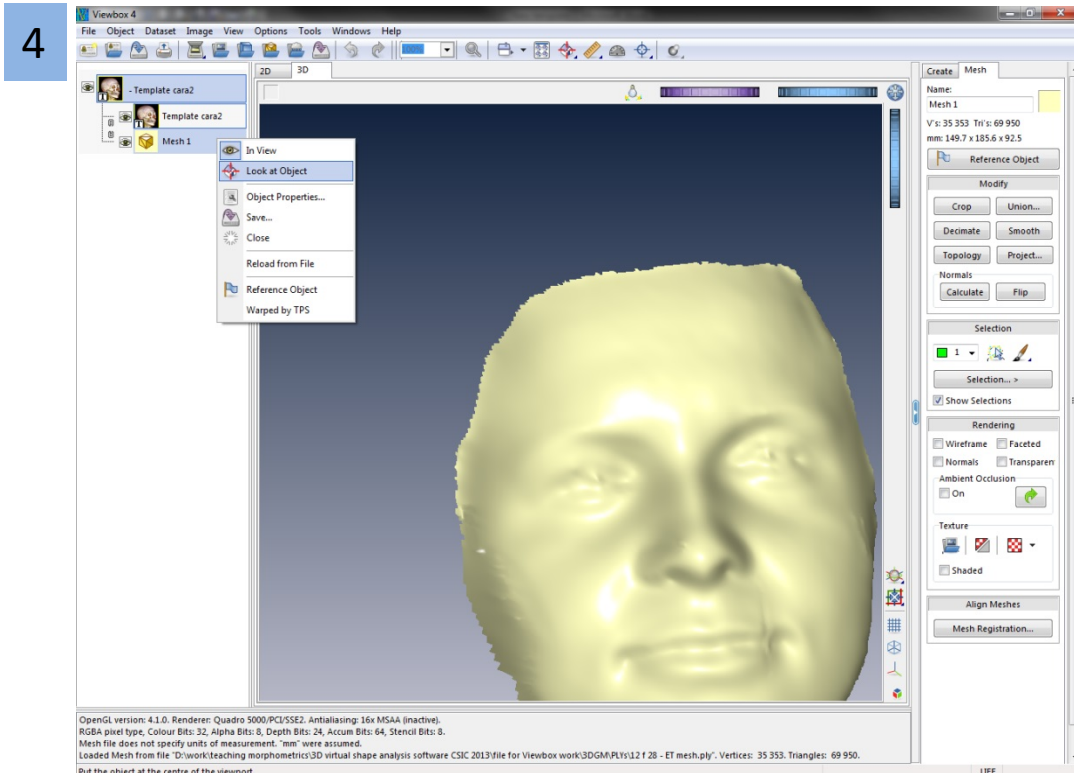
3) Object → Open → Open mesh, and choose the mesh that is going to be digitized.

4) Right-click on the mesh object and select "Look at object" to visualize the virtual model:

- Zoom: CTRL + Left-click
- Translate: "Shift" + Left-click
- Rotate: Left-click

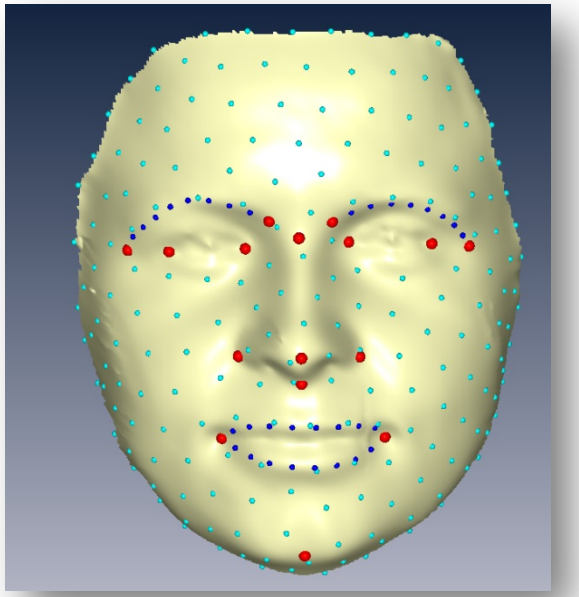
***To save**: Right-click on "Patient" → "Save Template" or CTRL + S.

4



Number and anatomical position of landmarks and semilandmarks (previously defined as an outline)

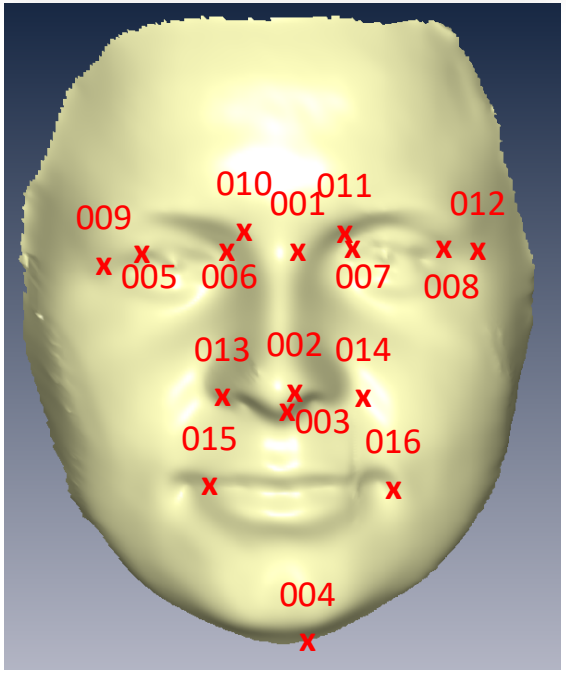
- Landmarks (N=16)
- Surface semilandmarks (N=200)
- Curve semilandmarks (N=8 per curve)



5) Create a table with the numbers and the names of the landmarks.

5

Landmark number	Landmark name
001	uppernose
002	nosetip
003	lowernose
004	chintip
005	leftlateye
006	leftmedeye
007	rightmedeye
008	rightlateye
009	leftlatbrow
010	leftmedbrow
011	rightmedbrow
012	rightlatbrow
013	leftnose
014	rightnose
015	leftmouth
016	rightmouth



Bastir et al., 2019; Journal of Anthropological Sciences

How to create, digitize and visualize the landmarks:

7) Right-click on “Template object” → Select “Digitised points”

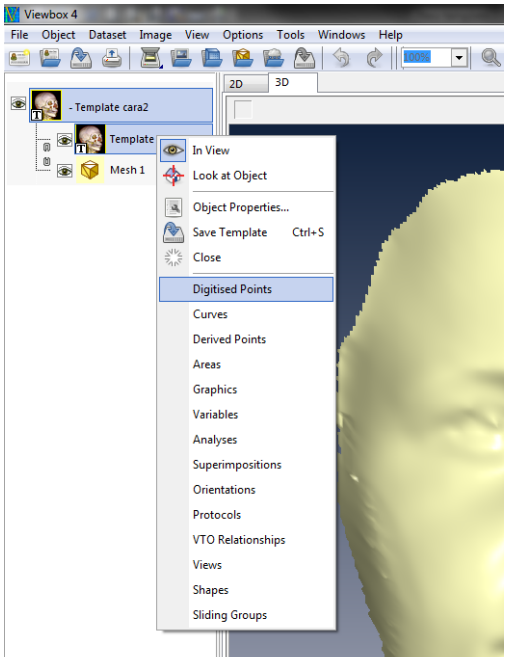
8) The pop-up window shows a menu for creating new points. Select “New…” and type the name of the first landmark and its corresponding number (for example “001uppernose”) and then click OK. Once the landmark has been created and named, it needs to be digitized on its corresponding anatomical location:

- Left-click on the “Digitiser” tool to activate the function of digitisation.
- Right-click on the mesh to digitise the point at its corresponding location.

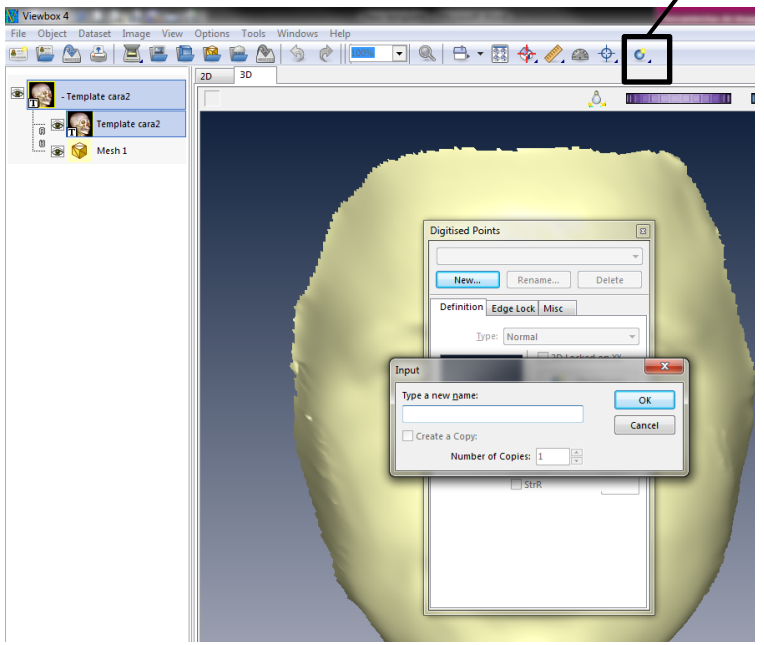
Repeat the steps 8-9 for each landmark.

9) After digitising all landmarks, close the window and press CTRL + S to save the template.

7



8



Define graphic options (size, shape and color) of the landmarks:

The “Graphics” menu allows the definition of the graphic attributes of the landmarks (i.e size (mm), shape and colour of the points). We need to create three groups or categories, each defined by the following attributes:

a) Landmarks: colour=**red**, size=1 mm, shape= ○

b) Surface semilandmarks: colour=**blue**, size=1 mm, shape= ○

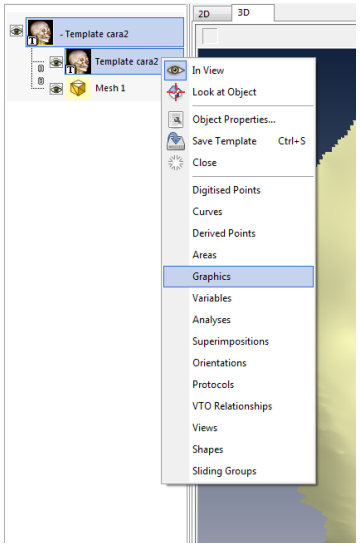
c) Curve semilandmarks: colour=**green** , size=1 mm, shape= ○

10) Right-click on “Template object” → “Graphics”

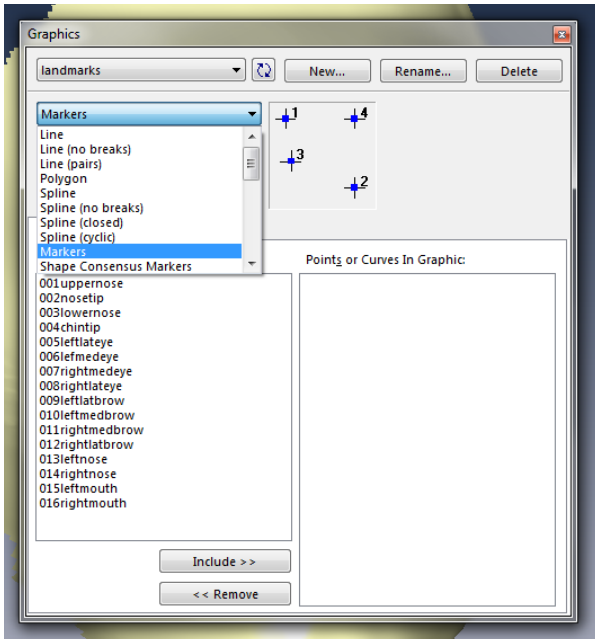
11) “New” and write the name of each group/category (**a**, **b** and **c**).

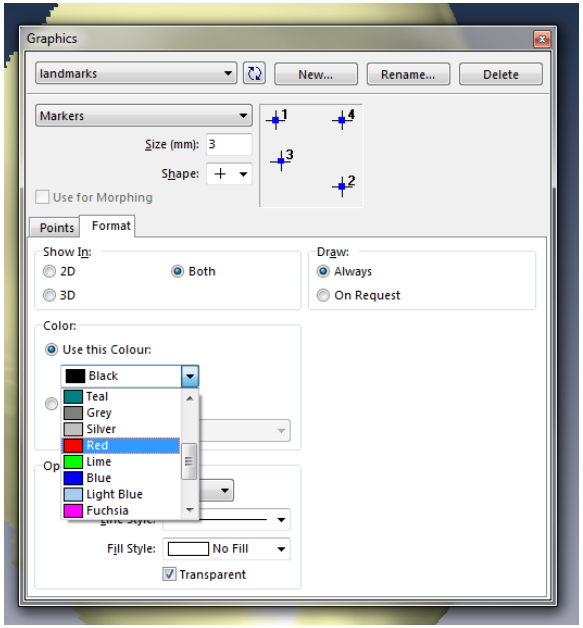
12) Define the attributes of each group.

