Introduction to Deformity Analysis and Planning

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The expression "deformity planning" is easily and incompletely understood as the analysis of imaging of a patient; it is the complete analysis of the patient. Etiologies, previous interventions, age, patient expectations, level of activity, deformity being either static or dynamic, and patient patience play important roles in deciding the treatment strategy. A treatment plan may sometimes aim to overcorrect or under-correct a deformity or even create a deformity in a normal bone segment to compensate for another. Therefore, an analysis of an extremity deformity and treatment planning starts before referring the patient to the radiology department and is never limited to imaging.

17.1 Normal Anatomy and Standard Values

To define a deformity, normal limb alignment has to be defined. Three-dimensional bone and joint architecture and three-dimensional deformities cannot be interpreted and quantified alone. Therefore, dividing the deformity into frontal and sagittal planes is an established concept. Even the most complex deformities are measured in these two planes. However, two more parameters are required to accurately define the three-dimensional problem: rotation and length. These four values form the basic characteristics of a deformity.

To analyze the deviation from "normal," the normal anatomy has to be defined. Many studies have assessed and tried to quantify the normal lower extremity measurements. Different researchers reported different methods to analyze and interpret deformities [1–5]. This resulted in conflicting values and incompatible methods in the literature. Paley finally defined the current method, which is widely used, and standardized the deformity analysis [6]. Abbreviations follow this constant order: (1) mechanical (m) or anatomic (a); (2) medial (M), lateral (L), anterior (A), or posterior (P); (3) proximal (P) or distal (D); (4) femoral (F) or tibial (T); and (5), the last letter "A" for "angle." Details of this concept, normal values, and principles of the analysis will be covered in the following chapters.

17.2 Radiologic Assessment Methods

Proper radiologic imaging is the mainstay of deformity analysis and can only be obtained with careful teamwork. Drawing correct lines or interpreting the measurements is only one aspect of this procedure. Technicians should be meticulously trained in clinics that deal with deformities, and briefly informing the patient about the position is necessary to achieve best results.

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Fig. 17.1 To determine the correct anteroposterior position, the extremity is rotated so that the patella faces forward

There are several techniques for assessing lower extremity alignment and quantifying deformities. An ideal radiologic assessment method should be low in cost and radiation while remaining accurate and reliable. Conventional techniques have various advantages and drawbacks, each of which will be discussed in this chapter. Recent advances in radiologic techniques offer low-dose accurate and reliable imaging.

Regardless of the radiologic method, patient positioning is the key element of obtaining proper imaging. For frontal plane assessment, the lower extremity rotational reference point is always the patella. It is positioned by palpating the patella between thumb and index fingers and rotating the lower extremity to orient it forward (Fig. 17.1) [2]. This technique eliminates errors related to torsional deformities of tibia. The exception is fixed subluxation or dislocation of the patella, where the knee flexion–extension plane is used to determine the correct rotation. Another critical point is to adjust limb shortening with blocks. Patients tend to compensate the shortening with contralateral hip and knee flexion, ipsilateral equinus, pelvic tilt, and spinal angulation. Technicians should support the short limb with blocks so that the patient evenly bears weight in both limbs without the mentioned mechanisms and both anterior superior iliac spines are level (Fig. 17.2) [6].

Sagittal plane assessment requires the extremity placed perpendicular to the beam axis. As with the frontal plane, sagittal plane assessment also requires weight-bearing radiographs. There is a 3–5° rotational difference between flexion–extension axis of the knee and the orthogonal plane of patella anterior position [7]. Both can be used; however, the ideal position is the orthogonal plane to the patella forward position, where the femoral condyles do not overlap. To move the contralateral hip and pelvis out of the view, the pelvis is rotated 30–45° externally.

17.2.1 Plain Radiographs

It is the most basic imaging method used in deformity analysis. Although never adequate for a proper analysis, it will accurately and reliably assess the deformity in a bone segment or a joint. Two orthogonal weight-bearing images are obtained for standard evaluation. Reference values are obtained from the contralateral side or standard values are used. Plain radiographs can only be used as an analysis tool, if the deformity is localized in a segment and other anatomic locations are previously assessed. Otherwise, compensatory secondary deformities or accompanying deformities can easily be missed. It can be used alone for deformity analysis of upper extremities or for follow-up of a long bone segment.

