8 Periprosthetic DXA

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8.1 Introduction

The first studies on measurement of periprosthetic bone mass started at the end of the 1980s. The single-photon absorptiometry (SPA) devices were soon abandoned due to the low spatial resolution. Also the devices for dual-photon absorptiometry (DPA) were limited in terms of spatial resolution, scan times, and poor precision; therefore, the application in the orthopaedic field was stopped after a few studies [1]. The introduction of dual-energy X-ray absorptiometry (DXA) marked a decisive turning point, so that these facilities were implemented on the first specific analysis software to measure the bone mineral content (BMC) and the bone mineral density (BMD) in the proximity of metal implants by their automatic insulation through recognition of extreme density outside the normal range of bone [2]. Additionally, the algorithms detect the bone-to-soft tissue and bone-to-implant interfaces, and the effects of heavily attenuating implants can be excluded. At the beginning of the first DXA applications, the methodological issues to evaluate accuracy and precision of the densitometric parameters were tested, and thereafter various analysis protocols for the study of bone remodeling around different stem design of cemented and uncemented prosthesis implants were proposed. After having obtained many encouraging results, the application of DXA technique in the orthopaedic field of research was gradually extended to different areas of interest and in particular to study:

- preimplantation bone characteristics;
- reaction of the bone to implant metal;
- periprosthetic bone stock;
- influence of stem design and different weight-bearing regimes after implant on bone remodeling;
- longitudinal evaluation of time-related bone remodeling after implant.

Periprosthetic bone loss is one of the most common complications of total hip arthroplasty (THA) and total knee arthroplasty (TKA). The aseptic loosening of prostheses and periprosthetic bone loss are thought to be consequences of both stress-shielding and an inflammatory process induced by foreign-body particles. Loss of periprosthetic bone mass can compromise the outcome of arthroplasty and may predispose to loosening and migration of prosthesis, periprosthetic fracture, and to problems in revision arthroplasty [3, 4]. Several diagnostic tools are available in the clinical diagnosis of failed arthroplasty (see Chaps. 6–7), but most of these

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techniques are insensitive, nonspecific, and imprecise for the determination of quantitative changes in bone mass about metallic prosthesis [5–10].

Qualitative data on periprosthetic bone can be obtained with magnetic resonance imaging (MRI), computed tomography (CT), and radiography. Scintigraphy is a sensitive but nonspecific technique for diagnosing loosening. MRI will often provide better anatomical details for preoperative planning in extensive deep collections although the portion of the image adjacent to the prosthesis will be degradated by metal artefacts [5]. Recently, it was reported that CT shows more and larger periprosthetic lesions than radiographs around an ankle prosthesis, and they recommend adding CT imaging to postoperative follow-up after total ankle arthroplasty for patients with suspected or known periprosthetic lucencies on radiographs [6]. Other prospective studies showed that quantitative evaluation of periprosthetic bone remodeling using quantitative CT allows an accurate analysis of bone structures with a consistent reduction in soft tissue and metal artefacts [7, 8]. However, these CT studies do not describe the method used to position the region of interest (ROI) to minimize the operator's intervention during the monitoring of periprosthetic BMD, and no data are available related to the precision of measurements performed. At the present time, owing to the high radiation dose required for CT imaging and the high cost of utilizing these technologies, the method is restricted to research purposes. Standard radiographs give direct information on prosthetic position and bone morphology, and they were applied to evaluate loosening and bone remodeling after prosthesis implant [9], but as reported by Engh et al. [10] are not very sensitive in the quantitative evaluation of periprosthetic bone resorption. In fact, although the method can precisely monitor the geometric qualities in the bone, bone mass changes of less than approximately 30 % are difficult to visualize. Furthermore, the radiographic features did not correlate well with clinical outcome [2]. This may reflect a true lack of correlation or might result from poor precision and accuracy of radiographic assessment.