10



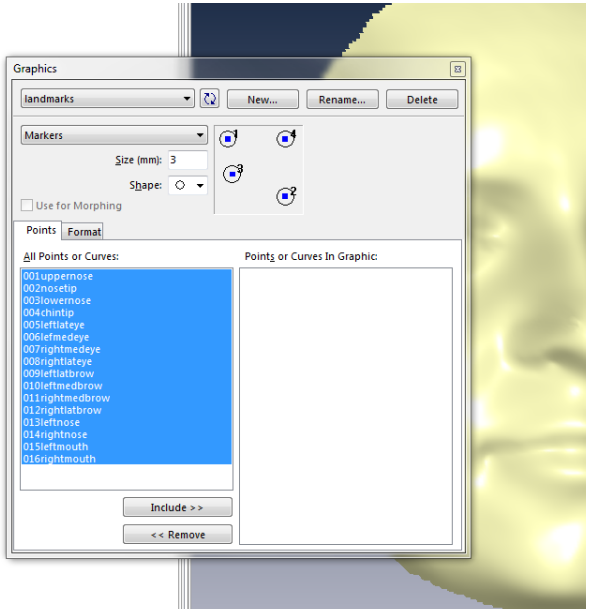
11 and 12

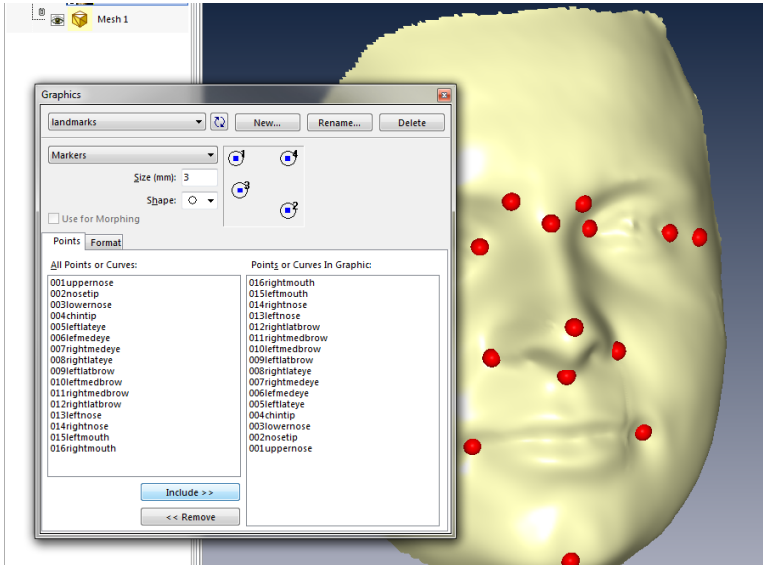




13) To visualize the points with the defined attributes, select all the points of each group and select “Include”. This will visualize the points created so far (landmarks in red color). Note: We do not see any landmark unless a corresponding graphic group is created.

13





How to generate surface semilandmarks

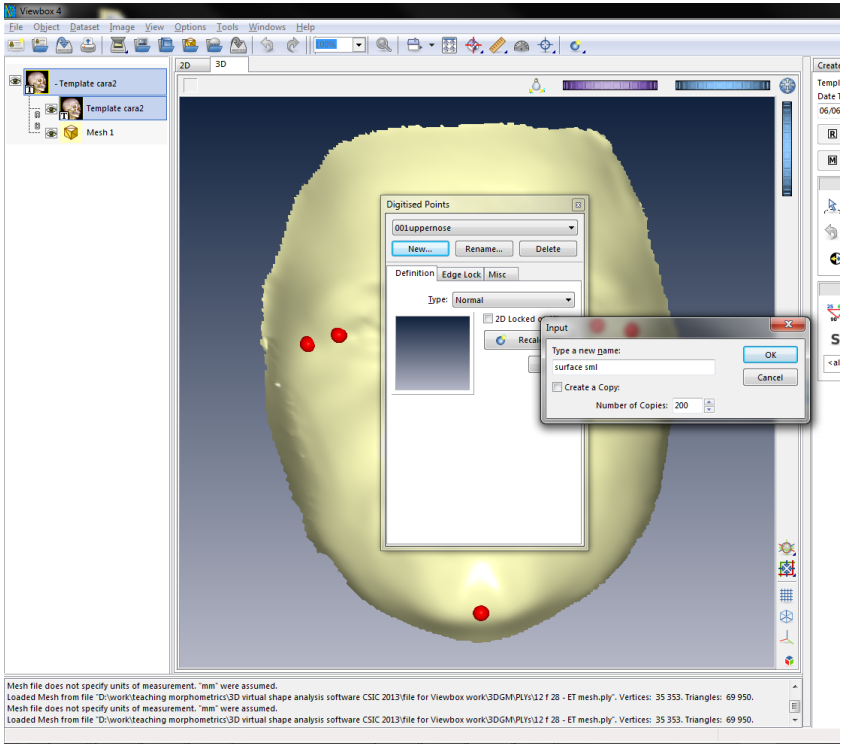
To distribute the points uniformly on a specific area of the mesh, we need to create 200 copies of an existing landmark. Then, these 200 copies will be distributed on the mesh.

14) Repeat step 8 in order to create a new landmark, but now typing the name “Surface sml” (surface semilandmark) without any associated number. Check the box “Create a Copy” and type 200 in “Number of Copies”. Then, click OK

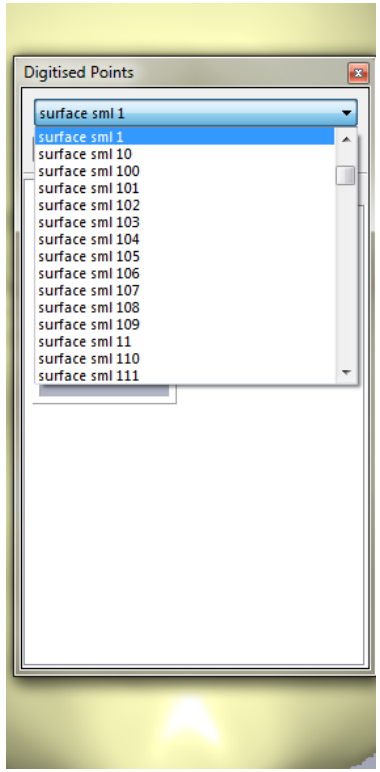
15) If we now display the list “Digitised points”, we can see 16 landmarks + 200 surface semilandmarks.

16) Right-click on the template object → Graphics → and include these 200 surface semilandmarks in the Surface sml menu.

14



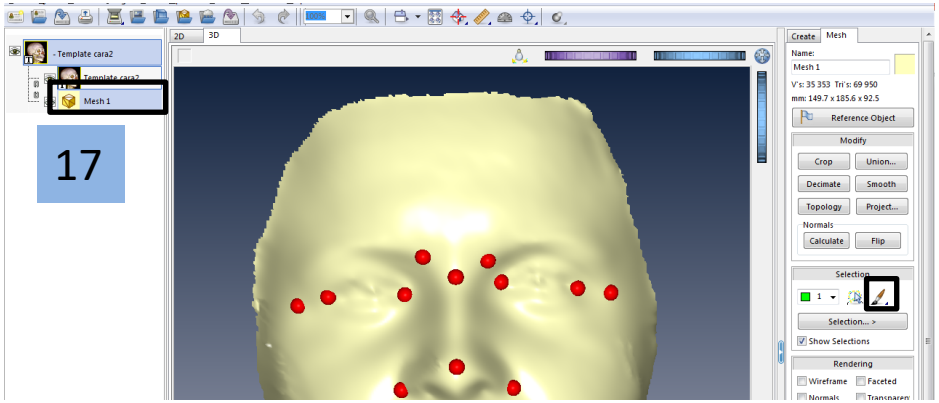
15

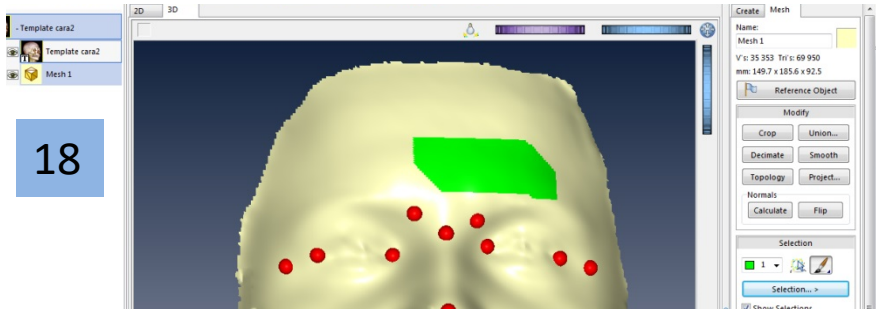


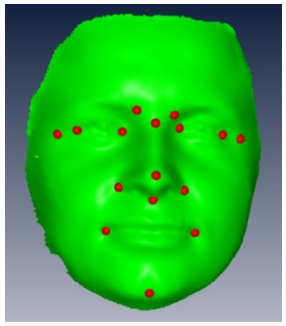
How to distribute surface semilandmarks uniformly on a mesh

17) Select the mesh. In the graphic menu on the right, right-click on the brush to choose an optimal size for painting (recommended size: 100-1000). Left-click to activate the brush option.

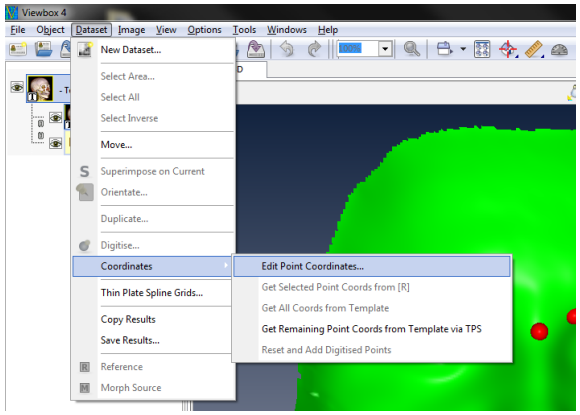
18) Right-click on the mesh to select (paint) the zones on which the surface semilandmarks will be uniformly distributed. It is recommended to select the whole face and then to delete the regions where no surface semilandmarks are needed (Right-click + shift to deselect selection).

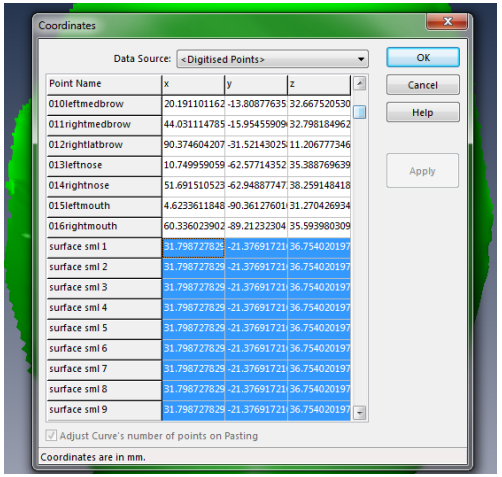




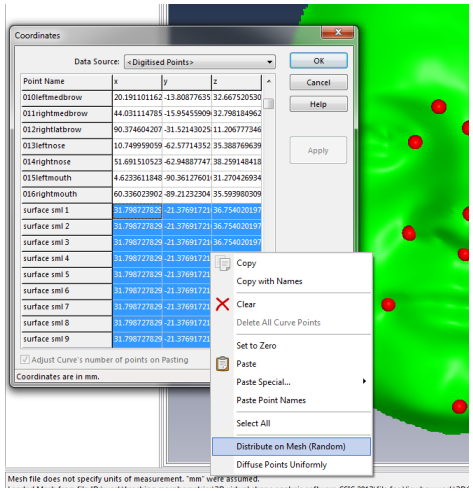


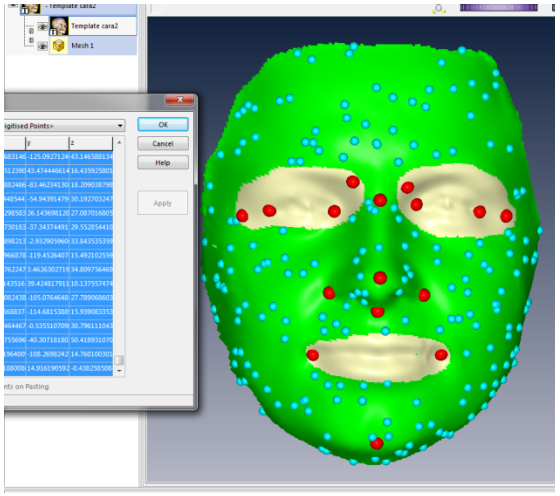
19) “Dataset” (activated Mesh) → “Coordinates” → “Edit Point Coordinates…”. The software shows a pop-up window with 16 landmarks and 200 surface semilandmarks (the latter with identical values of the 3D coordinates because they are copies of the same landmark as described in **step 14**). We need to select the 200 surface semilandmarks.



