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Digitization of Anatomical 3D Caricature for the Design of Biomedical Implants & Prosthetic Devices

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Abstract: *Surgical pre-operation planning, in the computer-aided way, is developing extensively. Image reconstruction is upfront step before the pre-op planning can be carried out. Accuracy, speed, and cost are the main concern of the image regeneration process.*

1. Introduction

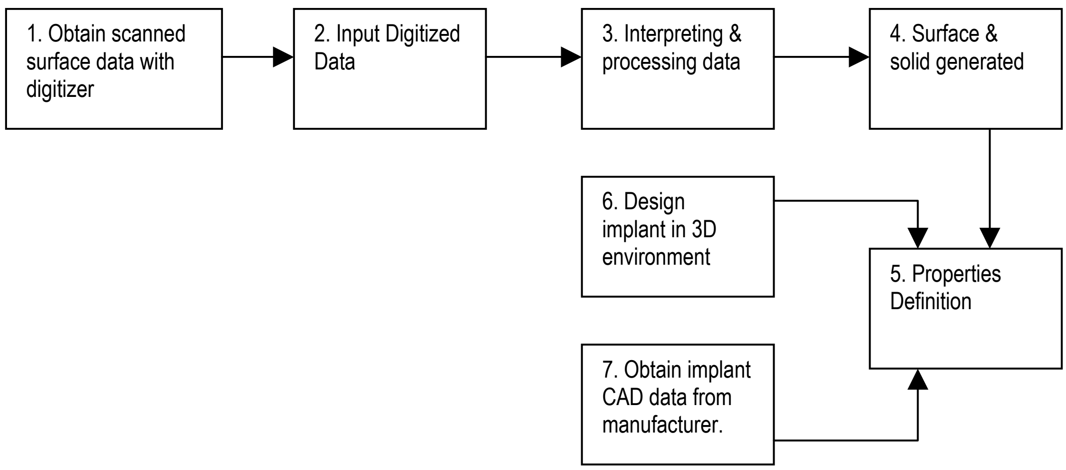
For surgical operation in the traditional way, for instant orthopedic reconstruction, surgeon will rely on X-ray film for case study. For computer-aided surgery, pre-op and intra-op, most commonly used image regeneration is CT. For higher accuracy, MRI is adopted. Ultrasound is not so commonly used in this case.

Minolta 3D digitizer, model VIVID 700, has been used to obtain the 3D surface of a tibia, in vitro. VIVID digitizer cannot produce a see-through image like what CT or MRI do to obtain the internal anatomy structure, for instant a knee joint, of a patient. But it provides an alternative to obtain the 3D caricature of bones, in vitro, for the purpose to carry out any studies such as implant design.

VIVID provide a speedy scanning process which takes a shot in less than 5 seconds. And can finish a 360° all-round shots (6 shots in 60° interval) in less than a minute. But all the views shots need post-processing to patch up to become an entire image.

2. Software Macro Architecture

This is the overall software architecture for the Design of Biomedical Implants & Prosthetic Devices. The content in this paper is about step 1,2 and 3.



3. Operation of VIVID Digitizer

There are two options for shooting, single shot and multiple shot. The procedures are the same except multiple shot needs to utilize a turn-table and needs a calibration. Below are the steps to carry out multiple shot.

Step 1 – Setting up: Position the turn-table and set up the object. Adjust the distance of the object from the digitizer, and also adjust the zooming distance of the digitizer, to ensure the entire object is captured.

Place the object in a way that its axis of rotation (while the turn-table turns) is collinear with rotational axis of the turn table, i.e. place the object in a way that it will revolve about itself.

This will help the later registration. If the object is rotating about an axis which is located outside its body, there will be difficulties for auto registration.

Step 2 – Image quality: Provide adequate lighting for good image quality. Dark spot on the object will generate a discontinuity (holes) on the object caricature. Object in dark color is more difficult to be captured.

Set the focus manually if the machine cannot detect the location of the object. Set the focus range so that the depth of field will cover the object entirely. Do not set a focus range that will capture the background.

For longer focus distance, higher laser intensity is preferred.