Changes not already visible on standard X-ray films can be detected early with DXA [2, 3]. The measurement of bone mass, since the first studies, was an indirect index of redistribution of the mechanical load induced by a particular prosthetic design and of the resulting biological response of bone [2, 11]. Using DXA periprosthetic software, it is possible to both quantify the host bone response in the presence of a prosthesis stem and relate it to its specific design, and study the dynamics of bone–prosthesis interaction. A cementless stem provides excellent results in long term if it has a good primary stability, which in turn ensures a good osteointegration (secondary stability). It is well documented that the more uniform is the transmission of forces from the stem to the bone, the smaller will be the phenomena of stress-shielding. Moreover, the more is the transmission of forces along the stem the greater is the stress-shielding [12, 13]. Periprosthetic bone resorption may be reduced in the absence of other complications, the longevity of the implant avoiding the prosthesis aseptic loosening. From this and other well-established scientific evidence was born and expanded with the passing of years the interest in the field of orthopaedic applications of the DXA technique. Although the periprosthetic DXA can be applied to evaluate different prosthesis joints such as humeral head [14] and spine [15], the majority of studies are currently conducted on hip and knee implants. This chapter summarizes the basic principles of periprosthetic bone densitometry and its clinical applications in the management of hip and knee arthroplasty in the light of a brief review of the literature and our own experience.

8.2 DXA Technique and Periprosthetic Software

DXA technique. Currently, DXA is the most widely accepted method for measuring periprosthetic bone mass for its accuracy, reproducibility, and low invasiveness [2, 16–18]. This technique uses X-ray absorption to determine the amount of bone in specified skeletal regions. DXA is commonly used for monitoring bone changes related to ageing, metabolic disorders, drug therapies, etc. Because X-ray tubes produce a beam that spans a wide range of photon energies, the beam must be narrowed in some fashion in order to produce the two distinct photoelectric peaks necessary to separate bone from soft tissue. The major manufacturers of DXA systems in the United States have chosen to do this in one of two ways. GE Healthcare of Madison, WI, and Norland Corp./Cooper Surgical Company, Ft. Atkinson, WI use rare-earth K-edge filters to produce two distinct photoelectric peaks. Hologic Inc., Waltham, MA, uses a pulsed power source to the X-ray tube to create the same effect. In these devices, the metal removal analysis algorithms are available. The amount of bone in the beam path is calculated as BMC in grams. BMC is then divided by the projected area of the region scanned, and this is reported as the BMD in g/ cm^2. BMD thus provides an "area density", representing bone concentration in a given region, corrected for size of that region. The DXA output is therefore similar to the AP projection in conventional radiography where a three-dimensional structure is imaged in two dimensions. The radiation dose is low (< 5 mrem/scan) [7], and scan time is very fast ranging from 4 to 12 min in relation to the equipment used. Phantom tests have shown that DXA is accurate for determining periprosthetic BMD with an error below 1 % [2].

Periprosthetic software. The DXA scan of sites containing metal is taken in a similar fashion as scanning other bone sites. Because the bone dimensions, such as the cortical shell, are considerably smaller than in the equivalent spine or hip regions, higher spatial resolution is needed. The metal removal software excludes the contributions of the heavily attenuating metallic implant, measuring BMD solely on the periprosthetic bone. Specialized algorithms automatically detect bone–soft tissue and bone–implant interfaces. This is necessary since precision results are better if the computer algorithm is allowed to define the edges of the bone or metal regions compared with manual exclusion. Once the metal-excluded bone region has been defined, the bone map is broken into regions small enough to be sensitive to local bone adaption but large enough to have adequate precision usually not less than 1 cm^2. There is no periprosthetic single ROIs analysis protocol that is universally accepted. To study periprosthetic hip, the most popular are the Gruen zones, originally defined for radiographic assessment of bone quality [19]. These seven regions are typically to be good compromises between precision and sensitivity. That is, smaller regions will have lower precision but higher sensitivity. However, different protocols of analysis have been proposed to adapt them to the study of different stem design [11, 20] and to evaluate bone remodeling around different metal joint prostheses [21–23]. Lunar GE Orthopedic software measures BMD on the medial and lateral sides of hip implants using an automated region of ROI positioned according to Gruen zones to minimize the operator's intervention (Fig. 8.1). Lunar has also included an optional cement exclusion boundary layer to aid in removing the effects of overestimation due to cement around prostheses [16]. Hologic metal removal and Norland software include a general ROI analysis that allows the user to create ROIs of arbitrary size and location, including the Gruen zones (Fig. 8.2). These softwares also allow for the mirror image of the analysis ROIs to be superimposed onto the contralateral femur (Fig. 8.3), which can be useful in different research applications, for example to compare operated versus unoperated limb or to compare different length prostheses (Fig. 8.4). The periprosthetic algorithms are most commonly used to analyse bone stock surrounding hip, knee arthroplasties, and spine fusions.