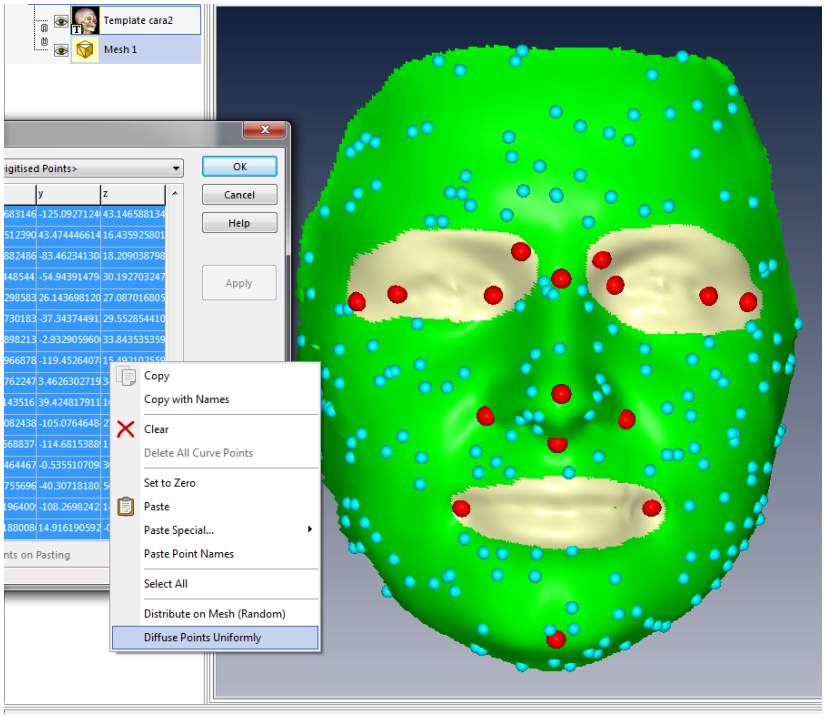


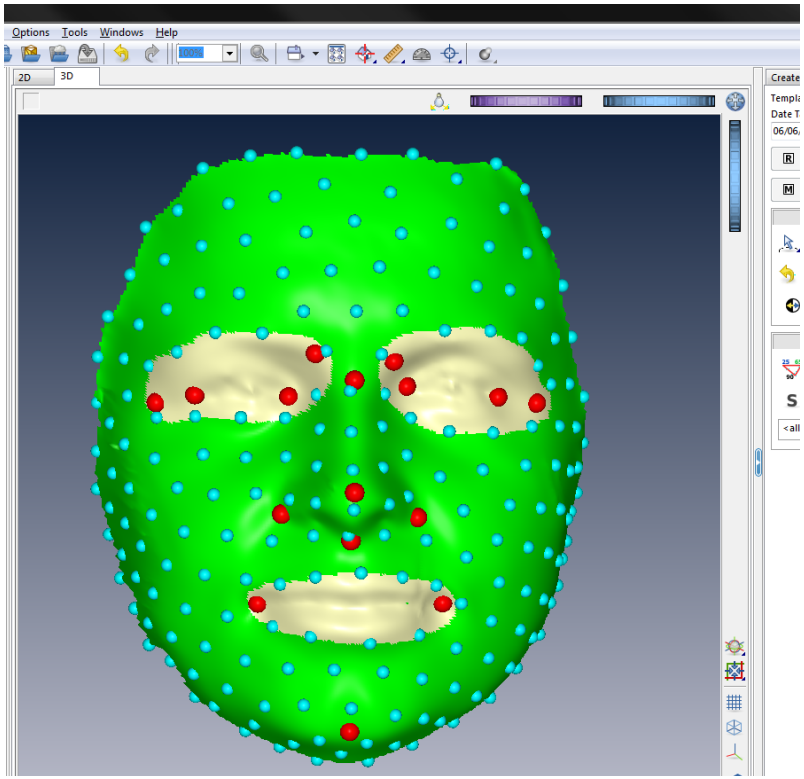
20) Right-click on the selected cells and select the function “Distribute on mesh (Random)”





21) Right-click again and select the function “Diffuse Points Uniformly”. This results in 200 semilandmarks uniformly distributed on the mesh. Close the window and save the template (CTRL + S).





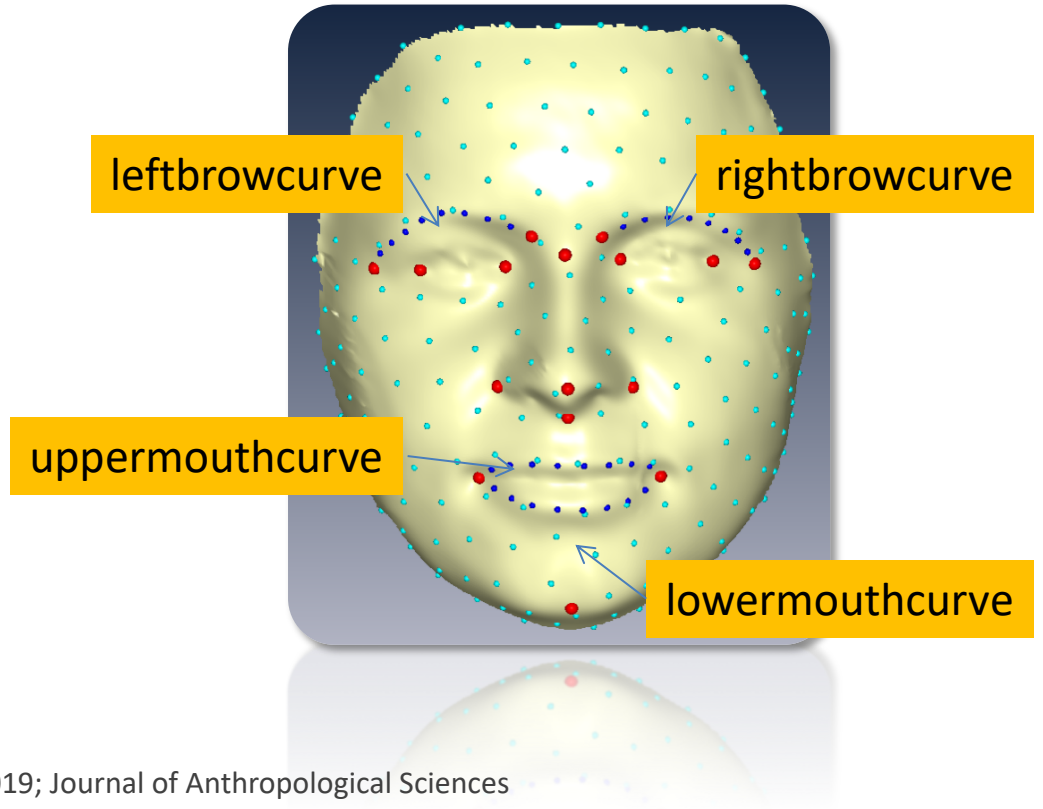
How to create curves and curve semilandmarks

Step 1: Generate a curve that is defined by a number of "*help points*" (these *look like* but *are not* landmarks).

Step 2: Generate the semilandmarks of each curve. These curves need to be defined between two true landmarks (lms). The curve semilandmarks will be slid along the curves to minimize the bending energy, i.e the energy of deformation of the face shapes of these patients with respect to the template, since the lower the bending energy, the more relaxed the specimen is with respect to the template (see main text).

This template has 4 curves:

1) Leftbrowcurve (between lms 009-010)
2) Rightbrowcurve (between lms 011-012)
3) Uppermouthcurve (between 015-016)
4) Lowermouthcurve (between 015-016)



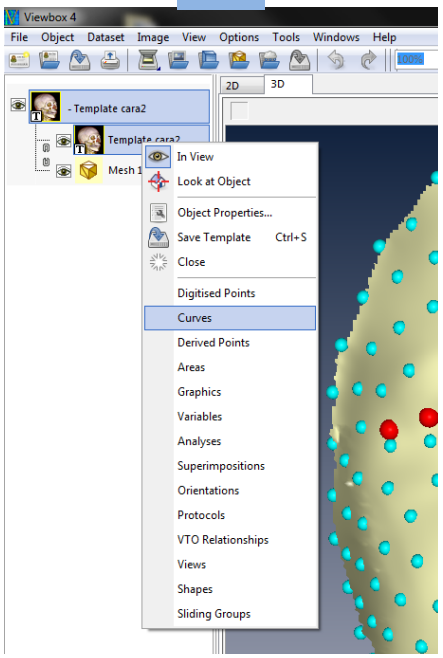
Bastir et al., 2019; Journal of Anthropological Sciences

Step 1: Generation of the curves

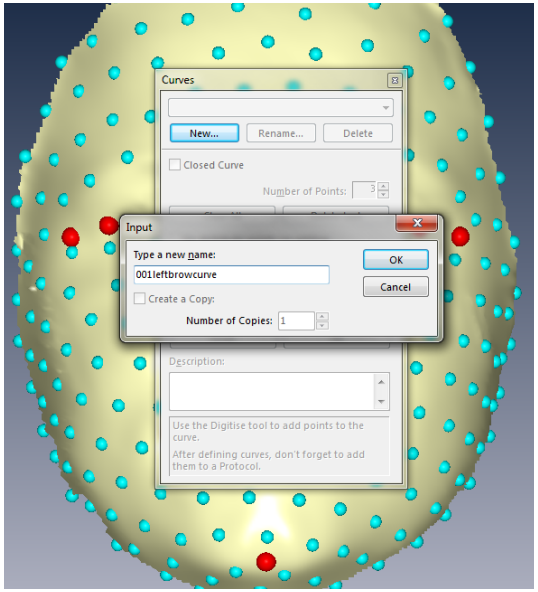
22) Right-click on the template object and select “Curves” → “New…” and give a name to the first curve, for example “001leftbrowcurve”. Click “OK”.

23) Digitise the curve point by point using the right button. Start the digitisation in the landmark “009leftlatbrow” and finish it with the landmark “010leftmedbrow“. In “Number of Points”, increase and reduce the number of points (until 8) in order the desired number of help points for this curve and similar distances between points are obtained. Repeat this step with the rest of the curves and close the window. The curves have been created.

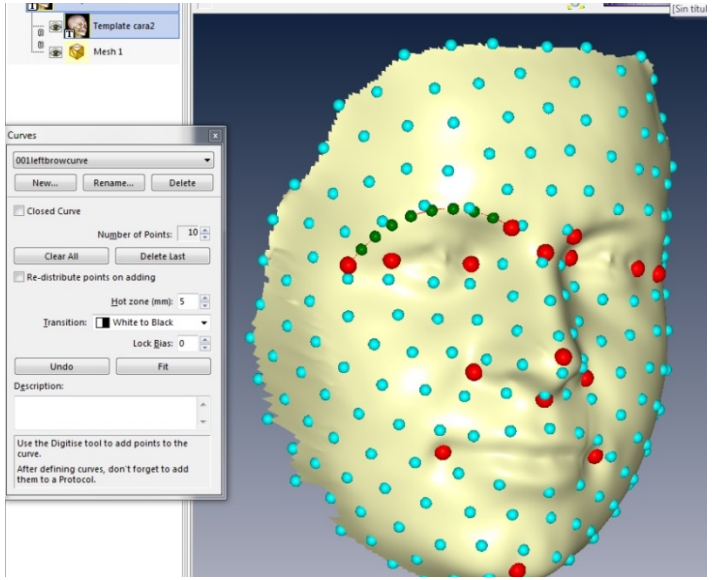
22



22



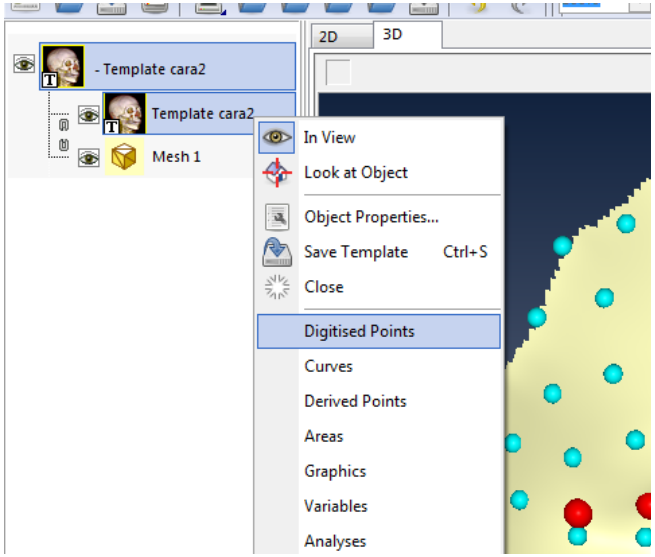
23

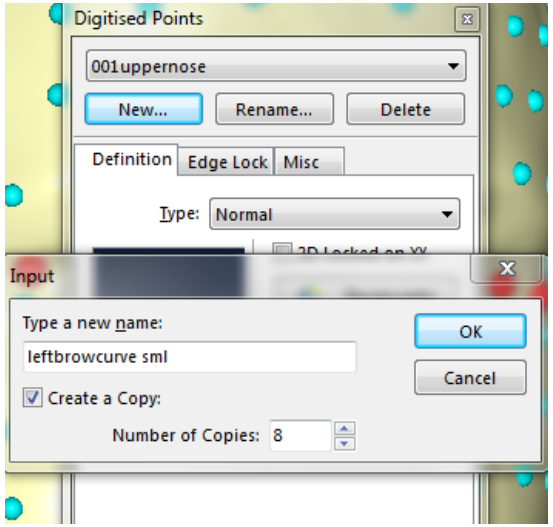


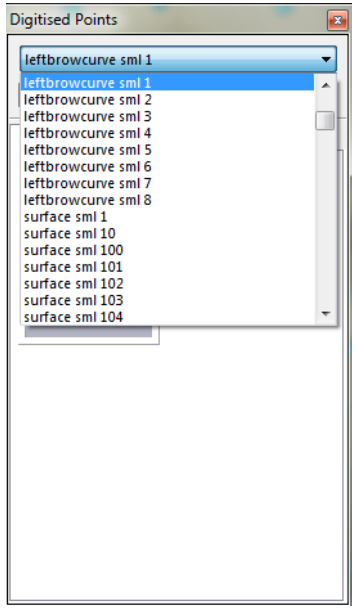
Step 2: Generation of the semilandmarks

After creating the 4 curves, we need to generate 8 copies of semilandmarks per curve.

