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Review

Trabecular Bone Score: Where are we now?

Clinical Case

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ABSTRACT

The Trabecular Bone Score is a rather new index obtained at the lumbar spine at the same time as a real bone mineral density. It was developed to reflect bone microarchitecture. It was proposed to be easily used in everyday practice as a surrogate of bone strength. Our aim was to review 1. technical points such as correlations between Trabecular Bone Score and bone microarchitectural parameters, Trabecular Bone Score and bone strength, the effects of dual-energy X-ray absorptiometry image spatial resolution, age, macroarchitecture, body mass index, and osteoarthritis, on Trabecular Bone Score, and 2. evidences to use Trabecular Bone Score for separating individuals with fragility fractures from controls, predicting fragility fractures, and for longitudinally monitoring changes related to treatments. Correlations between Trabecular Bone Score and bone microarchitectural parameters vary widely across bone sites, microarchitectural parameters, and study designs. In vivo, the Trabecular Bone Score explains little of the variance

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in trabecular microarchitectural parameters. We emphasize that it is a texture parameter. The Trabecular Bone Score is reduced in patients with fragility fracture. Several retrospective and prospective studies have shown its discriminative ability regarding the fracture risk. When combining the areal Bone mineral Density and Trabecular Bone Score, the Trabecular Bone Score remains a predictor of fracture but not the areal Bone Mineral Density. However in prospective studies, the best predictor of fracture remains hip areal bone mineral density. Due to the lack of evidence, we recommend not to use Trabecular Bone Score for following patients treated by anti-osteoporotic drugs.

1. Introduction

Areal bone mineral density (aBMD) measurement using dual-energy X-ray absorptiometry (DXA) fails to fully capture the fragility fracture risk. The Trabecular Bone Score (TBS) was developed to reflect bone microarchitecture. It analyses local gray-scale variations in 2D projection images. The method was initially described on 2D projection images of 3D micro-computed tomography (μCT) images [1], and subsequently adapted for DXA images. TBS and aBMD are computed in the same region of interest of the lumbar spine (LS) but successively and via different methods. A high TBS value is thought to reflect a trabecular microarchitecture associated with good mechanical strength. A low TBS value, in contrast, may indicate poor-quality microarchitecture. The TBS is currently easily used in everyday practice as a surrogate of bone strength.

On behalf of GRIO, we published in 2011 a review on the TBS [2]. Since this, the United States Food and Drug Administration approved TBS, and numerous studies have been published, encouraging us to update our work. In the first part of the manuscript, we further focused on the question: what evidence do we have today that TBS reflects microarchitecture and perhaps bone strength? Also, we analyzed the influence of spatial resolution, demographic factors (age and body mass index), and osteoarthritis, on TBS, and finally correlations between TBS and aBMD. Much of the first part is accessible as Appendix A (S1, S2 and S3: see the supplementary material associated with this article online). The second part focused on the interest of TBS in clinical practice.

2. What evidence do we have today that Trabecular Bone Score computed from dual-energy X-ray absorptiometry images reflects bone microarchitecture and perhaps bone strength?

2.1. Correlation between the Trabecular Bone Score computed from raw dual-energy X-ray absorptiometry images and microarchitectural parameters on one hand, and bone strength on the other hand, ex vivo and in vivo

Results from ex vivo studies are provided in [2] as well as in Text S1 [3–5].

There are few in vivo studies establishing correlations between TBS and microarchitectural parameters. In a study from Silva et al. [6], 71 pre- and 44 postmenopausal women were investigated using DXA, QDR 4500A, Hologic (aBMD at lumbar spine [LS], total hip [TH], femoral neck [FN], one-third radius, and LS TBS), QCT of the spine and hip (L1-L2 vertebral body cross sectional area [CSA], trabecular vBMD at mid-vertebra, FN minimal CSA, integral, trabecular [Tb] and cortical [Ct] vBMD at the FN and TH), and HRpQCT at the radius and tibia (total vBMD, Ct.vBMD, Ct.Th, Tb.vBMD, BV/TV, Tb.N, Tb.Th, Tb.Sp). TBS correlated with all QCT indices of vBMD, with the strongest association at LS trabecular vBMD ($r = 0.664$; $P < 0.001$). TBS correlated with an estimate of cortical thickness at the FN and TH ($r = 0.54$; $P < 0.001$ for both), but not with bone size (CSA). The strength of the association between FN integral vBMD and TBS was even greater than the association between FN integral vBMD and LS aBMD (0.651 vs 0.508, value comparison $P = 0.01$). Correlations between TBS and HRpQCT indices of vBMD at radius and tibia were weaker than those observed with QCT (at the radius $r = 0.22$; 0.23; 0.34 for total vBMD; cortical vBMD; trabecular vBMD respectively. At the tibia $r = 0.34$; 0.52; 0.33 for total vBMD; cortical vBMD; trabecular vBMD respectively). Correlations between TBS and microstructural indices at radius and tibia ranged between 0.135 and 0.266 (absolute r values). For example, Tb.N at the radius and tibia explained 4% of the TBS variance, Tb.Sp 6%. In summary, this study indicates that TBS is correlated to vBMD but poorly to microarchitecture, perhaps due to measurements performed on different sites.

Another in vivo study [7] tested correlations between TBS and microarchitectural parameters in 22 postmenopausal women with primary hyperparathyroidism (PHPT, mean age: 67 years). Correlations were observed between TBS and aBMD at the one-third and ultradistal radius ($r = 0.43$ and 0.45; $P = 0.047$ and 0.036), but not at the LS, TH, FN. TBS was significantly correlated with vBMD (HRpQCT) at the radius and tibia, cortical, trabecular and total (r ranged between 0.471 and 0.619), BV/TV, cortical thickness ($r = 0.453$ at the radius and $r = 0.515$ at the tibia), and whole bone stiffness. At the radius, TBS explained 25%, 21% and 10% of the variance in Tb.N, Tb.Sp and Tb.Th; at the tibia respectively 8.8%, 13.3%, and 0.3%. In addition, when body weight was included in the analyses, TBS was no longer correlated with HRpQCT indices, indicating interactions between TBS and weight. The authors also suggested a tendency for higher correlations between TBS and LS BMD when Hologic scanners were used in comparison with Lunar devices.

In summary, although TBS was proposed as a parameter reflecting bone microarchitecture, a critical point is that the correlations between TBS and bone microarchitectural parameters vary widely across bone sites, microarchitectural parameters, and study designs. In the only ex vivo published study [5], TBS explains 34% and 38% of the variance in trabecular BV/TV and SMI respectively. In vivo [6], some correlations are significant but even weaker. Based on these in vivo data, two questions remains without clear answer. Is the peripheral site for microarchitecture assessment a sufficient explanation for the weak correlations? Is there a confounding role for the interposition of soft tissues in the assessment of TBS? Concerning bone strength, TBS explains 41% of the variance in bone stiffness but does not explain a significant part of the variance in failure load [5].

2.2. Effects of image spatial resolution

The effects of image spatial resolution [8,9], age [10–17], macroarchitecture [5,6], body mass index [13,14], and osteoarthritis [10,17,18], on Trabecular Bone Score, and correlations between Trabecular Bone Score and Bone Mineral Density [1,7,16] are developed in Text S2.