Accuracy. In bone densitometry, accuracy describes the degree to which the measurement of bone density reflects the true bone density. In other words, if the bone in question was removed from the body, measured, and then ashed and assayed, the true bone density could be determined. The accuracy error is usually described as %CV that describes the proportion

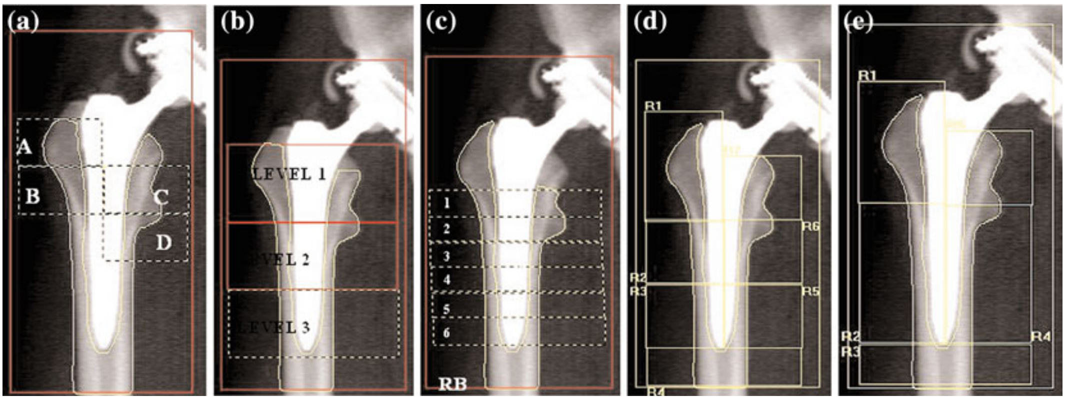
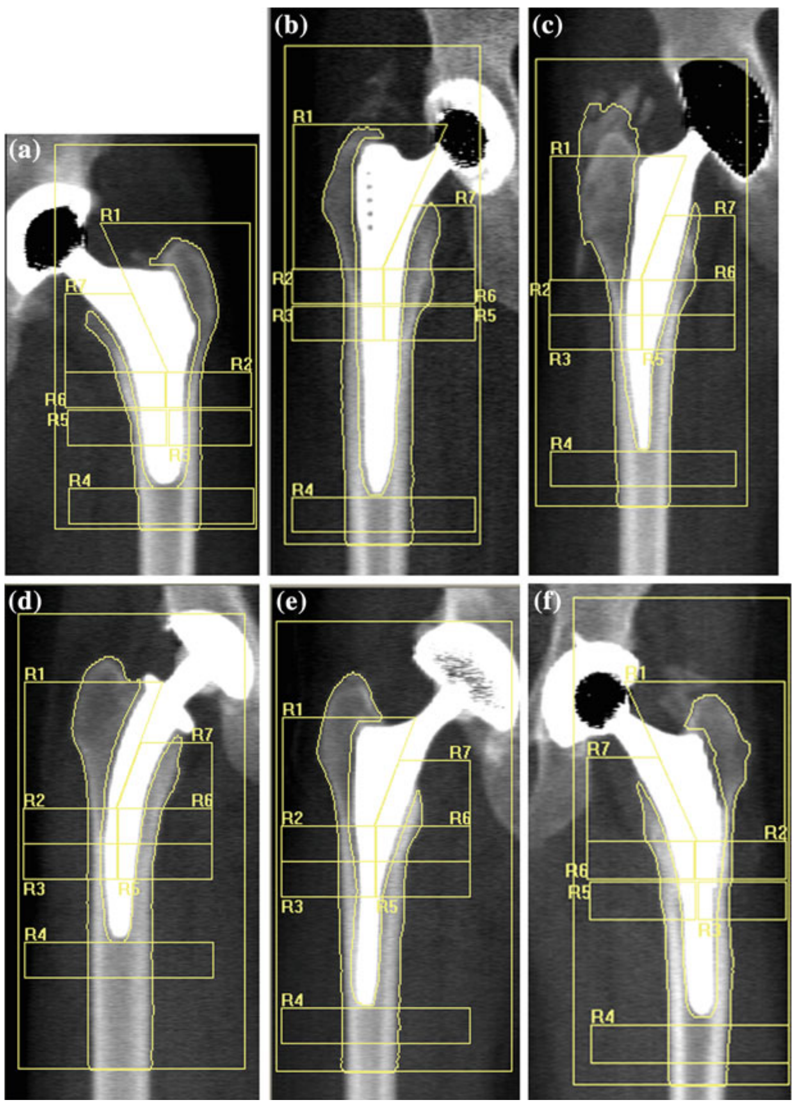