24) Left-click in “New…” and write “leftbrowcurve sml”. (to create 8 copies of the semilandmarks of the curve “leftbrowcurve”. Click in “Create a Copy” and adjust the number of points (the curve has 8 semilandmarks between 2 true landmarks, so the number of copies is 8). In“Digitised Points”, the list of points shows the 8 created copies of the semilandmarks and their names followed by 1, 2, 3… indicating a total of 8 copies.



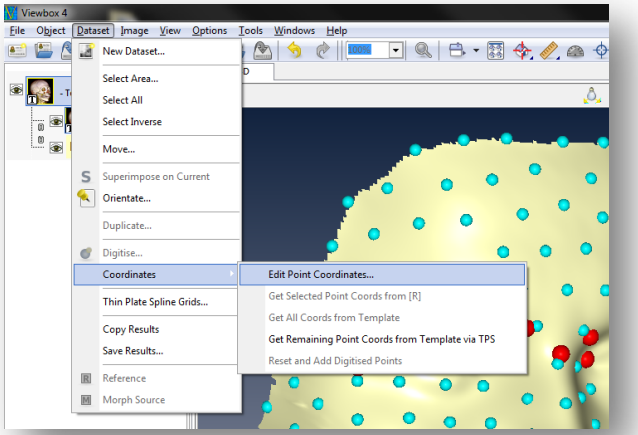


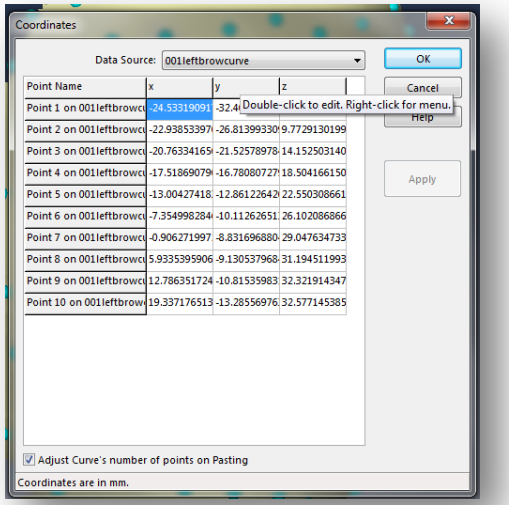


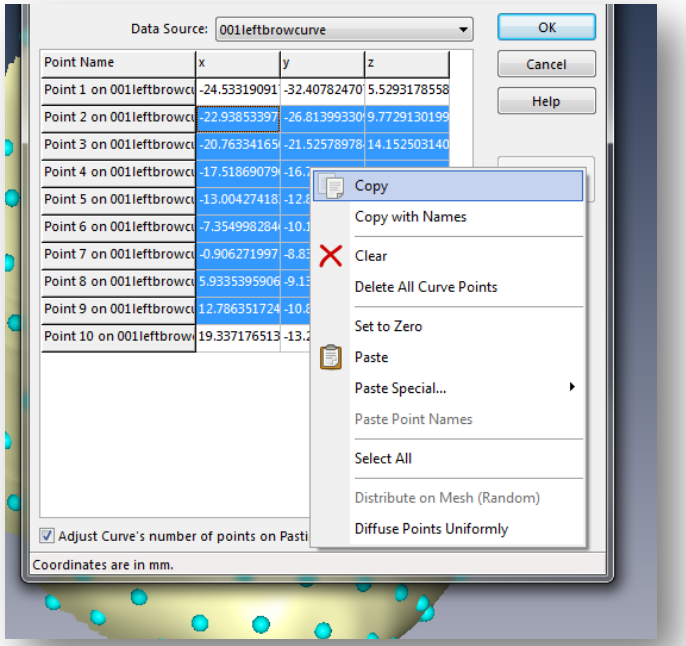
Now we need to define the coordinates of the semilandmarks, which are taken from the help points.

25) Click on“Dataset” → “Coordinates” → “Edit Point Coordinates”. In Data Source, select 001leftbrowcurve (the first curve).

The window shows the coordinates of 10 help points that belong to and define the selected curve (the first one and the last one coincide with the true landmarks and the other ones are coordinates of the curve semilandmarks). We only need to copy the coordinates of the curve semilandmarks (from Point 2 to Point 9).

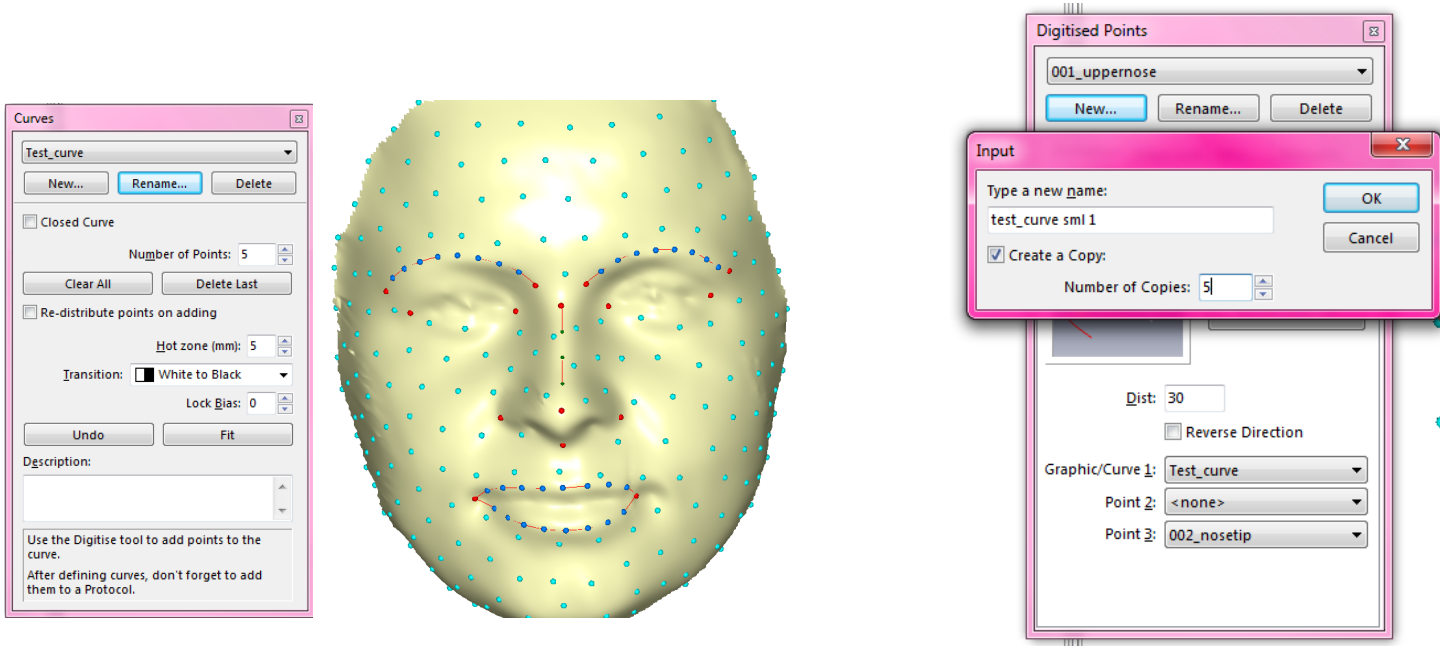


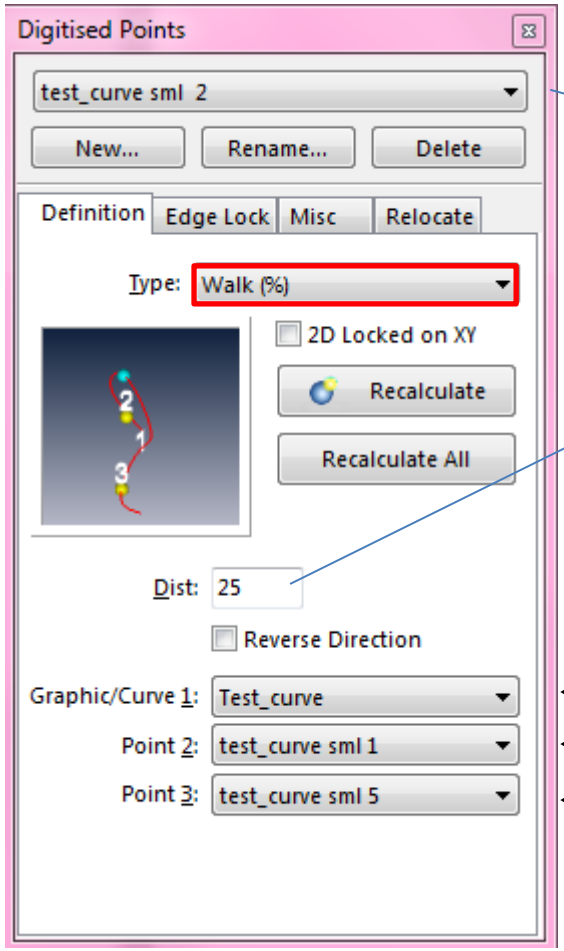




There is an alternative way to define and locate the semilandmarks along a curve. Here we illustrate an example using a new curve composed of 3 semilandmarks between 2 fixed points at the start and at the end of the curve in the nose of the 3D face model (this new curve will not be included in the final result of the template; it is only for explanation purposes).

We first create and digitize the curve as in step 22. Then, in “Digitised points”, we create 5 copies of the semilandmarks (the total number of points of the curve, that is, 3 sml + 2 fixed points. Then, we define each point as Type Walk%. Since we have 5 points, the 1st point will be located at Distance 0%, the second point at distance 20%, and so on, until the point at the end of the curve located at 100%.





Test_curve sml 1: Distance 0 (fixed point at the start of the curve)

Test_curve sml 2: Distance 25

Test_curve sml 3: Distance 50

Test_curve sml 4: Distance 75

Test_curve sml 5: Distance 100 (fixed point at the end of the curve)

← Here we select the curve along which we want to distribute the points.

