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A comparison between the total and best regions of trabecular bone scores and evaluating the added value of combining the trabecular bone scores with bone-mineral density

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Abstract

Introduction: Bone mineral density (BMD) and trabecular bone score (TBS) are recognized as two indexes for diagnosis of osteoporosis.
Objectives: The present study assesses the TBS performance as an alternative test for BMD.
Patients and Methods: A retrospective descriptive study conducted on 2,106 patients were referred to two central hospitals; Resalat and Loghman in Tehran, Iran. Necessary data have been collected for the analysis process, including age, gender, body mass index, and L1-L4 TBS.
Results: Four-hundred eligible patients were considered for our analysis process. Among these patients, about 13.8 and 86.3% were men and women with mean ages of 54.04 ± 10.92 and 53.83 ± 10.16 years, respectively ($P=0.88$). Our study showed a statistically significant difference between the mean TBS of all regions in patients ($P=0.001$), while this value was dependent on the gender and age of patients. The mean TBS of all regions in women younger than 50 years was significantly higher than those older than 50 years ($P<0.001$). Moreover, a statistically significant difference was observed between the means of the best regional TBS in all study groups ($P<0.001$). This study showed the lumbar spine TBS had a negative correlation with body mass index in women, while this correlation was not significant in men.
Conclusion: Trabecular bone score can be conducted as a complementary index along with BMD, it can be employed independently as an appropriate indicator for osteoporosis.

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Introduction

Osteoporosis is a skeletal disorder associated with weakened bones and increased susceptibility to fractures. It is recognized as a primary global health concern (1,2). The bone mineral density (BMD) test is a conventional technique for diagnosing osteoporosis, assessing the need for therapy in at-risk individuals, and evaluating the effectiveness of osteoporosis treatments (3). In general, bone mineral content increases during growth and reaches maximum density at puberty, and then it is lost with aging. A low-BMD results from several reasons, including decreasing bone absorption, increasing bone resorption, or both states (4). Bone mineral densitometry is a gold-standard method for diagnosing osteoporosis (5,6). Low-BMD in untreated, postmenopausal women is accompanied by a high risk of bone fracture (7). In most sites, BMD measurement has a similar predictive ability of fracture except for the spine and hip, which provides a better predictive ability of fractures in those places. It is necessary to note that patients with or without osteoporotic fractures have a broad overlap in BMD scores. As several studies demonstrated, more than 50% of postmenopausal women with hip fractures had T-scores higher than -2.5 (8,9). One of the BMD test limitations is the variations of the pharmacological intervention threshold based on the patient's

Key point

Although BMD is a principal method for diagnosing osteoporosis, TBS is recognized as a novel technique that can provide underlying bone texture information without applying bone-mineral density. In this study, we found TBS can be conducted as a complementary index along with BMD; it can be employed independently as an appropriate indicator for osteoporosis.

underlying conditions. Likewise, in similar BMD values, glucocorticoid-induced osteoporotic patients are more likely to develop fractures than their postmenopausal counterparts. The comparison of BMD test and age-matched controls showed that although patients with type 2 diabetes had high mean BMD, these patients were at higher risk of non-vertebral fractures (e.g., hip, proximal humorous and foot) than the risk of vertebral fractures (10,11).

The trabecular bone score (TBS) is a bone texture index derived from the unique imaging dual-energy X-ray absorptiometry (DXA) technique and provides additional skeletal information than standard BMD measurements (12). It is a gray-level texture measurement obtained from experimental variograms of 2D-projection images and involves quantifying the gray-level texture from one pixel to adjacent pixels. The gray-level texture represents how often a different combination of pixel values or gray levels co-occur in an image (13). Although TBS does not directly assess bone micro-architecture, it is related to 3D bone characteristics, such as the trabecular number, separation, and connectivity density (14,15). In the same way as BMD, the lumbar spine TBS is an age-dependent predictor of osteoporotic fractures (16).

Objectives

TBS and BMD have different units, but they are converted into T-scores, which allows reliable comparison. This study was conducted on 400 male and female participants into three groups TBS and BMD. We assessed whether TBS can be employed independently as an appropriate indicator for osteoporosis and if the pattern of changing its value in vertebras is similar to BMD.

Patients and Methods

Study design

This retrospective descriptive study has been developed to assess the TBS and BMD values. It has been conducted on 2106 patients referred to Resalat and Loghman Hakim hospitals, Tehran, Iran. Finally, 400 eligible patients were enrolled in the study. The inclusion criterion involved individuals in the age range of 20-70 years with qualified matched BMD. The BMD rule has been considered to monitor its proper performance as a correct method. Overall, the BMD value is supposed to be lower than 1.200 and it increases from L1 to L3, while it decreases from L3 to L4. In this case, the exclusion criteria were individual's age above 70 years, under 20 years, and non-enforcement of the BMD rule (17).

