5 Staging, Preoperative, and Surgical Planning

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5.1 Introduction

Orthopedic oncologic literature has demonstrated that CAS is a useful and novel tool. PVP and IVN can potentially improve resection of tumors located in the pelvis (1–5) due to its geometrical complexity.

Formerly, surgeons planned their pelvic tumor surgery with a bidimensional printed slice image from computerized tomography (CT) and magnetic resonance image (MRI). Surgeons study the films and integrate CT and MRI, taking the oncologic margin into account. For years, this method has been the only alternative presenting insufficient accuracy and tumor recurrence due to wrong cutting margins. However, poor preoperative information led to wider resections as to achieve oncologic security.

Recently, technological developments allow physicians to manipulate digital medical images. In this way, integration of CT and MRI in a virtual simulation scenario is possible (6, 7). This virtual environment has the ability to include 3D bone tumor reconstructions. Specialists use a virtual simulation scenario to plan the cuts before the intervention and then execute it under IVN. That is to say that physicians have greater knowledge of the tumor area, improving the accuracy of the intervention (8, 9). The aim of this chapter describes the basics of PVP and its execution in pelvis sarcomas under IVN.

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5.2 Preoperative Virtual Planning

PVP works in a virtual simulation scenario where it is possible to merge digital medical images. This platform is potentially reliable for physicians in order to decide about further surgical techniques for a better quality intervention.

Moreover, PVP is a tool that can be used to plan a case and address possible surgical techniques. PVP is a platform where many specialists of different areas can see the case's approach together and interact before the real intervention.

Image acquisition protocols (CT and MRI) with cuts of 1 mm (millimeters) or less thickness were used.

The requested CT and MRI are merged (image fusion), and the oncologic margins are defined within the virtual scenario. The oncologic margin is calculated with dots in the healthy bone tissue and tumor limits. Specialists, depending on the tumor histology, measure the distances and determine the safe margins. In tumors such as in low-grade chondrosarcoma cases without edema, the oncologic margin limit is easy to define between healthy and pathologic bone tissue (Fig. 5.1), whereas in other histological types such as Ewing tumors, the dots are more difficult to fix (Fig. 5.2).

Each oncologic margin distance is unique according to the histological type and the definition of tumor limits. As general criteria in low-degree chondrosarcomas with no edema, the plan is done with a 5 mm margin, in osteosarcomas 1 cm, and in tumors with undefined limits 2 cm or more.

After the process of defining the margins of the tumor, physicians start planning the type of osteotomy they will perform in the OR. Each case is given a name after the number of planes in which it is going to be performed: uniplanar if it is only one plane, biplanar if there are two planes, and multiplanar if there are more than two planes (Fig. 5.3).

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Fig. 5.1 This MRI slice shows that the limit between healthy and pathologic bone is clear since there is no edema

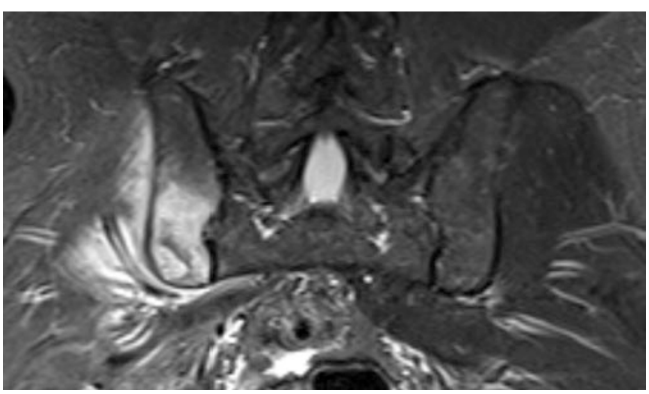

Fig. 5.2 This image shows a case where the tumoral limit is difficult to determine. This is frequent in Ewing tumors

The surgical approach is decided according to the proposed osteotomy; afterward, it is possible to perform a virtual resection. Specialists of different fields are able to actually see detailed features of the patient's pelvis and its tumor after virtual resection previous to the real intervention (Fig. 5.4).

Finally, after virtually resecting the tumor with its planned margins, physicians are able to foresee different reconstructive alternatives. Having access to the virtual library of banked allografts, bones allow to practice numerous reconstructions using structural bones (Fig. 5.5).

