Intraoperative Measurement of Mounting Parameters for the Taylor Spatial Frame

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Summary: The Taylor Spatial Frame (Smith & Nephew, Memphis, TN) is a powerful tool in providing gradual correction of deformity. The Taylor Spatial Frame has the potential to allow for very accurate corrections achieved over one or more schedules through the use of the software on www.spatialframe.com. The accuracy of the frame is contingent upon the input of precise parameters. The correction occurs about a virtual hinge in space called the origin. The location of the origin is defined by its spatial relationship to the reference ring. Mounting parameters are the measurements that define the location of the origin (virtual hinge). We present a simple practical method for obtaining mounting parameters during surgery using standard equipment.

Key Words: Taylor Spatial Frame, mounting parameters, intraoperative measurement

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INTRODUCTION

The use of the Taylor Spatial Frame (TSF; Smith & Nephew, Memphis, TN) has changed the way the Ilizarov method has been applied for treatment of nonunions, deformity corrections, and limb lengthening.[1–3] With the TSF, we can correct 6-axis deformity (rotation and translation in the axial, coronal, and sagittal planes). The deformity correction occurs with the movement of 2 bony segments around a virtual hinge that is determined by the surgeon. The software application that is used to generate schedules for patients requires the measuring and input of accurate deformity, mounting, and frame parameters.[4]

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The mounting parameters define the location of the virtual hinge point—known as the origin—relative to the reference ring. The origin is usually at the apex of the deformity or at the fracture/osteotomy site but can be placed anywhere the surgeon desires. This point is determined preoperatively on x-rays and then located intraoperatively using C-arm fluoroscopy. Mounting parameters essentially tell the computer where the frame and the bone are in relation to each other. The more accurately we measure the bone-to-ring position, the more accurately the deformity can be corrected via the computer-derived schedule. We offer a novel technique for obtaining precise intraoperative measurements of the ring center and its relationship to the origin.

TECHNIQUE

This technique requires the assembly of markers that will be mounted to the reference ring. These markers, 2 for the anterior–posterior (AP) and 2 for the lateral frame offset measurements, can be assembled by any member of the team while the reference ring is being mounted. It is critical that the reference ring be mounted perpendicular to the long axis of the bone (reference fragment axis).

The following example of our technique is for a proximal tibial frame using a proximal reference two-thirds ring. Once the two-thirds proximal ring has been securely attached to the

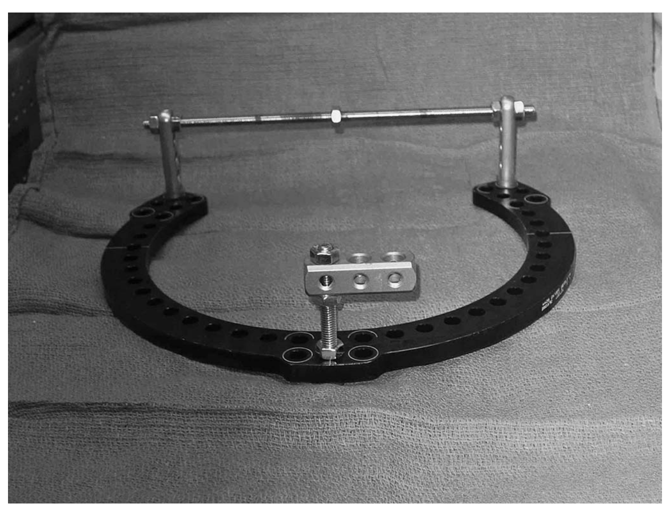

FIGURE 1. A 180-mm ring with a rod through a pair of 4-hole posts. This essentially closes off the ring. A ruler is used to ensure that the nut is centered. On the master tab, a 3-hole Rancho cube is mounted off a rod.