17.2.2 Teleroentgenogram

A long 1.3 m (51 in) cassette is used and a tube is placed at 305 cm (10 ft). This method causes a magnification error of 4–5 %. If necessary, a magnification marker can be positioned on the same

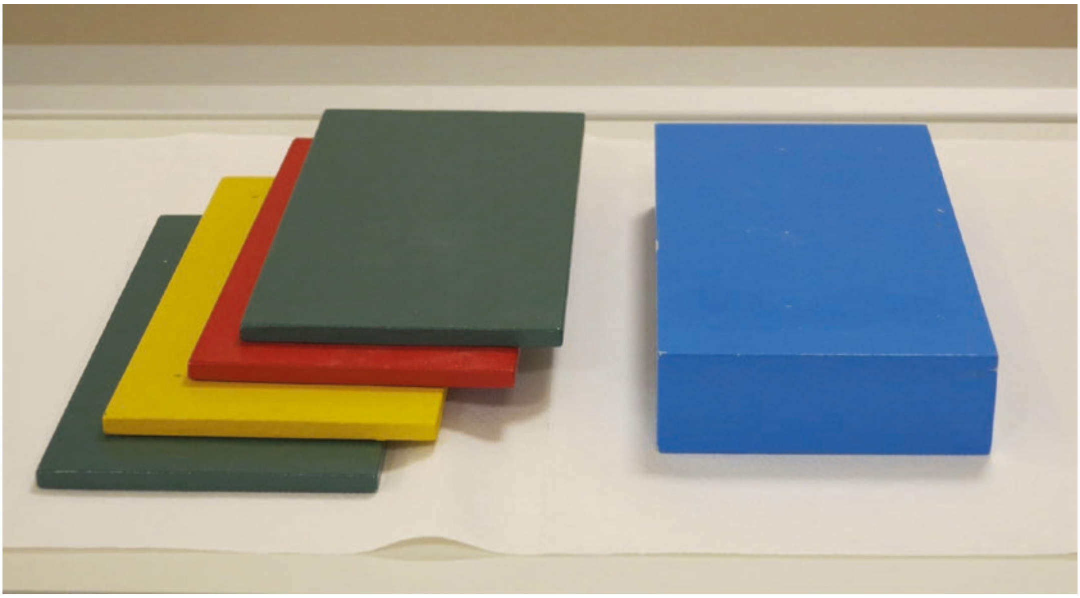

Fig. 17.2 Blocks in various sizes help the technician to level the anterior superior iliac spine and distribute body weight evenly between extremities

plane with the bone to correct the error. With this technique, a beam is targeted at the knee; therefore, the upper and lower ends of the image show brightness problems and distortion [8]. A single shot requires a higher dose to create an image on a wider surface. This is the most common method used.

17.2.3 Scanogram

Scanograms utilize three consecutive shots to form the image. Images target the hip, knee, and ankle and are not combined; therefore, it is not possible to perform a complete deformity analysis. It is possible to assess the orientation and angular relation of joints to each other; however, anatomic axis and diaphyseal deformities cannot be assessed. Low-dose radiation is the advantage of this technique and can be used in specific clinical scenarios.

17.2.4 Orthoroentgenogram

This was first described by Green et al. in 1946 and later modified as a standing imaging technique by Saleh et al. [9, 10]. A 105 cm high, 35 cm wide with 5 cm grid cassette is placed behind the standing patient. Three images targeting the hip, knee, and ankle are obtained and combined to form a single, long, standing image. Unlike in scanograms, there is no gap between the images and one continues into the other. The patient has to stand very still between shots. This is the most accurate conventional imaging technique, minimizing the distortion and magnification error (Parallax). Magnification markers can be used to increase the precision of measurements.

17.2.5 Computerized Tomography (CT) and CT Scanogram

This technique utilizes the lowest dose and flexion contractures do not affect the obtained image. The beam is always orthogonal to the bone; therefore, there is no magnification error. However, the costs of the hardware and non-weight-bearing image are the disadvantages of the technique. CT is the only radiologic assessment method to measure rotational deformities. It is useful as a complementary imaging method, instead of a stand-alone deformity analysis tool.

17.2.6 EOS

Low-dose stereoradiography is a new imaging technique based on a multiwire proportion chamber for particle detectors, named EOS (EOS Imaging, Paris, France). The system consists of a C-shaped vertical travelling arm that supports two image acquisition systems placed orthogonally, each composed of an X-ray tube and a linear detector. The source and detector thus move together, with the beam always horizontal to the patient [11–13]. The system provides 3D images, with low-dose radiation. The patient stands stationary during the 20 s scanning process, it is therefore vulnerable to motion artifact, but it is more accurate than an orthoroentgenogram [14].

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