5.2.1 PVP Summary

1. Study the tumor in MRI.
2. Delineate margins according to histology.
3. Determine the conformation of planar osteotomy: uni-, bi-, or multi-planar.
4. Perform a virtual resection.

5.3 Intraoperative Virtual Navigation

Intraoperative virtual navigation (IVN) is the tool that executes PVP osteotomies.

This type of navigation is the optical navigation based on images, a system of infrared cameras (emission lights) found in specific instruments. The instrument is a tracker fixed on the patient and a pointer held by the surgeon. In this case, it has been used as active instrumental (powered by lithium batteries), although there is also passive instrumental (without batteries). The navigator has two monitors, one for technicians and other one for surgeons; both screens display the same (Fig. 5.6).

The first important aspect to mention is the place we are going to designate to the physical navigator in the operating room. It is important to place the device in the operating room after the sterile fields have been placed so as not to disturb the surgeon and avoid contamination.

The device is placed opposite to the surgeon so he can see the camera 2 m from surgical approach.

It must be determined in PVP the fixing site of the registrar. The fixing is the insertion of two pins between 3 and 4 cm diameter in the bone. It is of great importance to dispose such pins far from the tumor area so as not to disturb the surgeon during the intervention as well as disposing the pins where the camera can visualize them. Once the tracker is fixed, specialists proceed with registration process. Through this process, the virtual bone from planning and the real bone of the patient are compared and matched. Registration process can be divided in two parts, a primary and a secondary.

During primary registration, it is numerically determined those recognized bones from 3D reconstruction which can