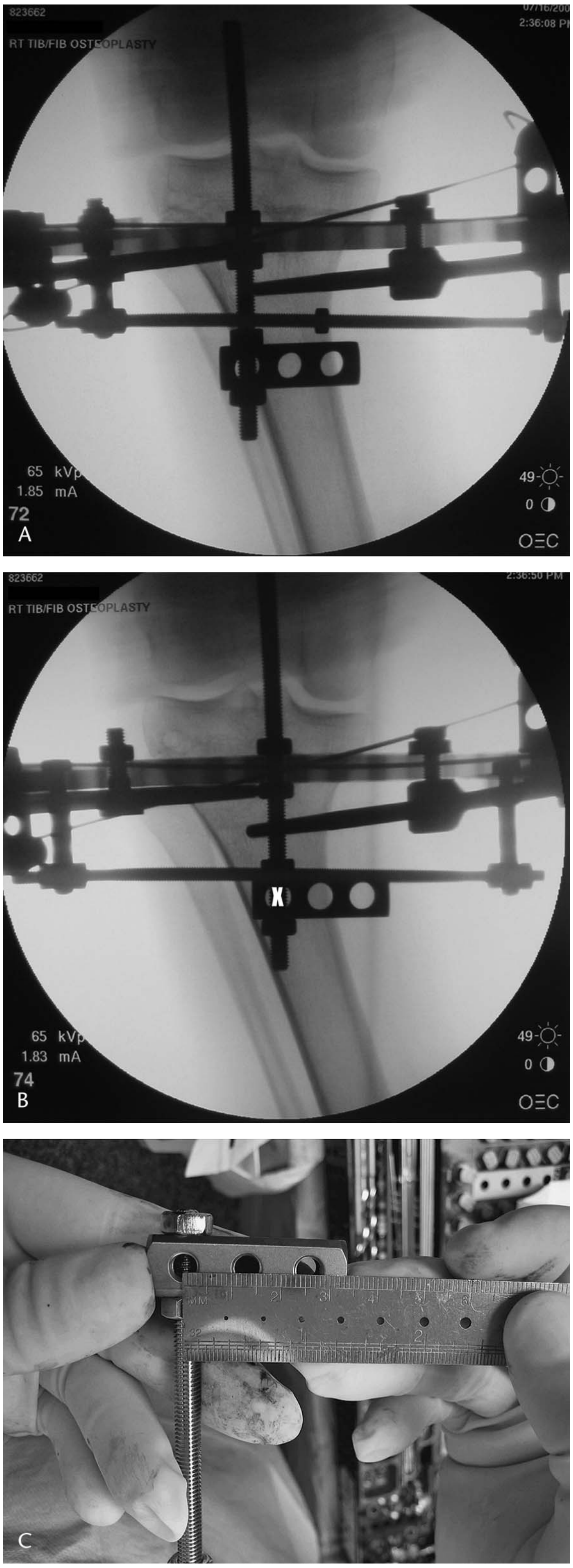

FIGURE 2. A, True AP image of the ring; notice the overlap of the anterior and posterior portions of the ring rendering the image as a straight line. Although the frame is properly angulated, the limb is rotated as evidenced by the medial displacement of the nut. B, Internal rotation of the limb has brought the center nut into position overlying the anterior rod. The origin in this patient (the center if the tibia) is overlying the center of the hole of the Rancho cube (marked with an ''X''). C, The surgeon then measures from the ring center (the middle of the hole through which the rod passes, marked with an ''X'' in B) to the point on the Rancho that overlapped the origin. In this case, the ''X'' is overlying the origin; there is no lateral displacement. Thus, the ring center is 0 mm to the origin.

patient, the mounting parameters may be determined. The AP parameters are determined first. To assemble the AP markers, the posterior marker is created by "closing the ring" posteriorly. We take a 200-mm connecting rod and place a nut in the center of it. A 4-hole male post is then attached to either end of the rod. The posts are temporarily mounted posterior to the leg onto the back of the reference ring in the most posterior holes (Fig. 1). In effect, this creates a full ring and allows the definition of a center point posteriorly. Using a ruler, the center nut position is measured from post-to-post to ensure that it is perfectly centered between the posts. (In the event that a full ring is used, a rod attached to the center hole of the ring will suffice as a posterior marker.)

AP Mounting Parameters

The anterior marker is created. It will be placed through the center hole of the master tab (anterior tab) on the reference ring. The marker is created by using a 3-hole Rancho cube (Smith & Nephew, Memphis, TN) placed at the distal end of a rod making an "L" shape. The rod is then mounted at the center of the master tab. The length of the rod depends upon the approximate distance from the ring to the origin but is typically 120 mm. The size of Rancho cube used may need to be increased depending on limb size and how centrally the ring is positioned on the tibia. Although x-ray magnification occurs secondarily to the offset of the Rancho cube from the bone, we feel this is negligible and is still more accurate than using standard plain films.