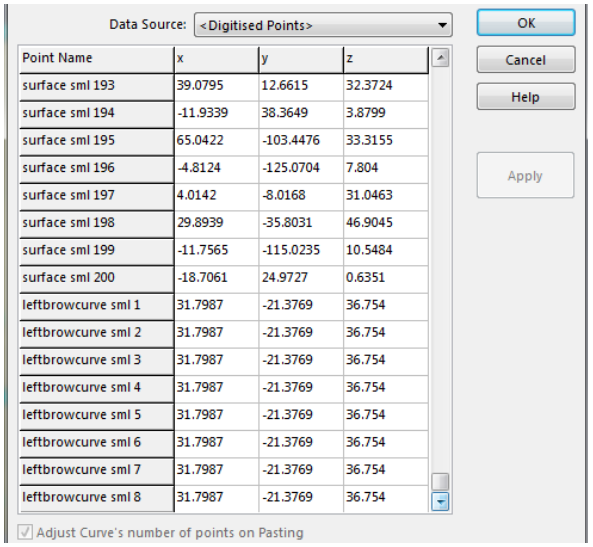
← Here we select the first point at the start of the curve

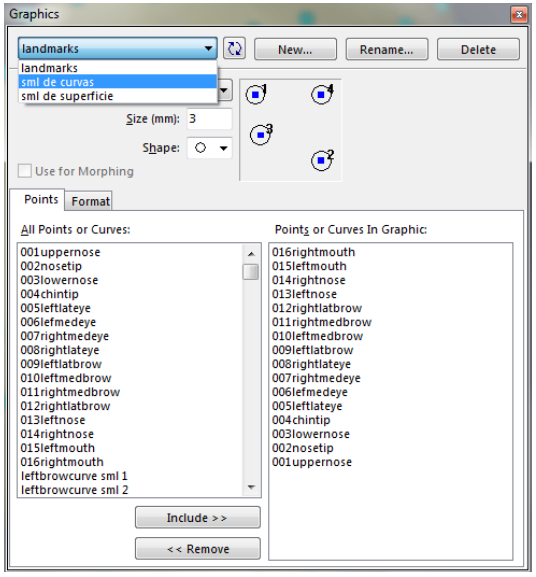
← Here we select the last point at the end of the curve

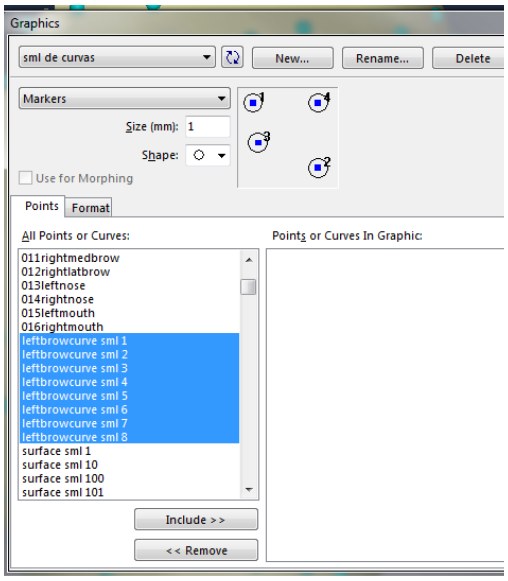
After this process, the fixed points at the beginning and the end of the curve will be defined as fixed landmarks in Sliding Groups (see page 22).

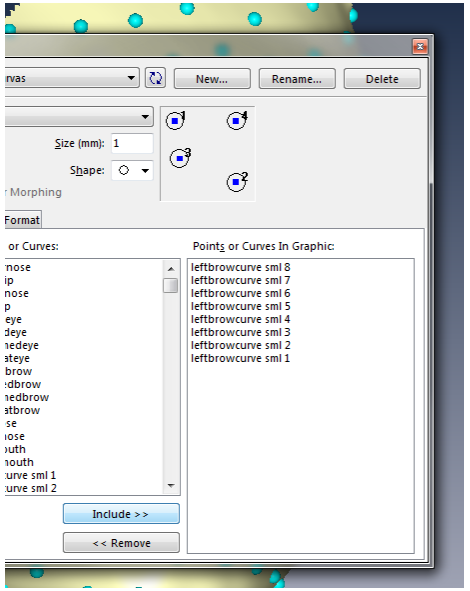
26) In Data Source, select “Digitised Points” to make all the points of the object Template cara2 visible. We need to paste the 3D coordinates into the cells belonging to the curve <<leftbrowcurve>>, so right-click on the first cell of the leftbrowcurve sml 1 and “Paste”. Then, click on “Apply”, close the window and save the Template.

27) Right—click on the mesh → “Graphics”, and include the curve semilandmarks in their corresponding group in order to see the semilandmarks on the mesh.





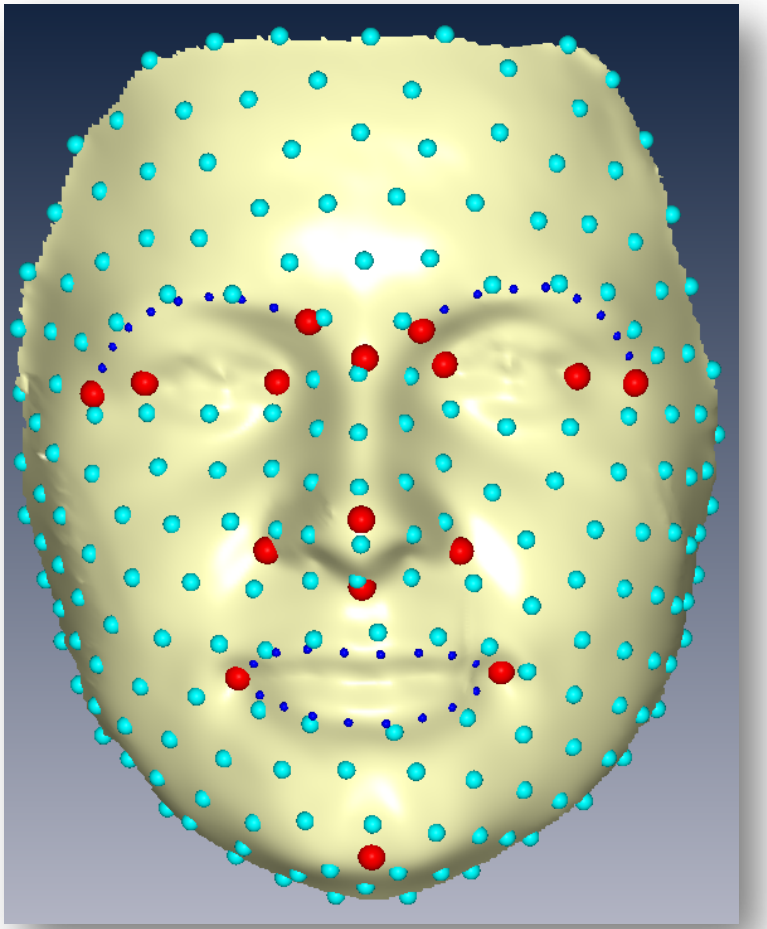




Repeat the steps 22-27 to create the rest of the curves, named:

1) Leftbrowcurve (between lms 009-010)
2) Rightbrowcurve (between lms 011-012)
3) Uppermouthcurve (between 015-016)
4) Lowermouthcurve (between 015-016)

This should be the final result →

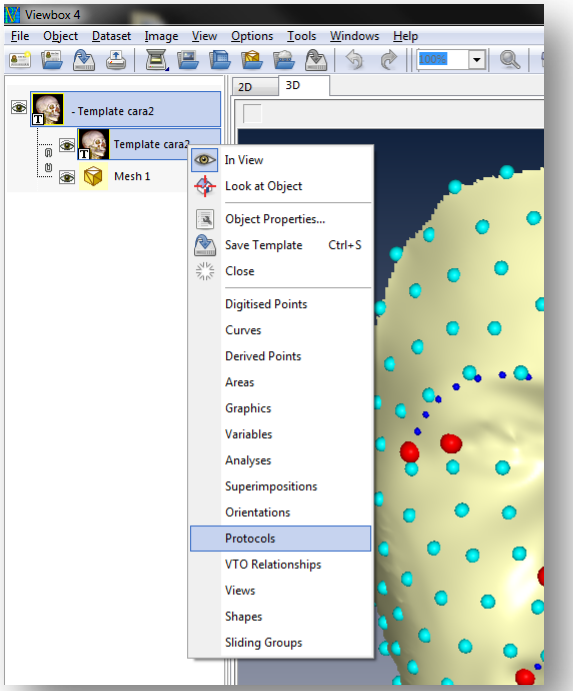


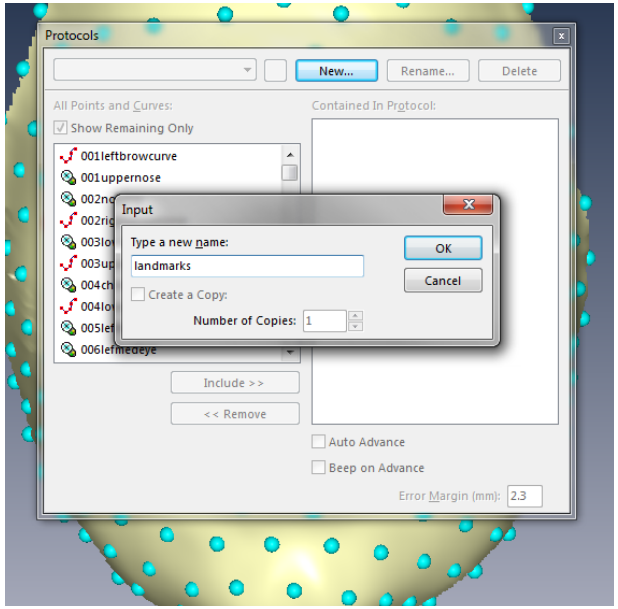
Two more steps before finishing…

Step 1: To define the order of the landmarks we will follow during the digitization of the landmarks, curves and surfaces

→ **PROTOCOLS**

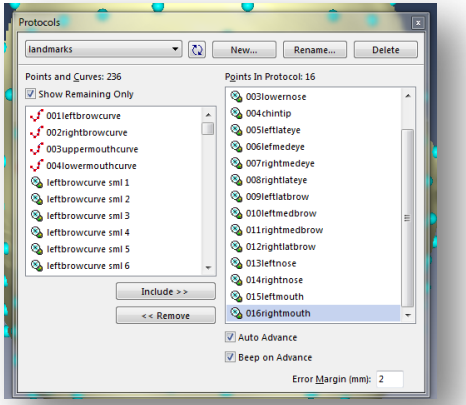
28) Right-click on Template Object and select “Protocols”. A list with all the landmarks, curves and semilandmarks is displayed. Click on “New” y type “landmarks”. Create two more protocols typing “curve sml” and “surface sml”.





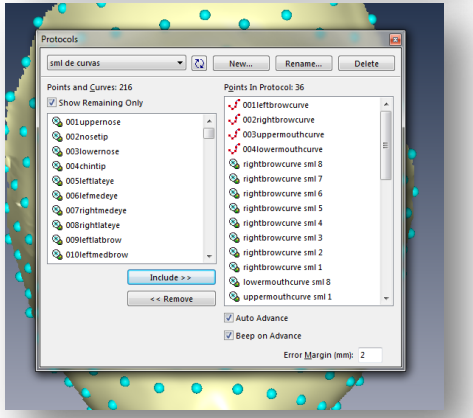
Landmark protocol

29) Choose the protocol “landmarks” and select the landmarks one by one in the desired sequence of the digitisation. This sequence will be the one followed in every specimen during the digitization process. Select “Include” to include the points in the list “Points in Protocol”. Note that this sequence should be practical (e.g. use a given orientation of the object to measure as many landarks as possible, avoid an order that makes you jumping from right to left sde, etc…)



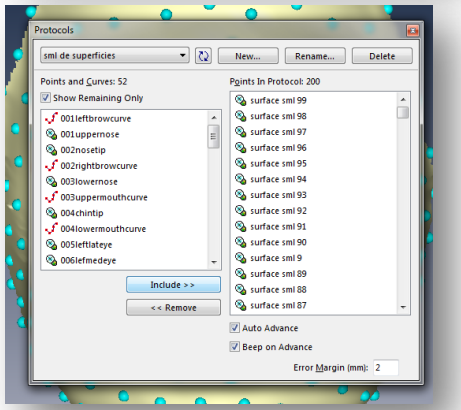
Curve semilandmarks protocol

30) Repeat step 29 by choosing FIRST the curves (red snakes in the desired order) and THEN the semilandmarks (in any order, because they will be digitzed automatically).



Surface semilandmarks protocol

31) Repeat the step 29 by choosing the surface semilandmarks (in any order, because they will be digitzed automatically).