Fig. 8.1 A few example of periprosthetic DXA protocols of analysis after total hip arthroplasty, proposed by various authors. (**a**) Kiratli et al. [2]; (**b**) Engh et al. [26]; (**c**) Kilgus et al. [17]; (**d**) Trevisan et al. [11]; (**e**) Albanese et al. [20]

Fig. 8.2 Periprosthetic DXA was used to compare bone mass after uncemented THA of a custom-made stemless design (**a**) with five groups of conventional cementless implants: Alloclassic (**b**), Mayo (**c**), CFP (**d**), IPS (**e**) and ABG (**f**). The adaptive bone changes of the proximal femur 3 years after implantation were evaluated. To allow the comparative analysis of prosthesis with different length of the stem, ROI 3 and 5 are placed more proximally with respect to standard Gruen analysis protocol [33]



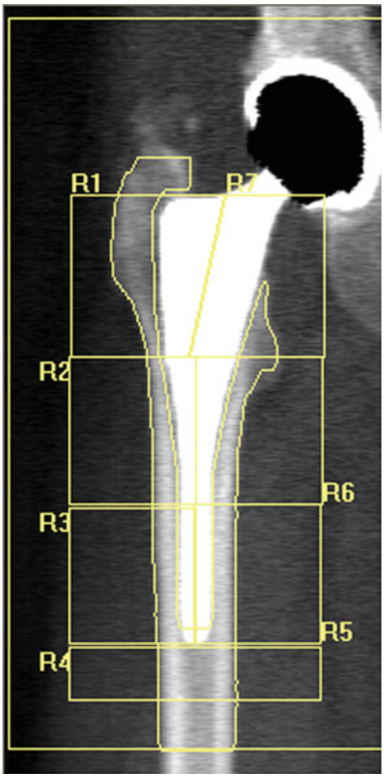


Fig. 8.3 Periprosthetic DXA: example of 7-ROI protocol of analysis according to Gruen zone

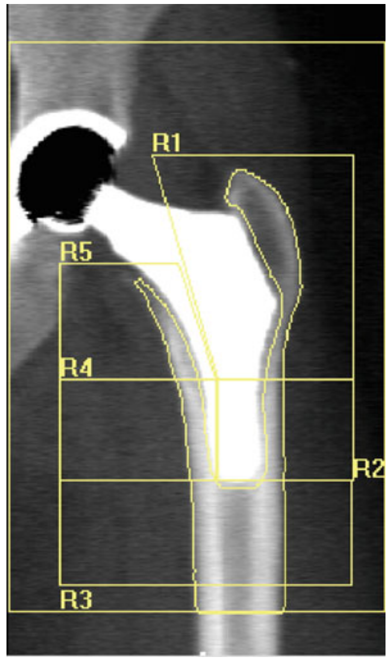


Fig. 8.4 Type 1 custom-made femoral implant featuring an extremely short distal stem. DXA images of the proximal femoral periprosthetic analysis with 5 regions of interest: R1–R5, [20]

by which the individual measurements vary from the mean value as a percentage that is synonymous with "true BMD". Therefore, lower values of %CV are better than higher because of the %CV describing the variability of the measurement about the true BMD. Different factors may affect the accuracy. It was reported that bone cement infiltration into bone and the cement mantle around the prosthesis may affect accuracy because they determine an artificial increase in BMD [3]. A study on implanted cadaver femora reported [24] that positioning of patients is essential to obtain reliable results. Rotation of the femur about its longitudinal axis altered the BMD measurement. The largest variations with rotation were in region 7, the calcar and lesser trochanter: 15° internal rotation caused a 24 % difference compared with neutral rotation. This is important as it is in this area where marked bone remodeling and resorption occur after joint replacement [13].

Precision. Precision is the ability to reproduce the measurement when it is performed under identical conditions when there has been no real biological change in the patient. Monitoring periprosthetic bone after stem implantation provides insight into the pattern of stress redistributions that occur after implant insertion [3, 4], so the precision error of bone density testing assumes great importance when the technique is used to follow changes in bone density over time in this specific context. Like accuracy, precision is usually described as %CV. Again, the smaller the %CV is, the better the precision of the technique. Accuracy is far less important than precision. This is because it is the magnitude of the difference between measurements that is of interest.