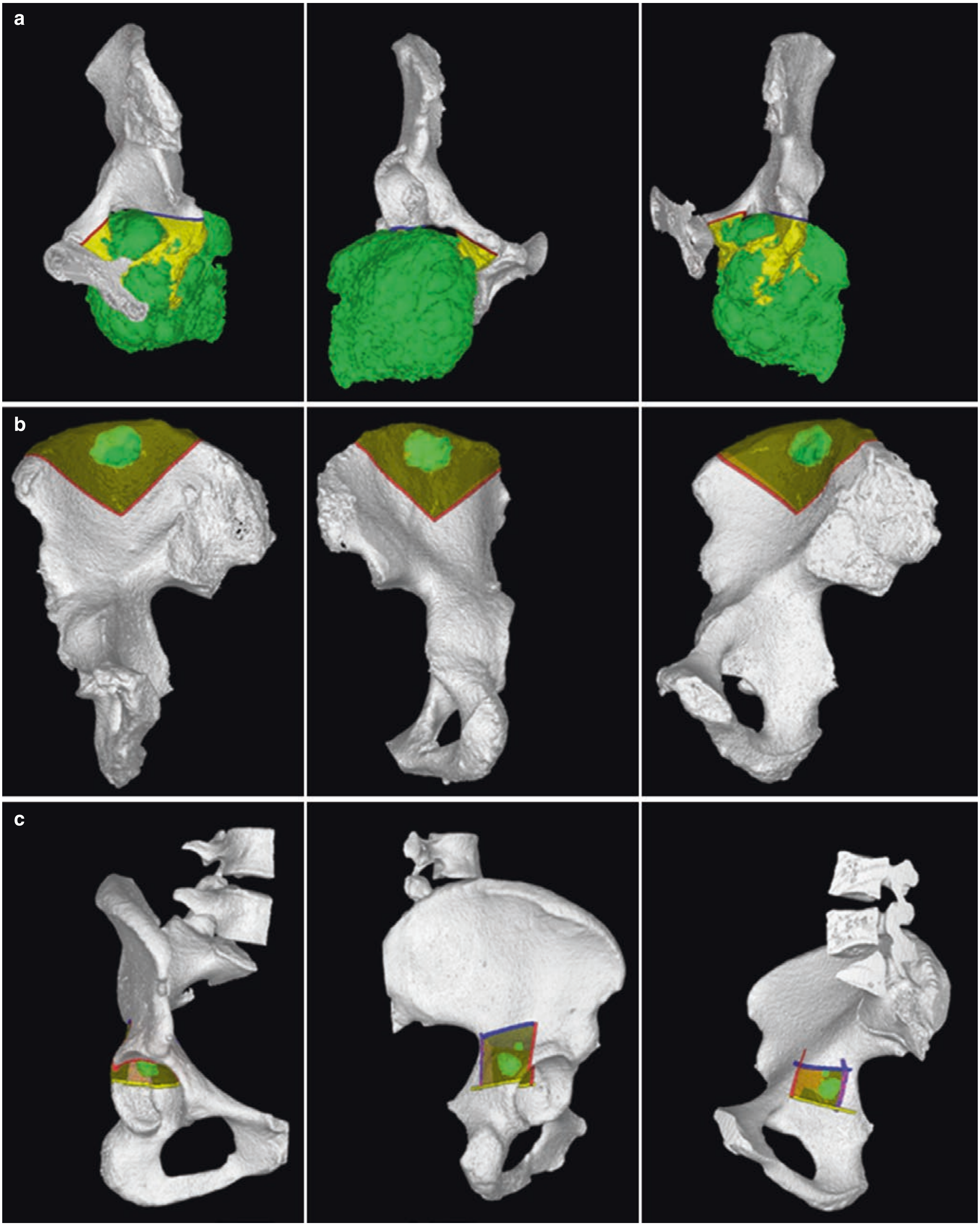

Fig. 5.3 Planar configurations: each configuration receives a different nomenclature. (**a**) Uniplanar, (**b**) biplanar, and (**c**) multi-planar

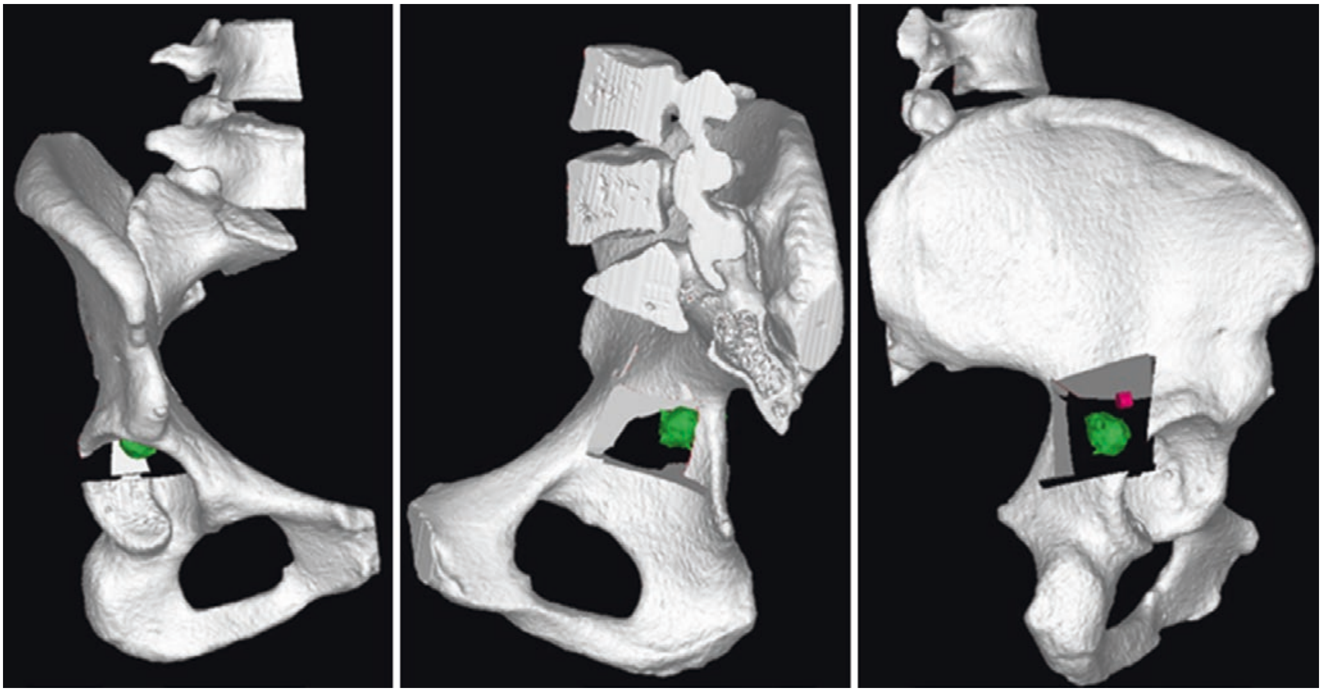

Fig. 5.4 A virtual resection is shown. The surgical approach is decided after a resection plan is built and evaluated in the virtual scenario

