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**Original Article**

# Peripheral quantitative computed tomography at the distal radius: cross-calibration between two scanners

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**Abstract**

Peripheral quantitative computed tomography (pQCT) is an important technique to study the interaction between the muscle and bone systems. We have recently established pQCT reference ranges for children, adolescents and young adults using a recent version (XCT 2000) of the Stratec scanners (Stratec Inc., Pforzheim, Germany). However, the previous version of this type of scanner (XCT 900) is still widely used and cross-calibration is needed to use these reference data. Therefore, both distal radii of 19 healthy subjects (age 21 to 59 years; 11 women) were analyzed at the "4% site" using both the XCT 900 and the XCT 2000. Cross-sectional area, total and trabecular bone mineral density (BMD), total bone mineral content (BMC) and polar Strength-Strain Index (SSI) results from the two scanners were compared using linear regression analysis. To achieve scanner calibration we used the intercept and slope of the correlations. The correlation coefficients between the two devices were 0.82 for the cross-sectional area, 0.81 for total BMD, 0.97 for trabecular BMD, 0.99 for total BMC and 0.86 for polar SSI. In conclusion, these data allow for the conversion of XCT 900 results at the distal radius to XCT 2000 values and vice versa.

**Keywords:** Children, Densitometry, Peripheral Quantitative Computed Tomography, Radius

## Introduction

Peripheral quantitative computed tomography (pQCT) is an important technique to gain insight into bone structure and to study the interaction between the muscle and bone systems[1,2]. The most widely used pQCT device at present is the Stratec XCT 900 scanner (Stratec Inc., Pforzheim, Germany)[3]. Using a more recent version of this technique, named XCT 2000, we have recently established a comprehensive reference database for distal radius pQCT analysis in subjects from 6 to 40 years of age[4]. The two devices differ in a variety of settings, such as voxel size and slice thickness, and are calibrated differently. Therefore, reference data established for one scaner can not be directly used for the other, and cross-calibration is necessary. In this study we therefore analyzed forearms of healthy subjects with both the XCT 900 and the XCT 2000 equipment.

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## Subjects and methods

Both forearms of 19 healthy subjects (11 women, 8 men) aged 21 to 59 years (40 ± 11; mean ± SD) were examined. All of these individuals were employees of the University Children's Hospital of the University of Cologne, Germany. Body height ranged from 152 to 190 cm (172 ± 11 cm), body weight from 51 to 103 kg (74 ± 13 kg), and forearm length (measured as the distance between the ulnar styloid process and the olecranon process) was between 220 and 295 mm (255 ± 21 mm).

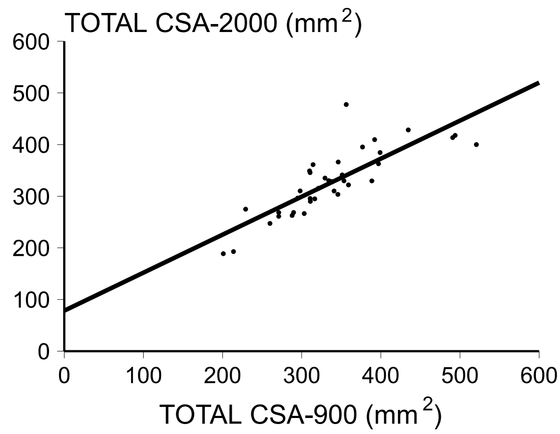
Peripheral QCT measurements were performed with both the Stratec XCT 900 and the XCT 2000 scanner (Stratec Inc., Pforzheim, Germany). The scanner was positioned on the distal end of the non-dominant forearm and a coronal computed radiograph (scout view) was carried out. A tomographic slice was sampled at a site whose distance to the medial border of the radial articular cartilage corresponded to 4% of forearm length[4]. Measurements on both machines were performed on the same day as described before[4].