Different factors may affect the DXA periprosthetic scan reproducibility. The precision relies on the quality of the scanner, the quality of the analysis software [25], mode of scan analysis in the case of cemented prosthesis [21], position of scanned limb [22], and the homogeneity of positioning of the patients at follow-up investigations [23]. The in vivo precision error of periprosthetic BMD measurement ranges from 1 % to 7.5 % depending on the ROI and type of the prosthetic stem [17, 24, 26]. Cohen et al. [24], in a study designed to evaluate the DXA accuracy, reported that the most significant factor affecting reproducibility was rotation of the femur. They found a CV variation of 2, 2.7, and 1 % using a hydroxyapatite phantom, an anthropomorphic phantom specimen, and in repeated measurements on implanted cadaver femora, respectively. In patients, the precision error was 1.1–4.5, depending on the ROI and rotation of the femur particularly in the region of calcar (ROI 7 according to Gruen analysis).

8.3 Periprosthetic Hip

The preoperative application of DXA, in THA to prospectively evaluate implant primary stability, is started from the observation that the efficiency of a prosthesis stem and the type of fixation are dependent on the degree of mineralization of the bone in which the prosthesis is implanted [27]. In case of poorly mineralized bone, the cemented prostheses are more suitable while in well mineralized bone with a potencially higher long-term mechanical quality, uncemented prostheses are better suited. DXA has been extensively used to evaluate the bone remodeling pattern associated with uncemented or cemented femoral stem implants. Bone cement alone or mixed with radiopaque substances such are barium or zirconium is the cause of artefacts in BMD measurements. Uncertainty remains as to whether mixed or alone cement should be included or excluded from analysis of ROIs when measuring BMD around cemented femoral implants. This had led various authors to study mainly prostheses fixed without cement [1, 2, 8, 12, 13, 17, 18].

Wilkinson et al. [21], in a study aimed at determining the effect of bone cement on the measurement of BMD in femoral ROIs after THA, reported that manual exclusion of cement from femoral ROIs increased the net CV from 1.6 to 3.6 % and decreased the measured BMD by 20 %. They concluded that manual removal of cement may be of use in population studies but of limited value in the monitoring of individuals. The main reason for this poor precision lies in the difficulty of consistently removing the same amount of cement from baseline and subsequent analyses. Venesmaa et al. [28] in a prospective 5-year study were likewise unable to distinguish cement from bone. However, it can be assumed that the density of the cement mantle does not change with time [16]. Therefore, to estimate long-term changes in periprosthetic bone density after cemented THA, BMD should be measured in the immediate postoperative period because all the BMD changes found during follow-up reflect the periprosthetic BMD measured baseline.

Uncemented prostheses, ensure high primary stability that on one hand reduces the risk of stress-shielding (loosening of the prosthesis) and on the other promotes the progressive bone integration between bone and prosthesis for direct adhesion. The evaluation of preoperative BMD makes it possible to obtain precise information about the mechanical quality of bone in the individual patient [28]. Patients with low preoperative BMD risk lose more bone near the prosthesis. Bone loss may make revision surgery more complicated or predispose to periprosthetic fractures. It was also shown that results obtained from "standard femoral DXA", can be used to provide the surgeon with useful data about the mechanical characteristics of certain areas of the femur involved in the fixing and support of the prosthesis, in particular the subtrochanteric region of the lesser trochanter that corresponds to the diaphyseal portion, bearing the maximum stress after insertion of a stem [29].

One of the most interesting and widely studied applications of DXA in orthopaedics is the evaluation of the changes of periprosthetic bone mass during the follow-up (secondary stability), also in relation to the design of the prosthesis stem. This application is started following the observation, in some patients of a marked demineralization in the proximal regions of the femur after implantation of a cemented or uncemented prosthesis that influenced the mechanical stability of the implant [30, 31].

In long-lasting implants, the persistence of the phenomenon of stress-shielding and bone ageing, which is manifested by the endosteal enlargement and reduction in cortical thickness, are also additive potential causes of failure of the anchorage between bone and prosthesis. The survival of an implant, therefore, depends on a number of factors, such as the mechanical stability achieved, the bone integration with the bone that hosts it, the stem type used, the surgical procedures adopted, and the bone quality [32].