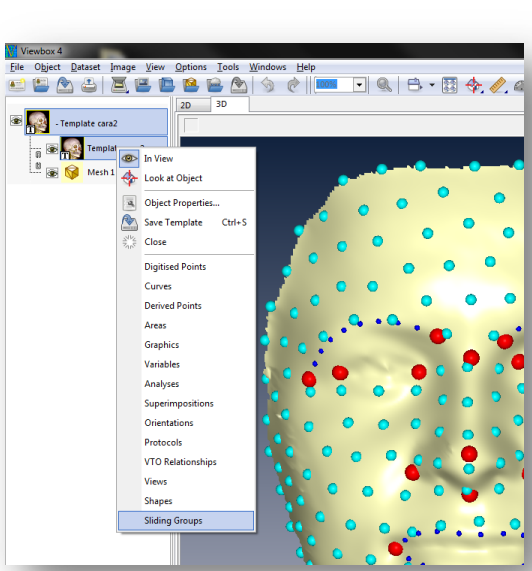


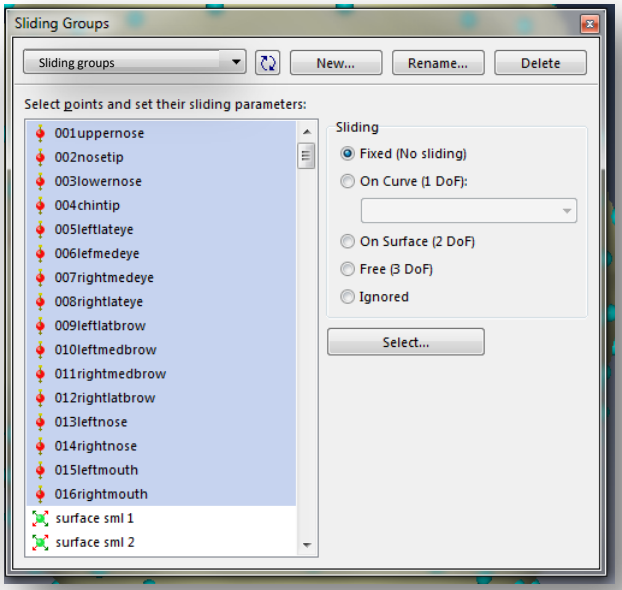
Sliding Groups

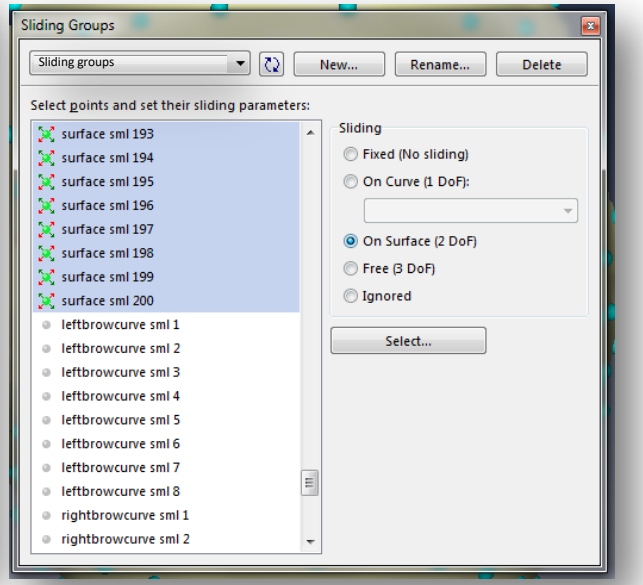
Step 2: To define the degrees of freedom of each point (true landmarks, curve semilandmark and surface semilandmark) for the sliding → **SLIDING GROUPS**

32) Right-click on Template object and select “Sliding Groups”. In “New…”, create a group named “Sliding groups”

33) Select the true landmarks 001-016 and click on “Fixed (No sliding)”. Select the surface semilandmarks 1-200 and click on “On Surface (2 DoF, degrees of freedom).



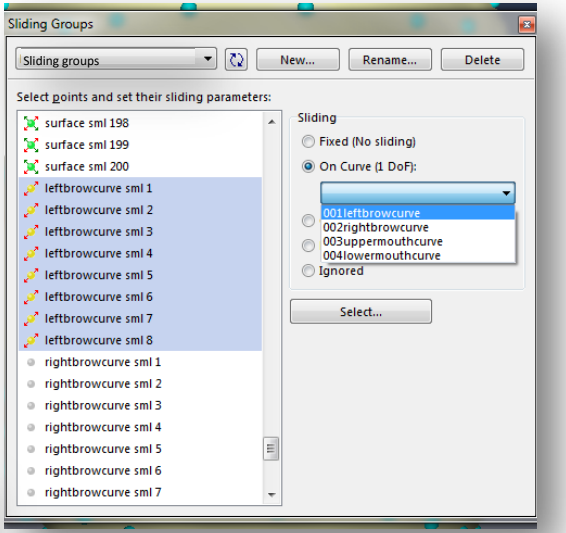


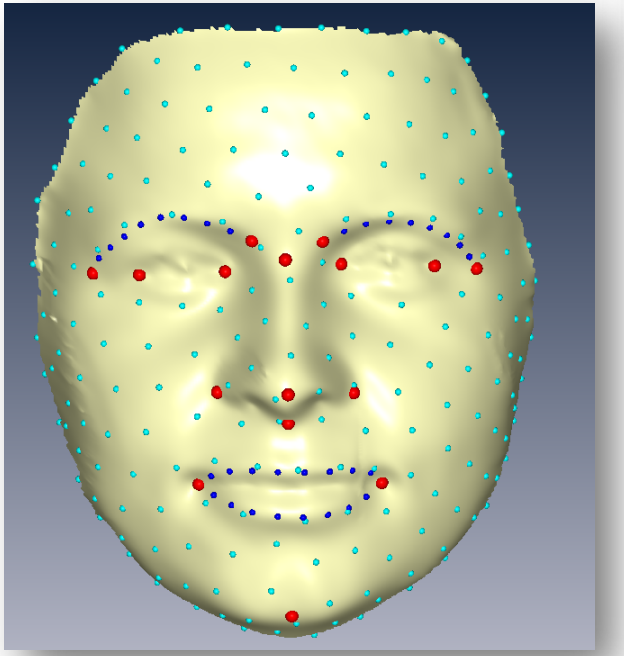


34) Select the semilandmarks belonging to each curve and choose “On Curve (1 DoF)” and the corresponding curve:

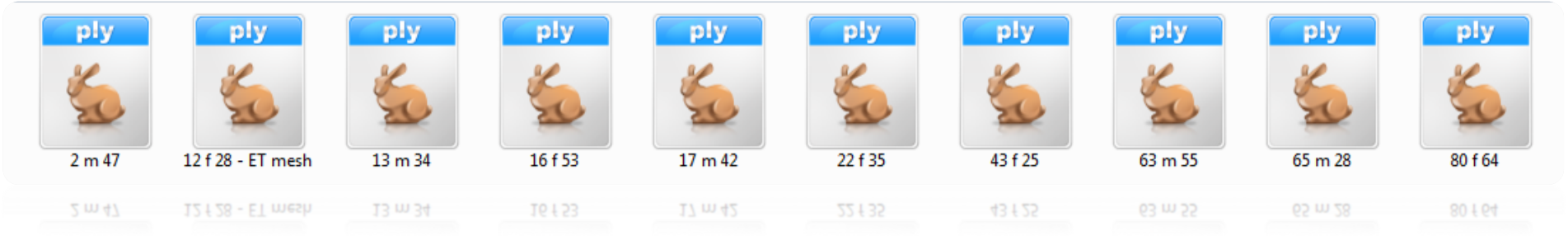
- “leftbrowcurve sml 1-8” to 001leftbrowcurve
- “rightbrowcurve sml 1-8” to “002rightbrowcurve”
- “uppermouthcurve sml 1-8” to “003uppermouthcurve”
- “lowermouthcurve sml 1-8” to “004lowermouthcurve”

Make sure the semilandmarks sets are linked with their correct curves!
Close the window and save the file. The template is finished.





Semi-automatical digitisation of new specimens using the template created in Viewbox

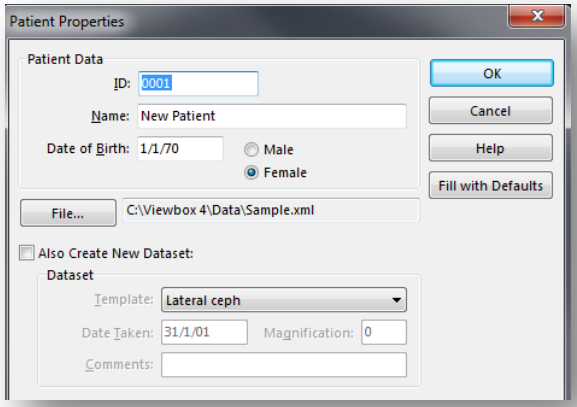


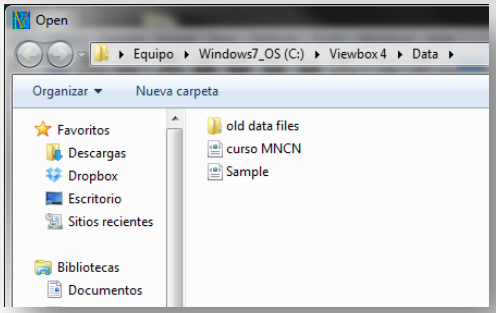
Bastir et al., 2019; Journal of Anthropological Sciences

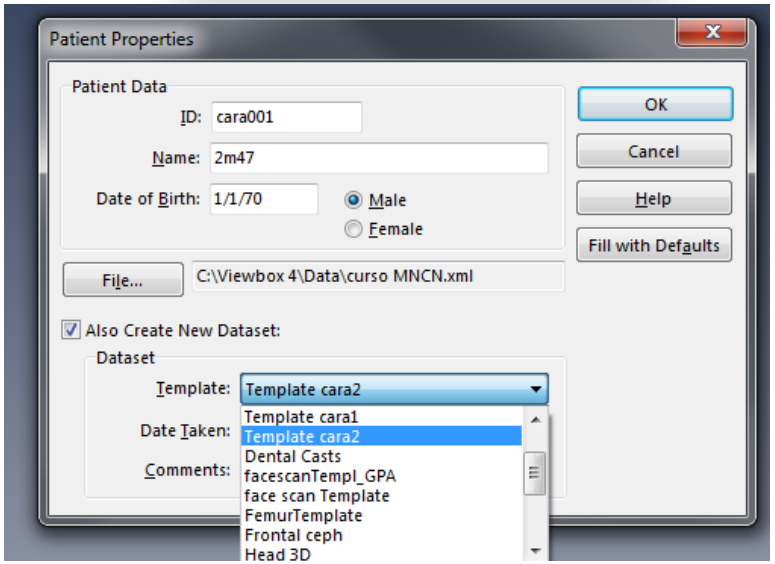
Aim

The aim of this part is to learn how to digitize the rest of the specimens using the template of digitisation generated previously.

1) File → New Patient, and type the ID and the name of the patient.
2) Click on “File”. In a pop-up window, copy the file “Sample” and paste it with a different name. The format of this new file is .xml and this is the file all landmark data will be saved during digitisation. Check the box “Also Create New Dataset” and select the template of the list.
3) Click on “Also Create New Dataset” and select the template previosly created “Template cara2”, as a reference for the semi-automatical digitisation of this new specimen.

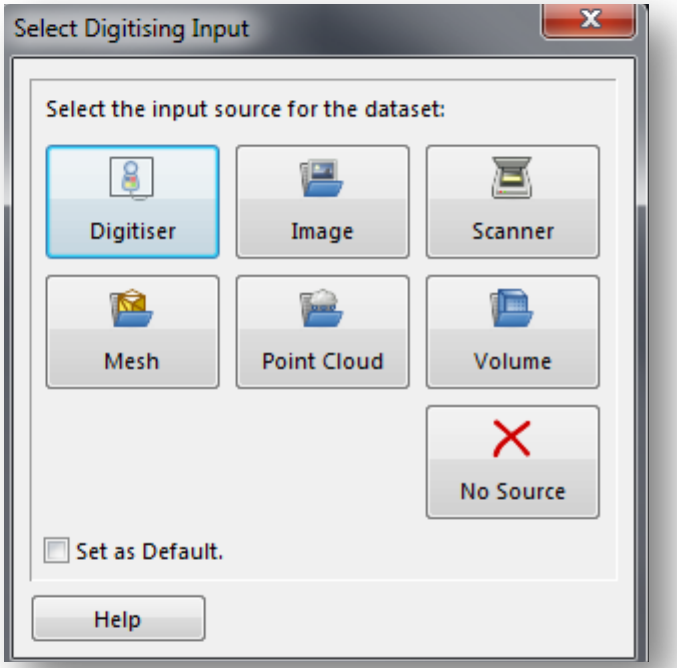


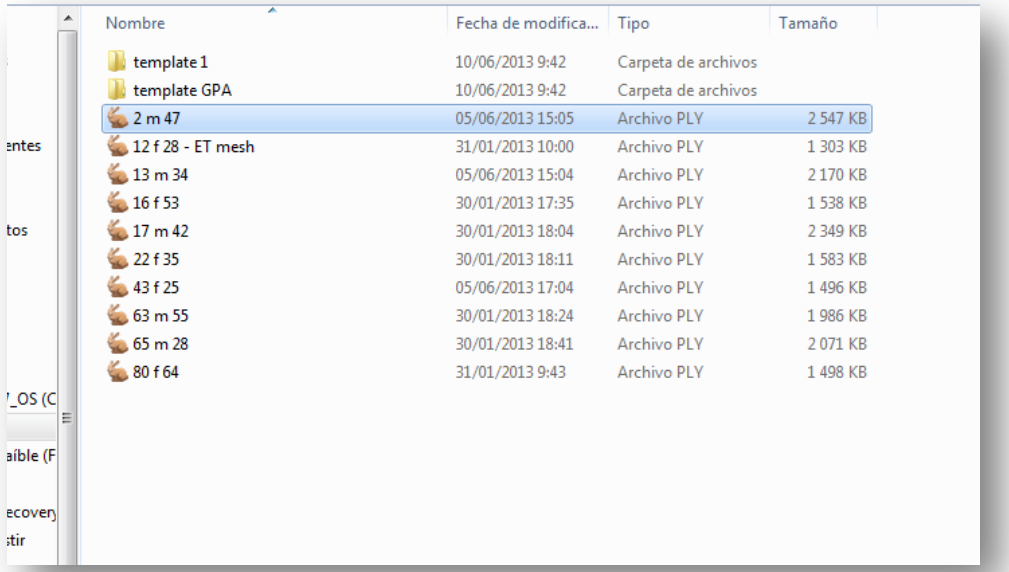




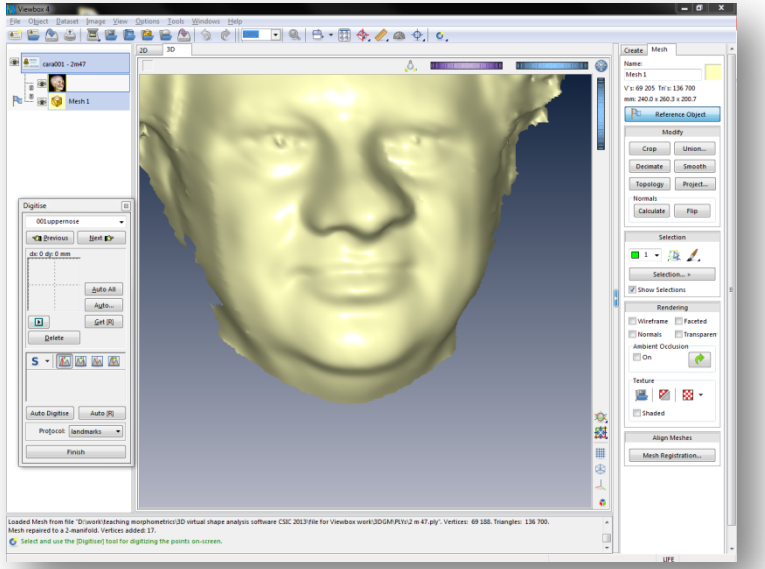
Bastir et al., 2019; Journal of Anthropological Sciences