A true AP fluoroscopic view of the ring is then obtained. The ring must be seen as a straight line, so that the posterior and anterior portions of the ring overlap. The anterior rod and posterior centering nut are identified. Under static or live fluoroscopy, the limb is slowly rotated so that the anterior rod now overlaps the posterior nut (Fig. 2A, B). Once this is accomplished, that image is saved and evaluated. If the rod is centered over the origin (typically the center of the tibia), then the AP mounting parameter is "0" medial–lateral. Often the rod is lateral to the center of the tibia. In this situation, the holes of the Rancho cube are used as a guide to measure the distance from the rod (representing the center of the ring) to the center of the tibia (the common location of the origin). This distance is measured with a sterile ruler directly off of the Rancho cube in millimeters (Fig. 2C).

At times the rod can push against the skin over the calf during the measurement of the mounting parameters. This is acceptable because the rod is only on the patient for a brief period of time, and it does not cause harm to the patient. In the advent of a very large calf, the rod can be translated directly posteriorly through the use of plates off the Ilizarov set. This does not affect any other step in the process of obtaining the AP-mounting parameters.

Lateral Mounting Parameters

The C-arm is brought into the lateral position for a lateral x-ray of the reference ring. Markers are placed onto the ring. The new markers include the same rod–Rancho cube combination used as the anterior marker previously, and a 30-mm bolt (Fig. 3). The rods and bolt are attached to the center of the medial and lateral aspects of the ring, 180° across from each other. (The location of this spot varies depending upon the size of the ring. A 180-mm ring has 5 holes between the lateral tabs. The center hole is the center of the ring. A 155-mm ring has 4 holes between the lateral tabs, so there is no center hole. The markers must be placed either anterior or posterior to the true center of the ring. We typically use the more anterior hole. The distance from the center point of the ring (between the holes) and the center of the rod in the adjacent hole is measured. This distance is added to the ultimate distance measured from the rod to the origin). Once these markers are mounted, the limb is positioned for a true lateral fluoroscopic image. Again, it is imperative that the ring appears as a straight line on the screen. The limb is rotated until both rods overlap each other. This image is saved for evaluation (Fig. 4A, B).

The surgeon then measures the distance from the center of the first hole (the hole through which the rod passes) to the part of the Rancho cube that overlaps the origin. This is the distance from the ring center to the origin (Fig. 4B).

Axial Mounting Parameters

Axial offset, the axial distance from the ring to the origin, is obtained by measuring the length of the Rancho–rod combination. If the Rancho cube is placed over the origin, then the measurement runs from the center of the frame to the center of the Rancho cube. Using the Rancho–rod combination from Figure 2B, the distance would be from the ring to the "X." In this case, the ring center was 30 mm proximal to the origin (measurement not pictured).

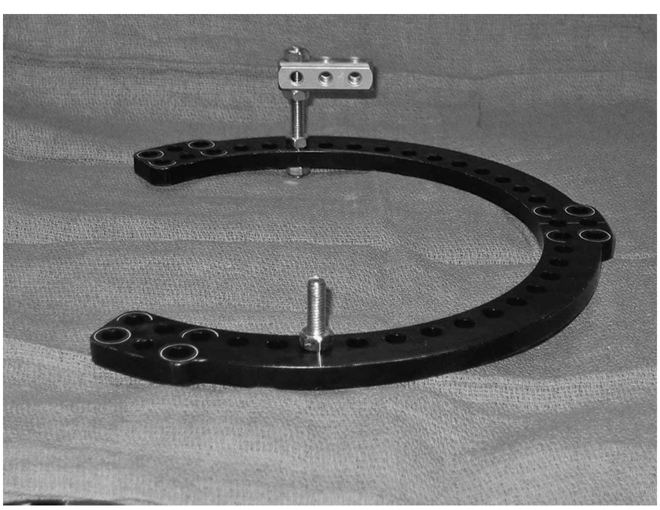

FIGURE 3. The set-up for the measurement of lateral mounting parameters.