DXA, along with other standard diagnostic methods (conventional radiography, bone scintigraphy, CT, and RM), has contributed substantially to being able to respond to questions relevant to the evaluation of the survival of the prosthesis. The measure of bone stock, from the first studies performed with DXA, has indirectly resulted in a measure for the redistribution of the mechanical loading created from a particular prosthetic design and the consequent biologic response [2, 11]. Bone response seems to differ between different stem designs and type of fixation. Thus, bone densitometry has an important role assessing new prosthesis designs. Over the years, different protocols of analysis have been proposed in order to evaluate the bone redistribution around the implant with regard to specific stem designs obtaining satisfactory results about accuracy and precision [2, 10, 11, 16, 17] and clinical outcome.

Figure 8.1 shows the main application models proposed by various authors in the evaluation of bone changes after hip arthroplasty using DXA technique. In a cross-sectional multicenter clinical study [33], we have used a modified Gruen protocol of analysis to evaluate BMD changes in the periprosthetic bone of five femoral uncemented conventional implants compared with a custom-made stemless implant proposed by Santori et al. [34, 35]. The study was aimed at evaluating the effect on bone remodeling of the proximal loading device with metaphyseal geometry (lateral flare). In order to compare a shorter stem implant to longest stems,

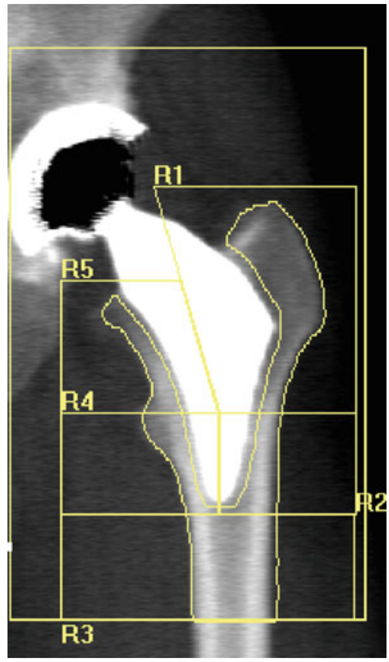


Fig. 8.5 Type 2 custom-made femoral implant featuring an almost complete absence of the stem. DXA images of the proximal femoral periprosthetic analysis with 5 regions of interest: R1–R5, [20]

six ROIs were placed more proximally and one under the tip (Fig. 8.2) with respect to the standard Gruen analysis protocol (Fig. 8.3). The short-term precision error was 1.8 %. The precision varied from 1.0 to 2.9 %, depending on the ROI. The short implant showed better strain distribution, resulting in a more favorable pattern of bone remodeling in the ROIs known to be at high risk of bone loss (calcar and greater trochanter). A similar finding was reported [20] when a short implant was compared to ultra-short custom-made femoral stem (Figs. 8.4, 8.5), and to another short-stem design with the same rationale [36]. In this study, a five-ROI protocol of analysis was proposed to test the flexibility of DXA in adapting the protocol of periprosthetic analysis to the specific requirements of new implant designs and its sensibility in the evaluation of the biological response of bone to changes in implant shape. The reproducibility was consistent with the literature [12, 25], ranging from 2.8 to 3.4 % in the implanted hip and from 2.5 to 3.7 % in the contralateral unoperated hip. Recently, Lazarinis [37] in a prospective cohort study on the short collum femoris-preserving stem showed that substantial loss in proximal periprosthetic BMD cannot be prevented by the use of a novel type of short, curved stem, and forces appear to be transmitted distally. They reported a precision error between 1.1 and 5.7 % for the seven ROIs that were studied. However, the DXA images allow us to observe that the dividing line between zones 6 and 7 was not correctly placed in the mid-line of the lesser trochanter. Furthermore, the ROI 6 (that entirely includes the lesser trochanter) has been positioned too close to the bone tissue. These factors may be the sources of variability in the assessment of bone loss. These methodological considerations were allowed by the fact that the authors showed their protocol of analysis as a DXA printout image. However, despite a great variability of the periprosthetic protocols of analysis proposed in the literature, most of the published investigations reported instead of the "real bone densitometry images" [13, 20, 21, 33, 35, 36] a "schematic drawing" [2, 12, 24, 38–40] of their DXA analysis. This could generate some remarkable differences with respect to the actual analysis performed using the DXA metal/removal or orthopaedic software, thus not allowing the readers to both evaluate the reported results and reproduce the described protocol.