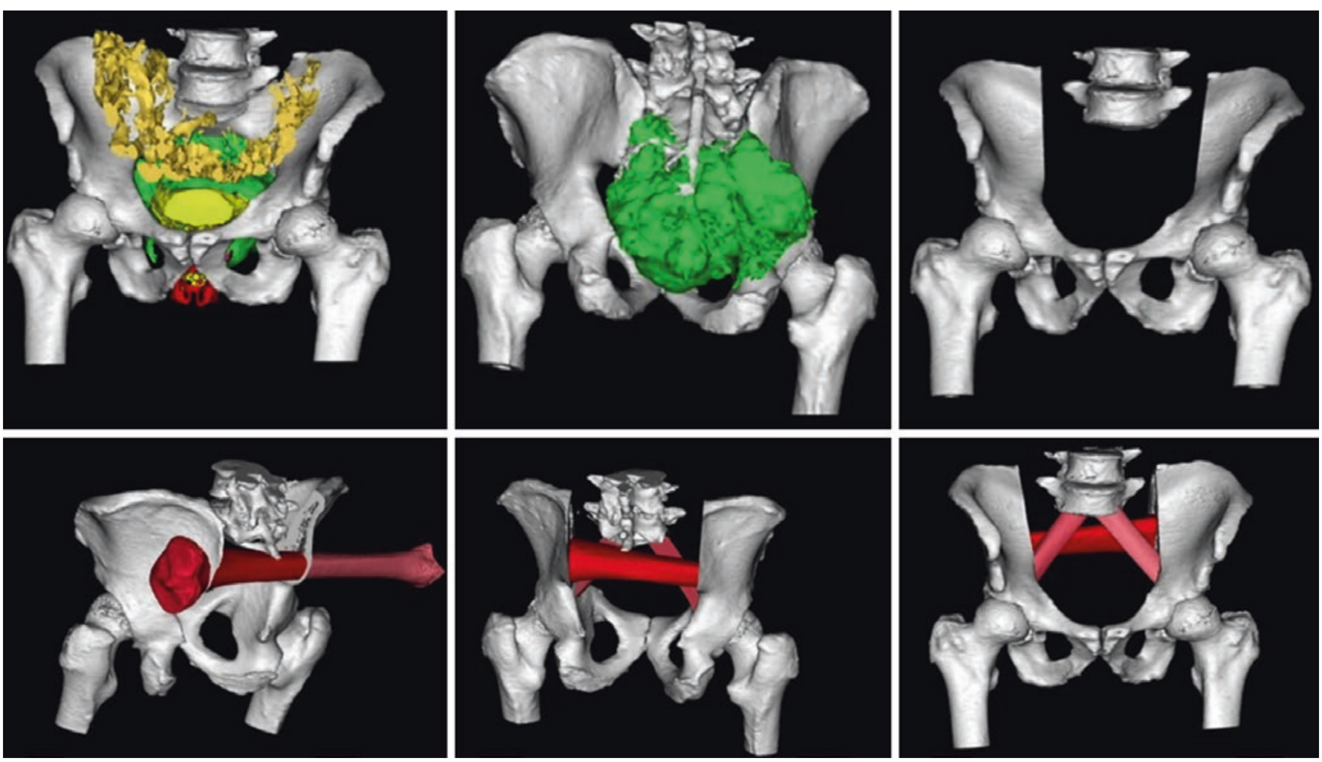

Fig. 5.5 Nonregular structural bone reconstructions using allografts bone models digitally stored in the virtual bone bank

Fig. 5.6 A navigation pointer in the front. In the back, the navigator screen showing the location of the tumor and the tip and angle of the pointer

be visualized after the approach. At least three landmarks are set. Then secondary registration consists of adding more landmarks to refine the area. This last step allows specialists to match completely 3D image with the real bone. In order to verify the accuracy of the process, specialists have to dispose the pointer over three different bone landmarks and corroborate visually that the pointer seen in 3D representation is found in air-bone interface (Fig. 5.7).

The following step is to mark the cut path in the bone with methylene blue that also resembles with PVP.

After marking the bone, the osteotomy is done with the saw blade. The saw blade thickness is foreseen in PVP, so it is left a 2 mm cut thickness.