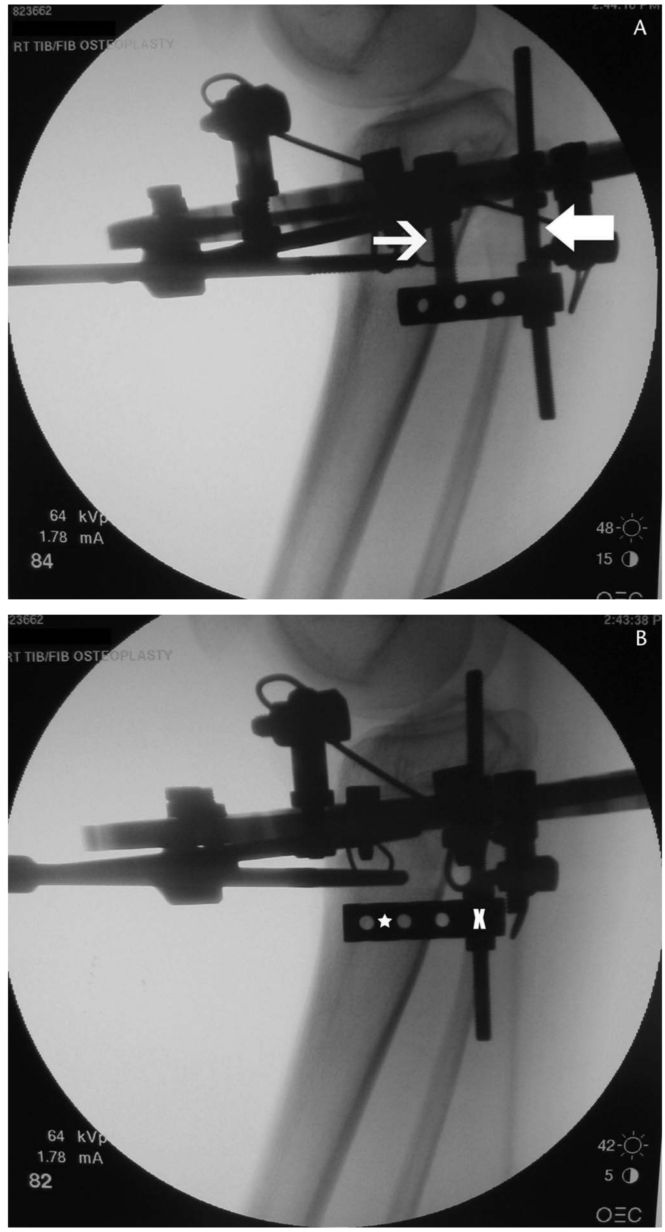

FIGURE 4. A, The ring is once again rendered as a straight line. However, the rotation is not quite perfect. The rod–Rancho cube combination (fat arrow) does not overlap the other rod (skinny arrow). B, The 2 rods are now overlapping and the origin (the center of the tibia—marked with a star) is halfway between the third and fourth holes. In this patient, the ring center (marked "X") was 33 mm posterior to the origin.

The placement of the rings in this fashion also enables accurate measurement of any rotational parameters that must be accounted for that may have occurred during mounting. Often the origin can be identified on the AP fluoroscopic image and marked on the skin. The distance from this mark to the ring is measured directly against the skin with a ruler.

The senior author also records the mounting parameters and the strut sizes and lengths. An assistant takes down the numbers, and then later, all of the parameters are entered into the system on www.spatialframe.com and a program is created (Fig. 5). A prescription is generated and given to the patient. The fluoroscopic image showing the ideal representations of the reference ring in the AP and lateral planes are printed and saved in the patient's chart in case the mounting parameter sheet is lost.

DISCUSSION

The TSF is an evolution of circular fixation that relies upon the basic principles of the Ilizarov Method and adds the concepts of Chasles Theorem of 6-axis motion.[5] The combination of the modularity of the frame and the online module makes the TSF an incredibly powerful tool in the hands of the orthopedic surgeon for correcting deformities.

The TSF is theoretically capable of accuracies to 1/1,000,000 inch and 1/10,000 degree.[6,7] The real world application of the frame does not allow such immeasurably accurate corrections, only to approximately 1 mm and 1°.[6,7] The capabilities of the frame are predicated upon accurate measurements of the mounting parameters. Slight errors in the measurement of the mounting parameters can be manifested as malreductions. It is for this reason that the mounting parameters must be accurately obtained. No technique is perfect, as currently most measurement techniques rely on human evaluators. One of the major benefits of the TSF is the ability to run further residual corrections as needed without having to remeasure the mounting parameters. Furthermore, each residual correction is more accurate than the last despite the possibility of poor initial mounting parameter measurements.