4) In the pop-up window “Select Digitising Input”, we need to select “Mesh” to upload (.ply, .stl , or .obj format) on which we are going to locate the landmarks and semilandmarks. Click “Open”.



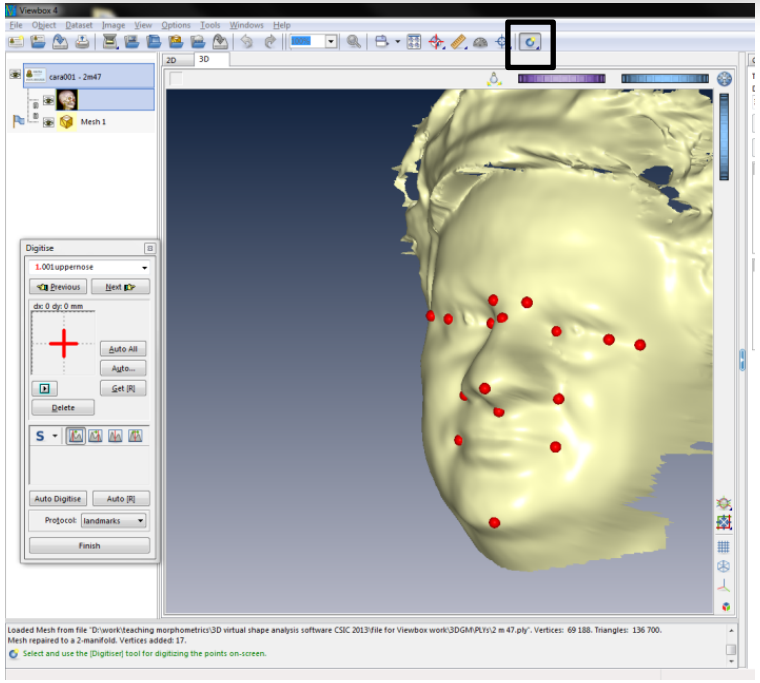


5) After opening the first specimen with ID=2m47, the window “Digitise” allows for the digitisation of the specimen following the sequence defined previously in Protocols in the template (the 1st landmark to digitise is “001uppernose” and so on).



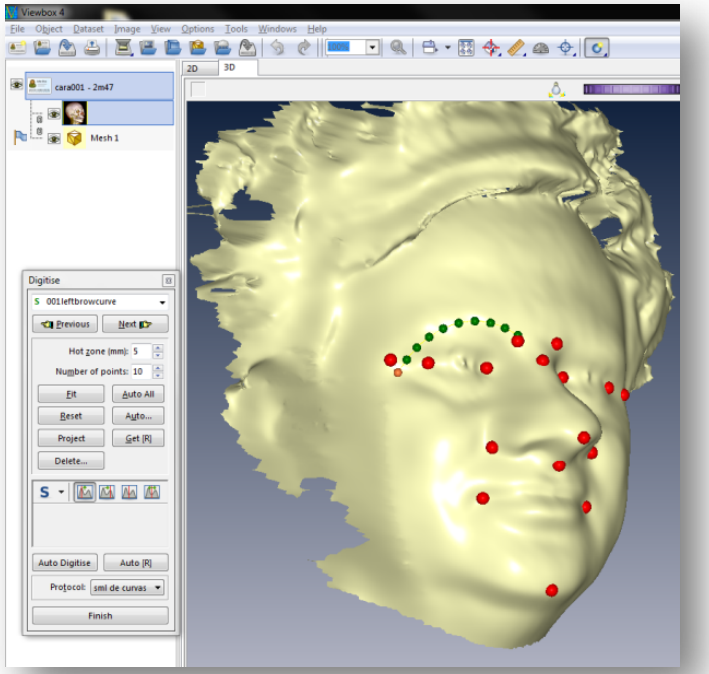
6) Left-click on “Digitiser” and right-click on the mesh to digitise landmark by landmark following the sequence prevously defined and displayed in the window “Digitise”.

7) The red cross on the left indicates that all the landmarks have been digitised and we need to move on to the next protocol of digitisation. In Protocol, choose “Curve semilandmarks” and start to digitize a new curve.



Bastir et al., 2019; Journal of Anthropological Sciences

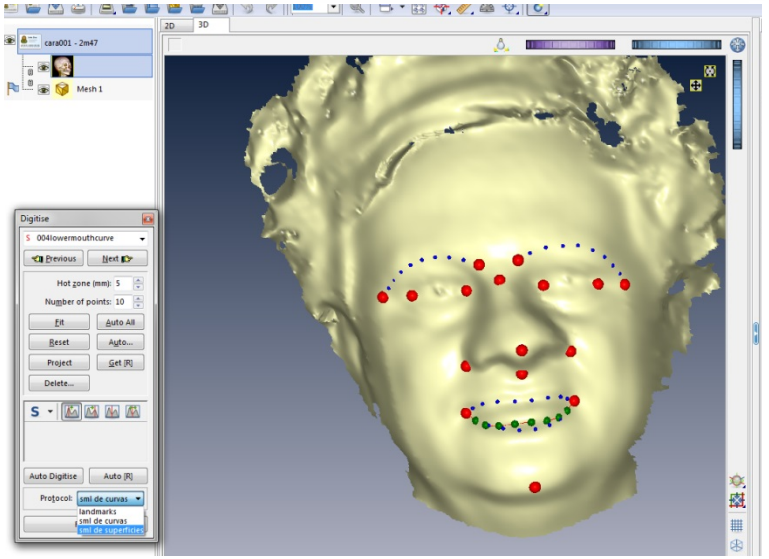
8) When we select the first curve, Viewbox suggests a curve based on the its position on the template. We need to adjust the position of the curve manually by dragging every single point of it. Moreover, we need to make sure that the first point of the curve (orange) is located on the first landmark of the curve (009leftlatbrow) and the last point of the curve (green) is located on the last landmark of the curve (010leftmedbrow).



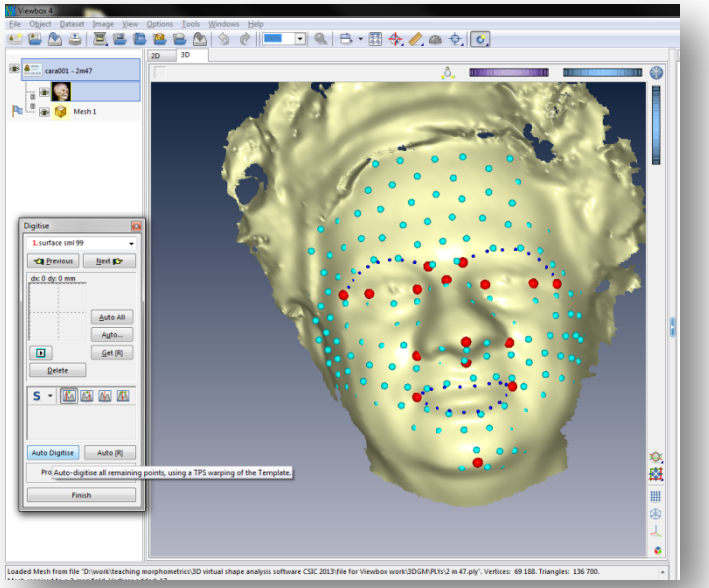
9) In "Number of points", reduce the number of points until 4 and then increase the number again to make the points equidistant. Click on "Project" to project the curve onto the mesh. (Note, these points only define the shape of the curve).

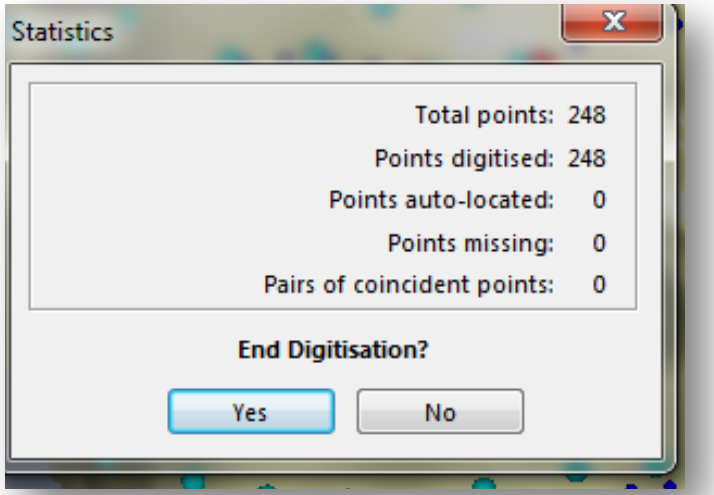
10) Repeat the steps 8 and 9 with the following 3 curves. After this, click on "Autodigitise". The landmarks will be projected onto their respective curves automatically. They will be reslid later.

11) Once the curves are digitised, we move on the the next protocol "Surface semilandmarks" and click on "Auto Digitise". The 200 surface semilandmarks appear on the surface and will be reslid later.



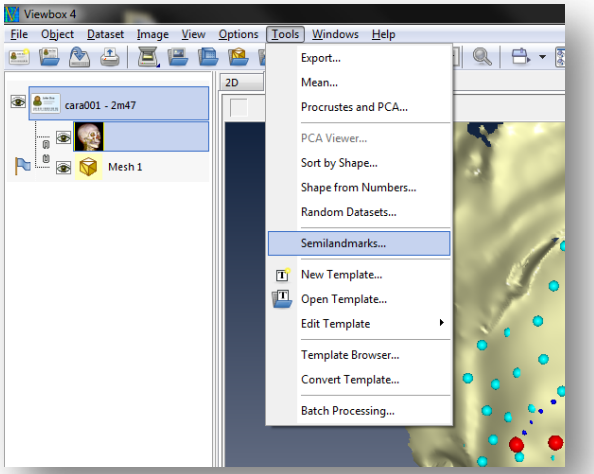
12) When all the landmarks, curves, and surfaces are digitised, click on “Finish”. A pop-up window shows a summary about the points digitised, whose number must be the same as Total points (with zero points auto-located, missing and zero pairs of coincident points”. Click on “Yes”.





Sliding semilandmarks

Now, the semilandmarks will be subjected to a “sliding” process, in which they will be adjusted along their curves and on their surfaces with respect to the template.

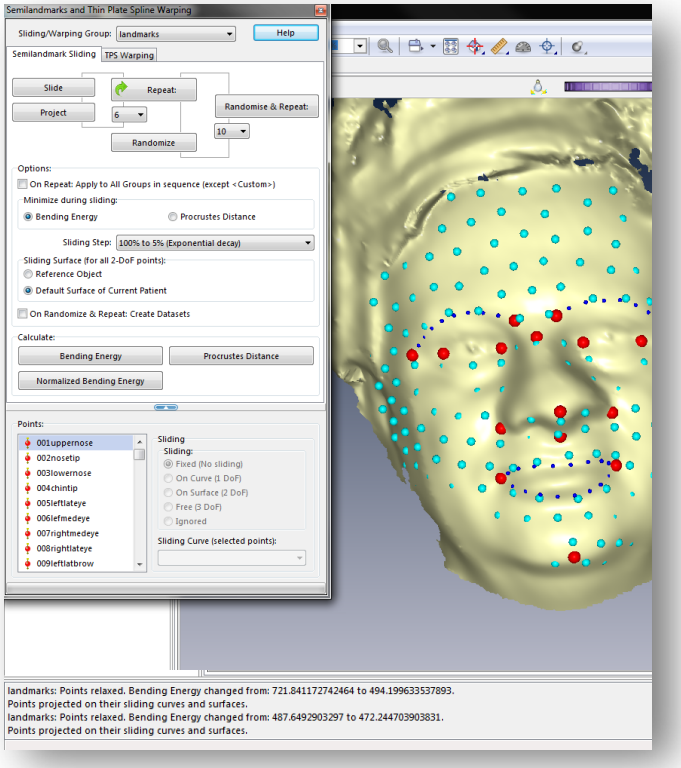


13) In the tools bar, choose Tools > Semilandmarks…

In the pop-up window “Semilandmarks and Thin Plate Spline Warping”, click on “Project” to project the points on the surface.