Step 3 – Step shots and calibration: The digitizer will perform the number of shot as specified, at different angle as the turn-table operate. Check the image quality of every shot before proceed to next.

After the last shot, place the calibration chart to the slot of the turn-table. By acquiring the image of the calibration chart, the distance from the digitizer to the rotational axis can be calculated.

4. Post-processing

After the shots are taken, the image has to be placed together, in proper alignment, to form the entire object. This process is called registration. Registration can be auto done by the software or done manually. After registration, the separate elements can be merged to form one.

Minolta Polygon is the software to operate the VIVID digitizer with built-in post-processing capability. It is less powerful though, especially in the auto registration. This will lead to subsequent difficult and tedious step of manual registration. There is commercially available third party software, for instant RapidForm from INUS Technology which can do a much better job.

5. Case Study

Images were taken from few objects. Object with distinctive feature will be easier registered. Object in which, the images are closely similar even in different angle, will have problem in registration.

All images attached below are captured using VIVID 700/900, but were processed with different software. Fig. 5.1, 5.2 and 5.3 show sample data digitized and rendered on the screen. The results indicate that 3D digitization gives the desirable models quickly and can be done in a non-invasive manner. However, capturing and digitization needs the skill of an expert. Same is true even in the capture of images using the MRI, CT and other scanning devices. The initial results are encouraging. More works need to be done to validate the acceptability of a 3D digitizer for medical applications.

Tibia A was captured using turn-table and processed under Polygon software. Tibia B was captured with a few single shot, without turn-table, and then processed with RapidForm. Trial by taking few single shot on Tibia A and auto-registered by Polygon, failed, as this bone looks very much similar in different angle. But RapidForm can perform this task nicely. Tibia A is shown in wire mesh, shaded, and textured. Data for Tibia B is imported from RapidForm which carry no information for the texture view.

Multi-body system like the scapula complex, which has the overlapping structure, will have a lot of portion being blocked as there is feature in front of other feature. The scapula complex is processed using Polygon.

6. Conclusion

The quality of the outcome of the digitizing depends on the preparation of the specimen, the strength of digitizer hardware, the intelligent of the post-processing software, and the skill of the person that manipulate the entire process.

Digitizing has the potential application in orthopedic reconstruction surgery. Digitizing method has the advantages of speed compared to CT and MRI. Although digitizing cannot capture the internal anatomical structure, but its ability to quickly capture the external profile has its advantages.

Surgeon can base on the digitized leg profile of the patient to carry out preliminary study of the operation, and to study for the matching implants or prosthesis. By using digitizing, prosthesis manufacturer can assist their R&D by easily collecting ton of data for statistical study.

Small size of the digitizer means it has the portability. Surgeon and doctor can have this alternative in the circumstances, such as in the battle ground, in which using CT and MRI is difficult. The future and continuing improvement and the digitizing technology which increases the accuracy will further enhance its role in biomedical field.