The tomographic slice thickness of the XCT 900 is 2.5 mm and a voxel size of 0.59 mm was used. 72 projections are produced per scan. Image processing and the calculation of

| Parameter | XCT 900 | XCT 2000 | p |
|---|---|---|---|
| **total CSA ($mm^2$)** | 337 ± 70 | 326 ± 63 | 0.11 |
| **total BMD ($mg/cm^3$)** | 361 ± 63 | 390 ± 51 | <0.0001 |
| **trabecular BMD ($mg/cm^3$)** | 170 ± 40 | 196 ± 35 | <0.0001 |
| **total BMC (mg/mm)** | 120 ± 24 | 126 ± 24 | <0.0001 |
| **polar SSI ($mm^3$)** | 372 ± 98 | 339 ± 77 | 0.0003 |

Values are mean ± SD. p denotes the significance of the difference between the two scanners (paired t-test). Abbreviations: CSA, cross-sectional area; BMD, bone mineral density; BMC, bone mineral content; SSI, Strength-Strain Index.

**Table 1.** Description of the study population and test results.



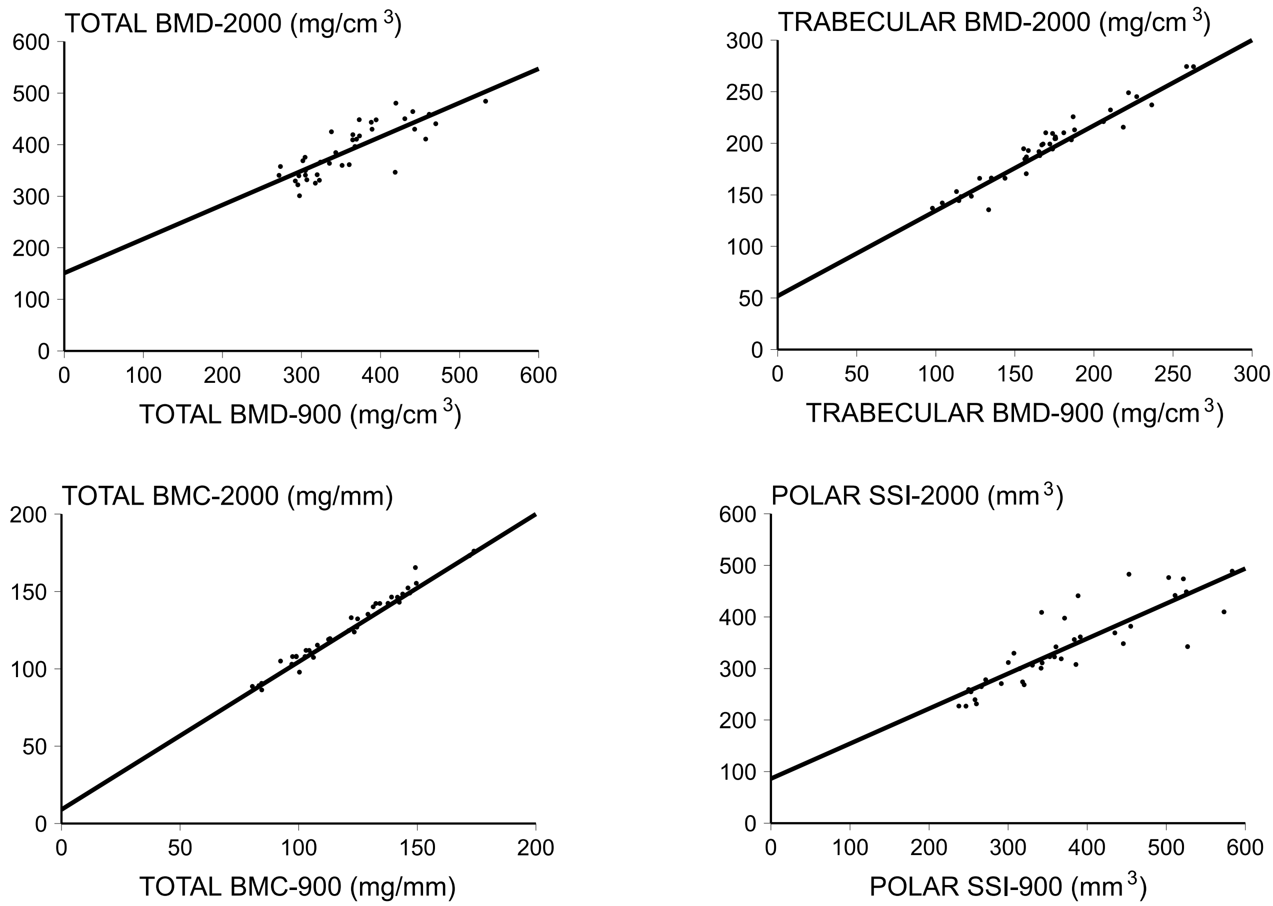




**Figure 1.** Comparison of results obtained with XCT 900 and XCT 2000 at the 4% site of the distal radius.

numerical values were performed using the manufacturer's software package (version 5.20). For the XCT 2000, 90 projections are used at a slice thickness of 2.0 mm. Voxel size was set at 0.4 mm. The XCT 2000 data were analyzed using version 5.40 of the manufacturer's software package.

The cross-sectional area (CSA) of the radius was determined after detecting the outer bone contour at a threshold of 280 $mg/cm^3$. Total BMD was defined as the mean density of the total cross-section. Trabecular BMD was determined as the mean density of the 45% central area of the bone's cross-section. BMC was calculated as the product of total CSA and total BMD. Polar SSI of the entire cross-section was calculated by the software using a built-in algorithm[5].

Results obtained with the two scanners were compared by linear regression analysis. Cross-calibration equations were derived from the slope and intercept of the regression lines. Differences between the mean values obtained with the two devices were tested for significance using the paired t-test.

| | Equation | r |
|---|---|---|
| total CSA-2000 = | 0.736 x total CSA-900 + 78 | 0.82 |
| total BMD-2000 = | 0.660 x total BMD-900 + 151 | 0.81 |
| trabecular BMD-2000 = | 0.847 x trabecular BMD-900 + 52 | 0.97 |
| total BMC-2000 = | 0.975 x total BMC-900 + 9 | 0.99 |
| polar SSI-2000 = | 0.679 x polar SSI-900 + 86 | 0.86 |
| All associations are highly significant ($p<0.0001$). Abbreviations: CSA, cross-sectional area; BMD, bone mineral density; BMC, bone mineral content; SSI, Strength-Strain Index. | | |