Certain factors will affect the ability to obtain accurate mounting parameters and may result in new deformities during bony corrections and lengthenings. The further away the reference ring is from the origin, the less accurate the measurements will be. For this reason, the ring closest to the origin is usually chosen to be the reference ring. The reference ring needs to be mounted perpendicular to the long axis of the bone in both AP and lateral planes. If the ring is mounted in varus or flexion, for example, there is currently no way to convey this information to the computer, and it will assume the ring is straight (perpendicular). Interestingly, the other ring (corresponding ring) does not have to be mounted so carefully and needs only be fixed to the leg comfortably. If the reference ring is mounted with an unintentional rotational deformity (eg, the master tab is not in line with the patella), then that can be accounted for in the program by entering the degrees of rotational deformity under the "rotary frame offset" section. (If there is unintentional rotary frame offset, then we will obtain the mounting parameters in the fashion described above. All subsequent images taken for planning residual schedules will be taken as a true AP and Lateral of the *tibia* and not an AP and lateral of the *master tab.*) The worst example of these circumstances is when the ring is mounted poorly (not perpendicular) in the lateral plane and it is far away from the origin. The further away the ring is, the further translated it will be in the lateral plane from the intended origin.

The authors use this technique every time a TSF is placed. We feel that it is easily reproducible in the operating room and allows for accurate measurement of the mounting parameters. What is more, all the information that is needed to

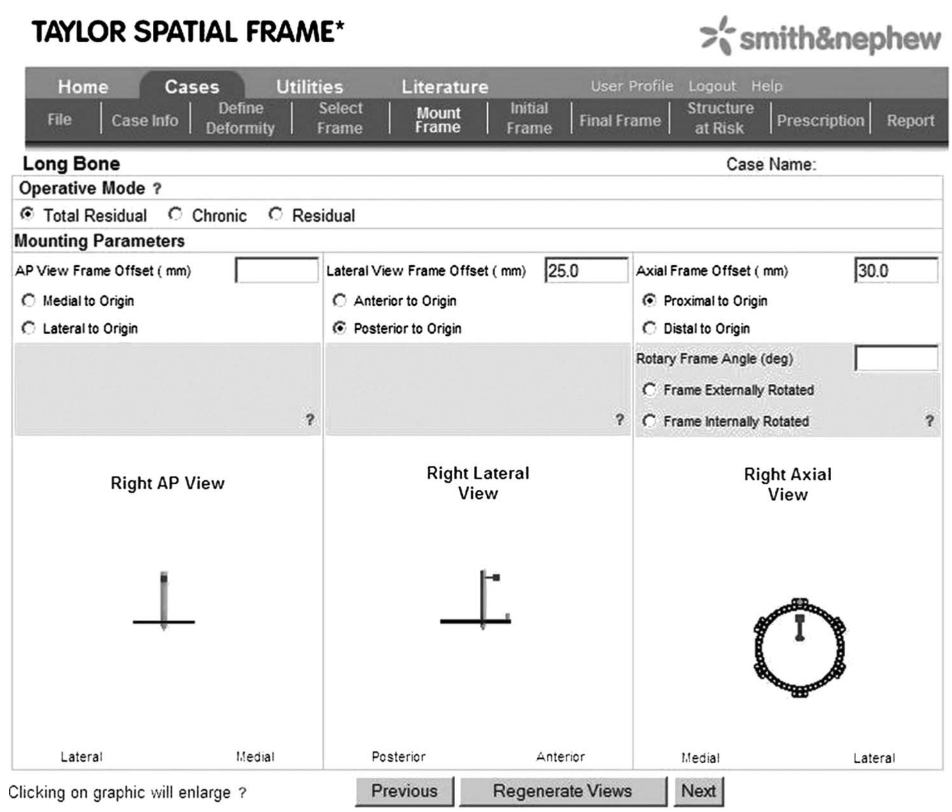

FIGURE 5. An example of the mounting parameters website at www.spatialframe.com.

start correction is available to the surgeon while still in the operating room. We feel that this technique is quick and cheap utilizing equipment already available in virtually all settings in which a TSF will be used.

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