8.4 Periprosthetic Knee

DXA periprosthetic analysis software was applied to total knee artroplasty (THA) less than in hip prostheses. DXA was mainly used for the assessment of bone remodeling of the tibial plate and/or of the femoral condyles after TKA. The first report of local bone mass measurements after TKA was by Seitz et al. [41] using a CT device in a longitudinal study. They observed a significant reduction in the trabecular bone mass and in the cortical thickness around the tibial component immediately after the implantation. The application of QCT, after the initial enthusiasm, has been little used for artefacts due to the presence of metallic implants. Traditionally, the results of TKA have been evaluated by postoperative assessment of clinical parameters such as knee function, stability, range of motion, pain and plain radiographs. Plain radiographs can be used to assess implant position and knee alignment to evaluate bone–prosthesis and bone–cement interfaces, and to provide evidence of infection, loosening, or subsidence. However, the quantitative evaluation of periprosthetic bone density is unreliable in plain radiographs. Robertson et al. [42] showed the superiority of DXA compared to other methods in assessing changes in bone mass after TKA. DXA is a precise and reproducible method for assessment of changes in periprosthetic bone following TKA [43, 44]. However, the precision relies on the quality of the scanner, the quality of the analysis software, and the homogeneity of positioning of the patients at follow-up investigations [45, 46].

The applications of DXA to knee prostheses implies several differences from the protocols used for hip prostheses. A first substantial difference concerns the scarcity of soft tissues around the knee compared to the hip. A thin layer of soft tissue may be responsible for errors in the measurement of BMD or BMC. When using computer programs that are developed for different anatomical regions, it is necessary to imitate the expected tissue-equivalent density by use of tissue-equivalent material. Rice, nylon, or water bags are commonly used to trick the software into running in automatic mode and to avoid air gaps when these are not expected by the software. Recently, a specific "knee program" was proposed instead of traditional spine-mode DXA software that seems to alleviate the use of tissue aids and makes clinical use much simpler. However, it is currently only available for use in clinical research [47].

A second aspect concerns the placement of the limb, which is of crucial importance in TKA. It is well known that the DXA does not measure the volumetric density but only the surface density. Therefore, small movements of the femoro-tibial axis are able to jeopardize the reproducibility and accuracy of the test. In the case of studies in PA projection, the knee must be carefully aligned to the longitudinal axis (0° rotation). The use of a heavy-duty polyethylene leg brace to fix the knee in full extension and neutral rotation has been advocated in analysis protocols [43, 44] and has also been shown to improve the precision of scans in a small-scale setup [45]. However, due to pain and swelling, TKA patients often have a temporary extension deficit of the operated knee. Baseline BMD scans are usually performed within the first week after surgery, when many patients may not be able to fully extend the knee, which is often possible in later follow-up scans. The clinical reliability of the suggested fully extended leg position is therefore questionable. Stilling et al. [22] found that flexion deficiency (range 5–30°) is a problem for two-thirds of patients in the first days after TKA surgery, and that even small changes in knee flexion (range 5–15°) substantially influence the periprosthetic bone density measured in the proximal tibia. They tested the clinical reproducibility of BMD measurements in the proximity of stemmed tibia components with a generally applicable foam positioner that would ensure neutral leg rotation and 25° degrees of flexion. A high degree of precision with CVs between 1.8 and 3.7 % for the most and least precisely assessed ROI is in accordance with other reports [43, 48]. However, even with a leg positioner at hand, a dedicated protocol must be available, and the positioning of the lower leg and knee must be meticulously handled to obtain high-precision scans over a long period of time by several technicians, which are the typical conditions in clinical studies.

Finally, the extension of the bone–prosthesis interface in hip prostheses is quite large, and this allows an accurate analysis of the established ROIs. In TKA, this space is greatly reduced since the extension of the prosthetic components can significantly reduce the area to be examined.

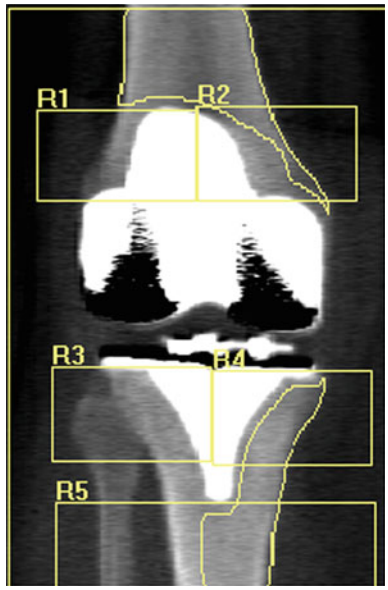


Fig. 8.6 Periprosthetic DXA after TKA. Example of 5-ROI protocol of analysis. The ROIs are manually placed to allow the assessment of bone mass around femoral and tibial components of the prosthesis. The bone of the fibula was excluded from the analysis