References

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5.1. Tibia A

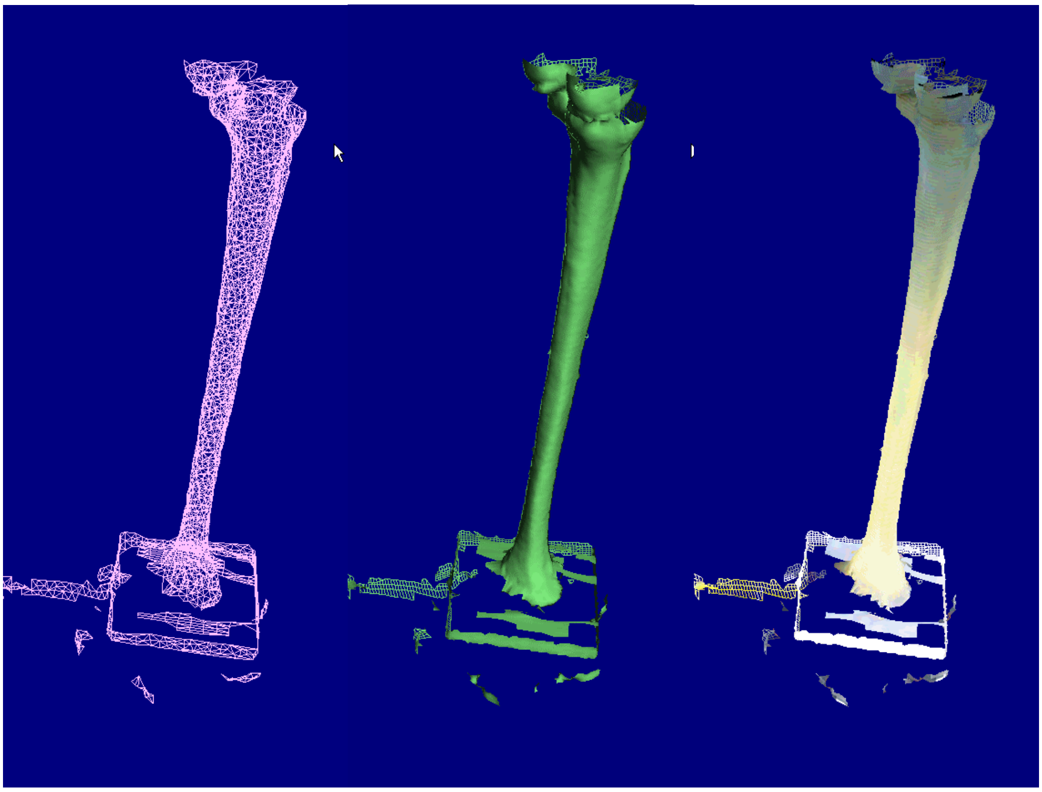

Fig. 5.1 Tibia (wireframe, shaded and with texture)

5.2. Tibia B

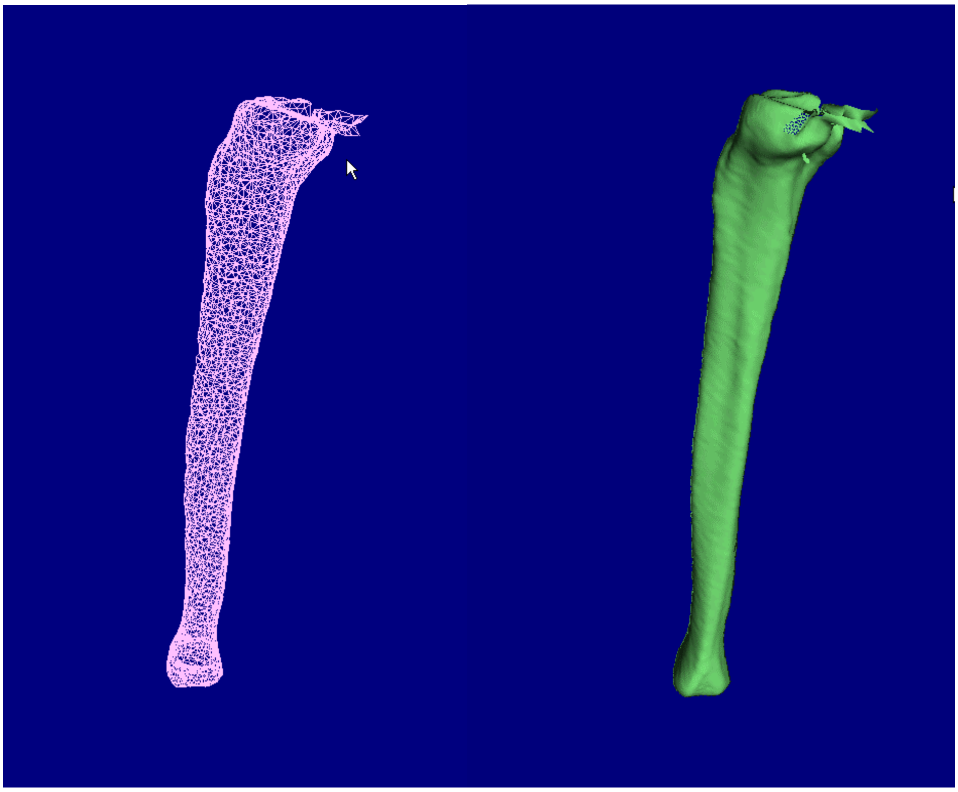

Fig. 5.2 Tibia with post processing (wireframe and shaded)