When osteotomy is initiated, IVN is an asset in order to guide the procedure. The pointer is placed in the created slot, visualizing the exact position on the navigator screen and trajectory by three bidimensional windows.

Finally, an ultimate control can be done with the pointer after tumor resection. It is pointed to the remnant defect in order to verify visually the exactness of the osteotomy.

5.3.1 IVN Summary

1. Place the navigator device.
2. Tracker fixation.
3. Primary registration and secondary registration.
4. Air-bone check over three spots.
5. PVP navigation.
6. Defect control.

5.4 Accuracy in PVP and IVN

An experimental design scans the surgically removed specimen in a CT in order to determine the accuracy of the above-described procedure. The following procedure is to reconstruct three-dimensionally the surgical specimen and superimpose it to PVP (Fig. 5.8). This allows physicians to perform a comparative study between osteotomies virtually planned and those executed.

Although the first impression of the comparative study is a visual appreciation, virtual reconstructions and planes can be transformed into a map of dots (Fig. 5.8). This enables physicians to measure dot to dot, obtaining as a result a numeric value. A comparative study informs physicians quantitatively the accuracy between planned and executed.

The values can be expressed by colored graphs (colorimetric). For instance, green color is given when planned and executed osteotomy match. Red color is given when the osteotomy dangerously approached the tumor, and blue color is given when osteotomy shifted away from the tumor. Colorimetric graphics depict cut pathways behavior tridimensionally (Fig. 5.8).