**Table 2.** Equations for the regression lines between results of XCT 900 and XCT 2000.

## Results

BMD and BMC results on average were higher on the XCT 2000 than on the XCT 900 scanner, whereas the reverse was true for polar SSI (Table 1). Slightly larger measures of total CSA were obtained when using the XCT 900, but the difference did not achieve significance. The correlations between the two devices were closest for trabecular BMD and for total BMC, but were not as good for total CSA, total BMD and polar SSI (Fig. 1, Table 2).

## Discussion

In this study we examined the relationship between pQCT results at the distal radius as obtained with the XCT 900 and the XCT 2000 scanners. The XCT 900 has found widespread use, but one of the practical shortcomings for its application in the field of musculoskeletal research is that detailed reference data for children, adolescents and young adults are lacking. We have recently established reference data for the XCT 2000[4] and we are in the process of creating normative data for the relationship between isometric grip force and distal radius pQCT results. The main utility of the conversion equations presented in Table 2 is to make these data applicable for users of the XCT 900 equipment. It would certainly have been ideal to do this cross-calibration study also in subjects below 20 years of age. However, it was judged unethical to perform studies involving ionizing radiation in children and adolescents only for methodological purposes.

Ideally, there should be no difference in the means of the parameters obtained with the two devices, the regression lines should have a slope of 1 and an intercept of zero. However, BMD results were higher for the XCT 2000. This is probably largely due to the differences in calibration between the two scanners, because the XCT 900 was calibrated to read zero at the density of water, while the XCT 2000 measures zero at the density of fat[6]. In addition, the larger voxel size of the XCT 900 causes "blurring" of the outer bone edge resulting in an overestimation of CSA. Although the difference in total CSA was not statistically significant, this contributes to the lower BMD readings with the XCT 900. In fact, total BMC, which is the product of total BMD and total CSA, showed the best correlation between the two machines, with a slope and intercept close to the ideal values.

In conclusion, these data allow for the conversion of XCT 900 results at the distal radius to XCT 2000 values and vice versa.

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