5.3. Scapula

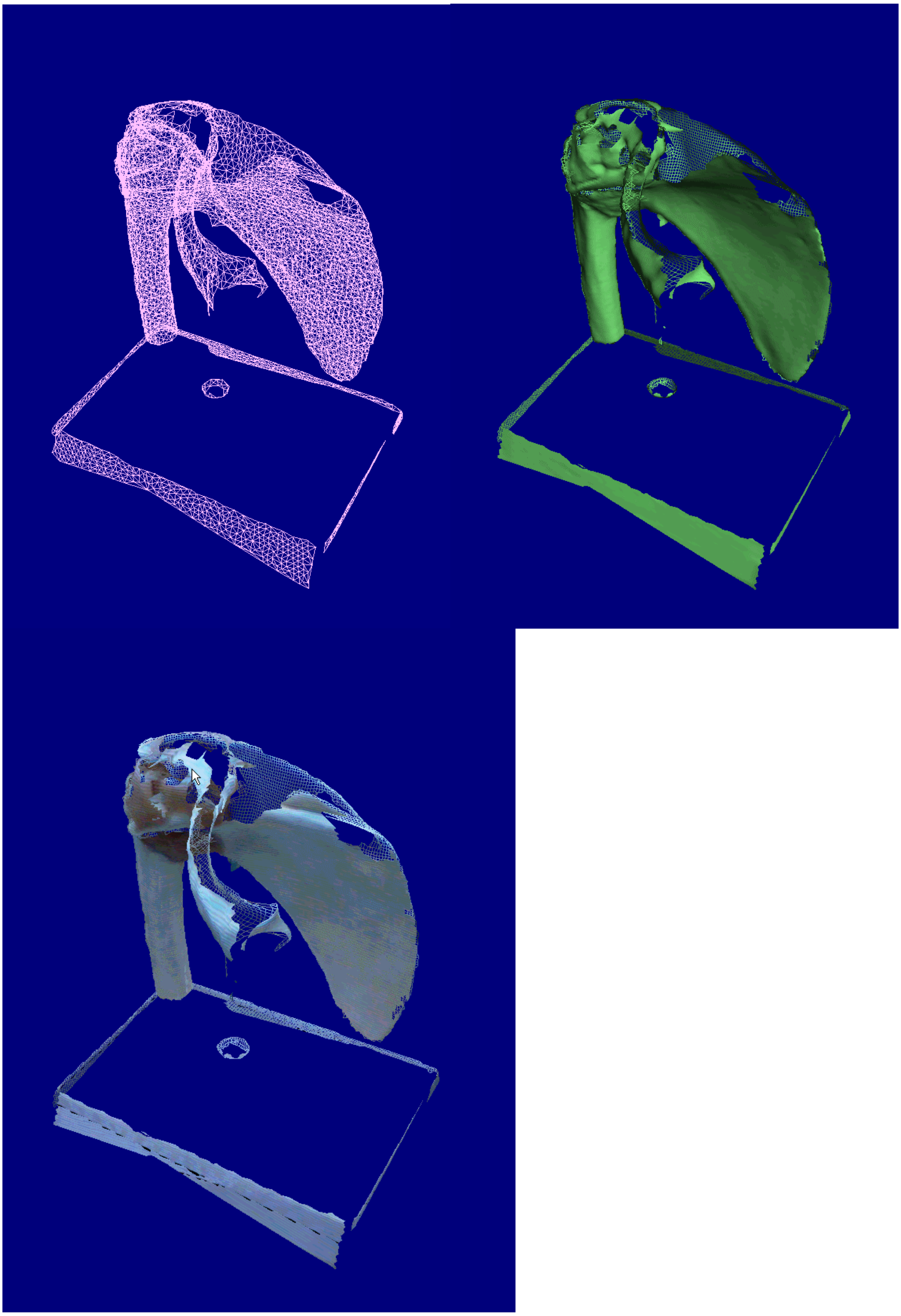

Fig. 5.2 Digitized Scapula (wireframe, shaded and with texture)