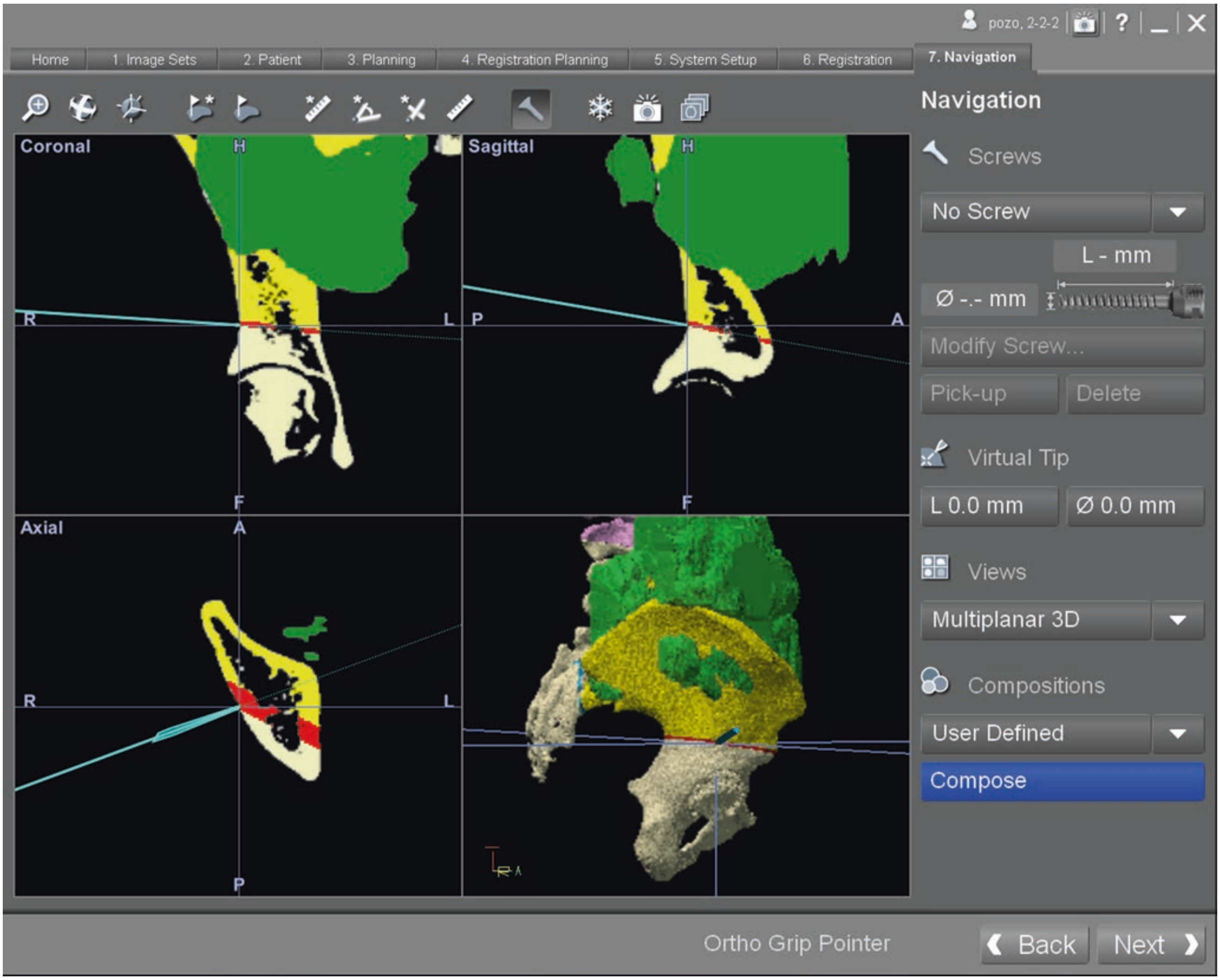

Fig. 5.7 The pointer is used to visually verify the registration process. This is done by checking the air-bone interface area in well-known locations

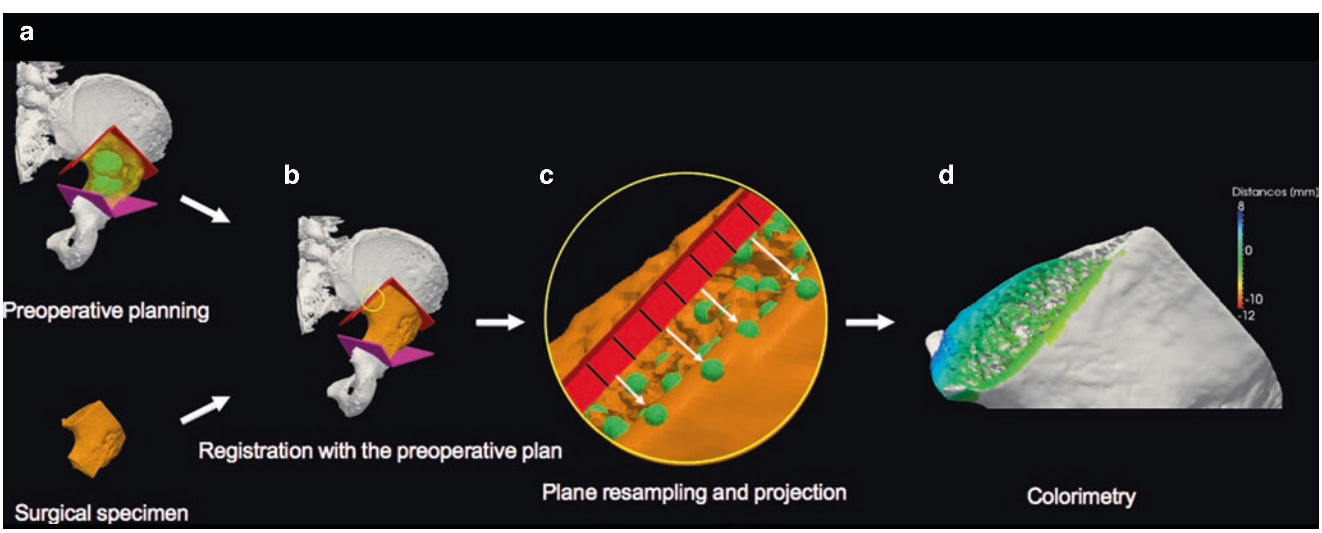

Fig. 5.8 The accuracy evaluation workflow. (**a**) The surgical specimen is CT scanned; (**b**) the preoperative plan is registered against the surgical specimen; (**c**) the distances from the osteotomy surface to the planar cut are measured; (**d**) the measured data is displayed so the surgeon can perform adjustments

5.5 Conclusion

PVP and IVN are tools used in the novel field of computerized assisted surgery area. They are important assets to perform pelvic sarcomas resections as they provide potentially optimal surface approach before surgery. Furthermore, these tools give specialists the necessary instruments to study a case in depth before the intervention and to prevent unexpected situations. Executing what was previously planned supported by accurate tridimensional images potentially improves safeness, quality, and, foremost important, predictability in osteotomies during oncologic surgery.

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