Soininvaara et al. [49] reported an average precision error of 3.1 % in femoral ROIs and 2.9 % in tibial ROIs after TKA. In the prosthesis-free control knees, CV% were similar: 3.2 and 2.5 %, respectively. They found the best precision in the femoral diaphyses above the implant (1.3 %), whereas the least reproducible BMD was determined in the patellar region of the TKA knees (6.9 %). However, three smaller ROIs in the distal femur showed slightly lower BMD precision (3.2–5.4 %) compared with the larger ROI 8, which enclosed the area of all three ROIs (1.9–2.6 %). This is consistent with previous findings: the smaller the area examined, the greater is the intrinsic system variability in evaluating the relevant BMDs [2, 24, 43]. Figures 8.6, 8.7, 8.8, and 8.9 show several densitometric analysis protocols in the study of bone remodeling of the knee after TKA.

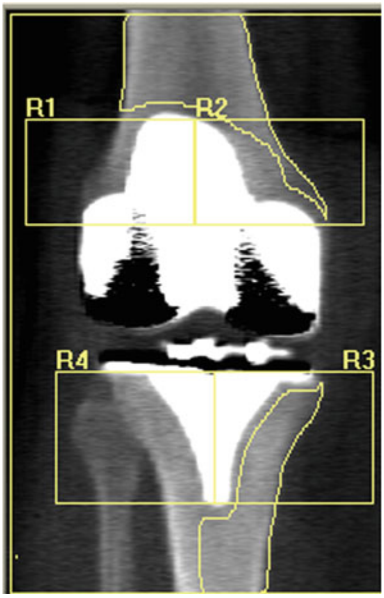


Fig. 8.7 Periprosthetic DXA after TKA. Example of 4-ROI protocol of analysis. The ROIs are manually placed to allow the assessment of lateral and medial bone mass around femoral and tibial components of the prosthesis. The bone of the fibula was excluded from the analysis

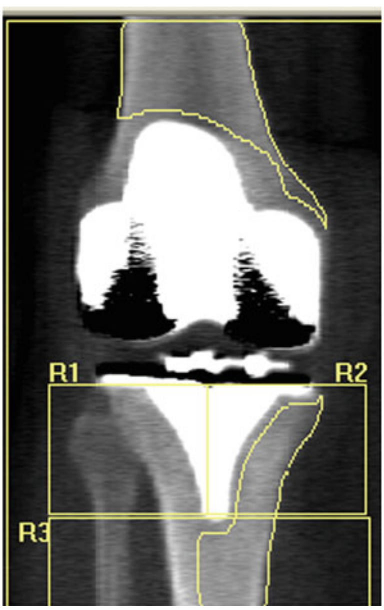


Fig. 8.8 Periprosthetic DXA after TKA. Example of 3-ROI protocol of analysis [22]. AP densitometry analysis of a right tibia (implant) with software-automated metal removal (*white*) and bone edge detection (*white line*). The bone of the fibula was excluded from the analysis

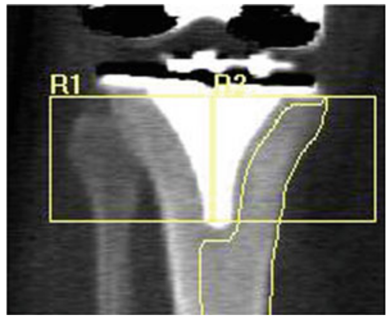


Fig. 8.9 Periprosthetic DXA after TKA. Example of 2-ROI protocol of analysis. The ROIs 1 and 2 are manually placed to allow the assessment of lateral and medial bone mass around tibial component of the prosthesis. The bone of the fibula was excluded from the analysis

8.5 Conclusions

Bone densitometry has far-reaching implications for orthopaedic practice and research. As the clinical survival of joint arthroplasties is clearly associated with the quality of surrounding bony i.e., BMD, it is important to measure bone strength and quality after arthroplasty. Small bone mineral changes around prostheses can be measured using DXA with special software algorithms providing a feasible method for monitoring over time. Furthermore, DXA requires only a small volume of bone to detect potential changes of BMD. Therefore, DXA is appropriate for the evaluation of bone mass adjacent to cemented or cementless prostheses and provides both the accuracy and the precision required to detect and quantify bone mass and remodeling around prostheses.

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