14) After this, click on “Slide” iteratively in order to allow the sliding of the curve semilandmarks along the tangent vectors to their corresponding curves and on the tangent planes to their corresponding surfaces (Gunz et al., 2005, Gunz and Mitteroecker, 2013).

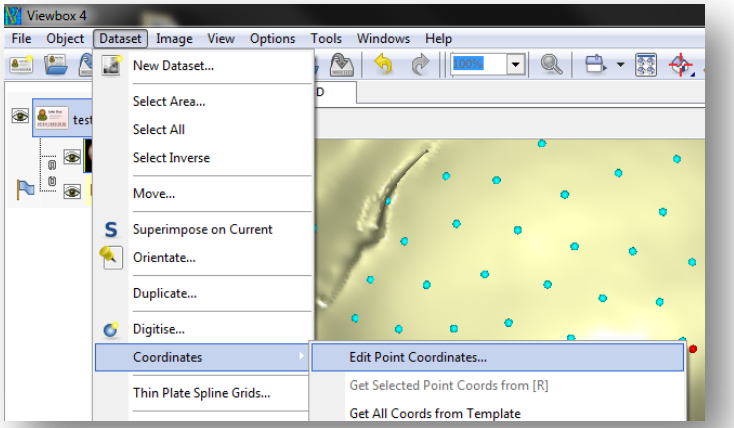
* Step 14 is crucial in the detection of possible errors in the template.



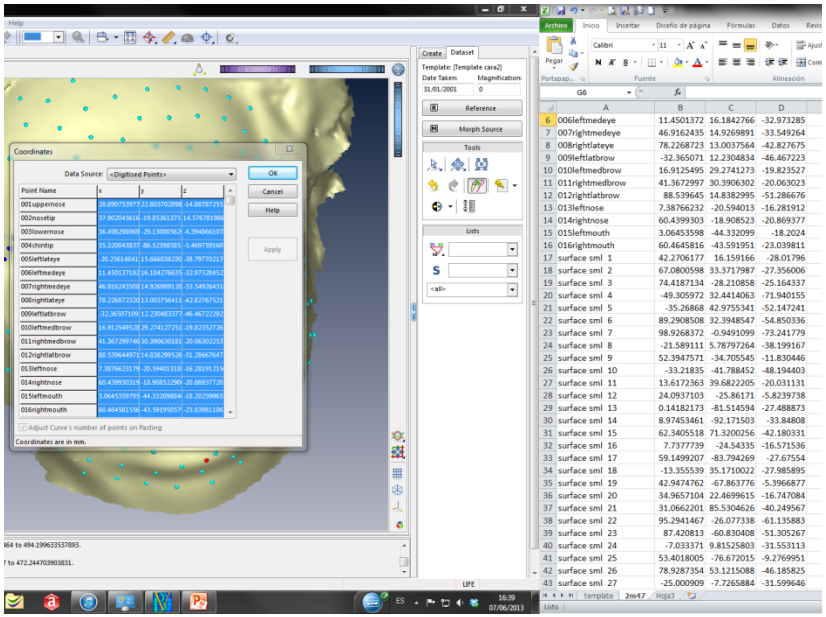
15) We need to repeat this step iteratively to minimise the bending energy, that is, until the energy of deformation of this object with respect to the template stops decreasing notably.

The first specimen has been successfully digitised. Now we need to export the x-y-z coordinates corresponding to all the points of this first specimen.

16) Click on Dataset > Coordinates > Edit point coordinates > Right-click on any cell > "Select all" to select all the 3D coordinates. After copying these 3D coordinates with names in another file, we have digitised the first specimen. CTRL+S



* We will repeat this step with every single specimen until creating a 3D array containing all the coordinates. This 3D array will be the base of all the 3D Geometric Morphometrics analyses.

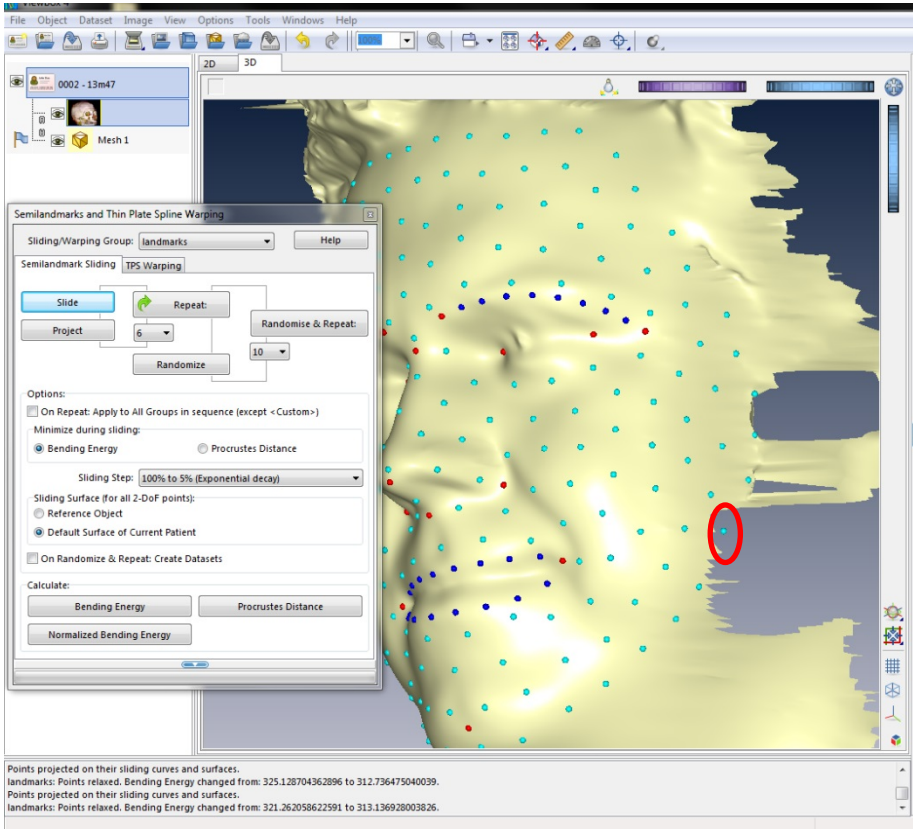


There is an alternative to export the coordinates of all the specimens after digitization, which is particularly useful for large data sets:

Click on Tools > Export and we can export all saved specimens' coordinates directly to an Excel sheet, or to a text

Missing data estimation in Viewbox 4

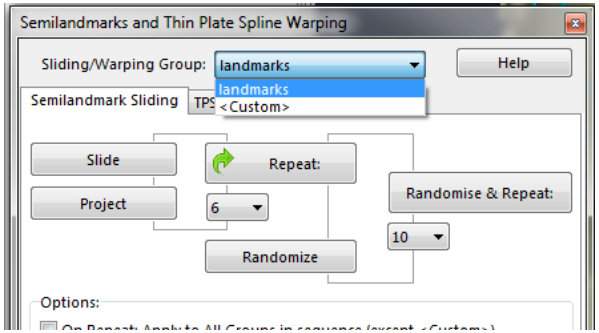
We can estimate missing landmarks in ViewBox. For example, the screenshot on the left shows a landmark that is not located on the surface. We need to estimate the position of this point on the specimen with respect to the template.

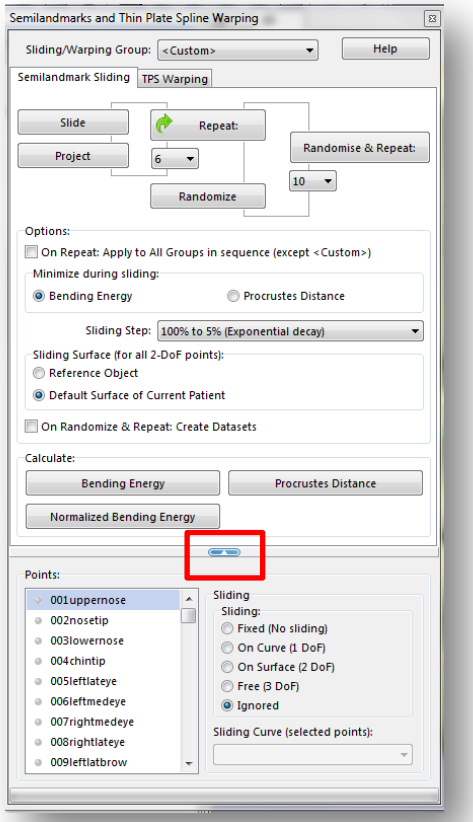


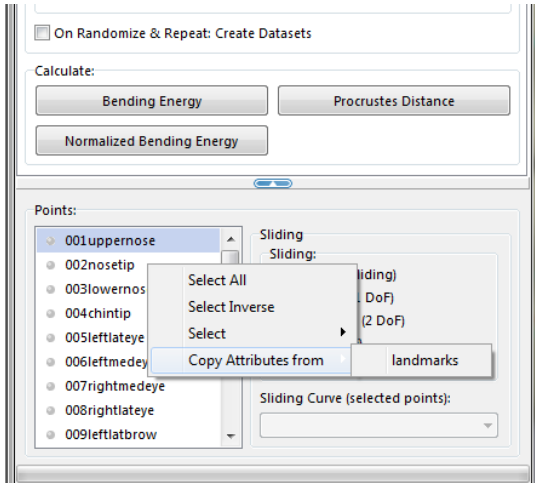
Bastir et al., 2019; Journal of Anthropological Sciences

1) Tools → Semilandmarks → "Sliding/Warping Group" and choose <Custom>, to customize the attributes of the sliding.

2) Click on the arrow to display the attributes of each point. Right-click on any point randomly and choose "Copy Attributes from" and select "Sliding groups" (previously defined in Part 1, step 32). Now, the points have their corresponding attribute (Fixed for landmarks points, "On Curve" for curve semilandmarks and "On Surface" for surface semilandmarks).

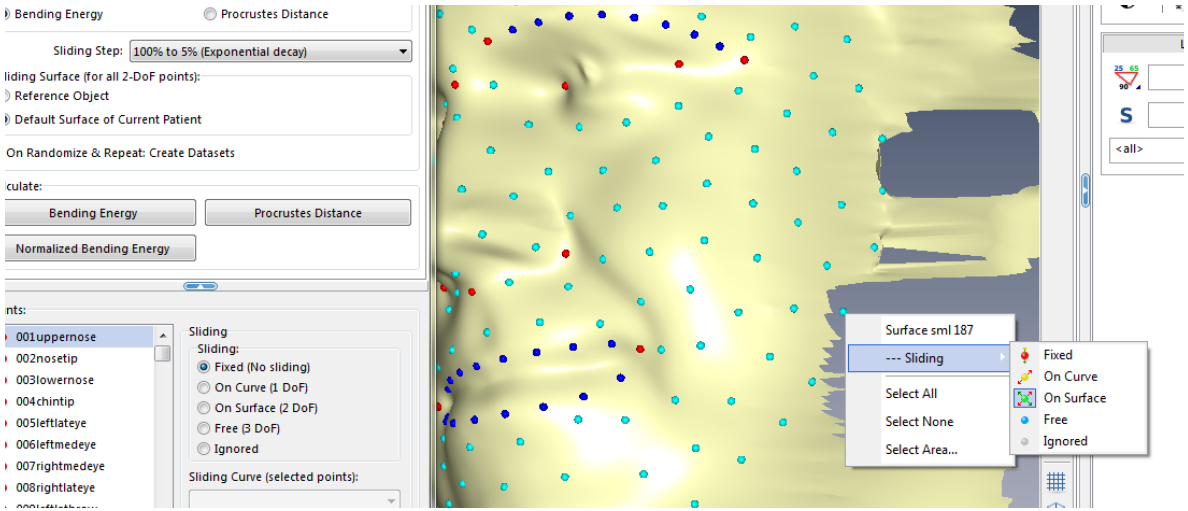






3) Activate the tool “Select and move area”. Right-click on the missing point (Surface sml 187 in our case) → Select “---Sliding” → “Free”

4) Tools → Semilandmarks → “Slide” and “project” iteratively. The landmark will occupy its accurate position with respect to the template and the bending energy.



Select and move area