The collected data included age, gender, body mass index (BMI), and TBS values of spine L1, L2, L3, L4 separately and total L1–L4 vertebrae. The best region of TBS was introduced as the region with increasing value from L1–L3 or decreasing value from L3 to L4 under the BMD rule. If all the vertebrae followed the rule, the total L1–L4 was chosen. Otherwise, it was suggested to consider the TBS values in the adjacent vertebrae that complied with the rule as the best region of TBS. TBS was stratified into three categories based on its values, entailing the normal microarchitecture (NM) group with TBS >1.350, partially degraded microarchitecture (PDM) group with 1.200< BS< 1.350, and fully degraded microarchitecture (FDM) group with TBS <1.200. In addition, it was verified whether the BMD rule has complied with TBS in the study subjects or another best region would be chosen.

Data analysis

A dataset was provided by collecting data of 400 patients. In this regard, these patients were first categorized into three groups based on age and gender. The relationship between BMD and TBS has been evaluated in each group. Additionally, the effect of BMI on TBS has been investigated in the study subjects. The mean and standard deviation have been utilized to analyze quantitative data, and the frequency and percentage have been conducted to describe qualitative data. The chi-square test has been considered to examine the relationship between qualitative variables. Besides, the analysis of variance (ANOVA) has been employed to compare the quantitative variables between the study groups. The Tukey post hoc test has been performed as needed. In addition, the Pearson's correlation coefficient has been calculated to evaluate the relationship between quantitative variables. Weighted kappa has been computed to check the agreement between the TBS results and the best region. R software version 3.6.1 has been used to analyze the collected data. It is essential to note that the significance level for statistical tests was set to 5%.

Results

A total of 400 people participated in our study. These people included 55 males (13.8%) and 345 females (86.3%). Besides, the mean age of the participants was 53.85 ± 10.26 years. The youngest and oldest patients were 21 and 70 years, respectively. The mean ages of male and female participants were 54.04 ± 10.92 and 53.83 ± 10 years, respectively. The analysis results showed no statistically significant difference between the ages of males and females (P = 0.88). About 129 (32.3%) and 271 (69.1%) patients had normal and abnormal BMI, respectively. In addition, 4 (1%), 164 (41%), and 103 (25.8%) of patients were underweight, overweight and obese respectively.

The patients were divided into three groups. Group 1 included 103 females (25.8%) <50 years, group 2 involved 242 females (60.5%) ≥50 years and group 3 consisted of 50 men (13.8%).

Some patients in each group had a BMI higher than the normal range (i.e., normal range: 18.5-24.9 kg/m^2). These patients included 63 females (61.2%) in group 1, 170 females (70.2%) in group 2, and 38 males (69.1%) in group three. The results showed no statistically significant difference in the ratio of abnormal BMI in none of the study groups (P = 0.249; Figure 1).

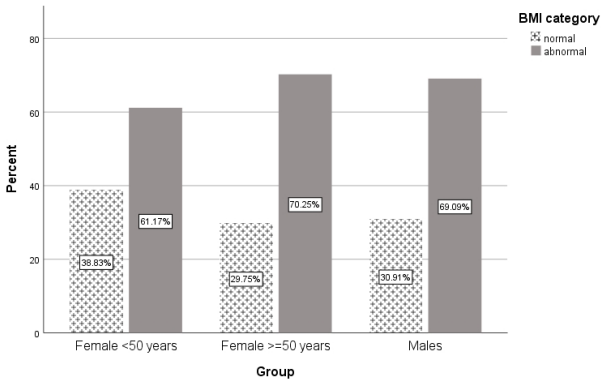

Figure 1. Description of body mass index of the subjects

Table 1 presents the mean TBS for different regions in each study group. In group 1, the mean TBS for L1, L2, L3, L4, and L1–L4 were 1.42 ± 0.104, 1.45 ± 0.098, 1.44 ± 0.094, 1.38 ± 0.092, and 1.42 ±0.083 , respectively. In group 2, the mean TBS for L1, L2, L3, L4, and L1–L4 were 1.31 ± 0.127, 1.35 ± 0.109, 1.33 ± 0.099, 1.28 ± 0.105, and 1.32 ± 0.094, respectively. There was a statistically significant difference between the mean TBS in the study groups within all areas ($P<0.001$). The results of Tukey's multiple comparison tests in each region showed that the mean TBS in group 1 was significantly higher than the mean TBS in the other groups. In this case, $P<0.001$ was observed in all binary comparisons between groups 1, 2 or 3.

There was no significant linear relationship between the males' age and TBS in different regions. While the females' TBS significantly decreased with age. In this case, the r values for L1, L2, L3, L4, and L1–L4 were –0.473, –0.471, –0.511, –0.454, and –0.541, respectively. The results are presented in Table 2.

In group 1, no statistically significant difference between the BMI and mean TBS in L1 was detected ($P=0.224$). In other regions like L2 ($P=0.009$), L3 ($P=0.007$), L4 ($P=0.034$), and L1–L4 ($P=0.013$), the mean TBS in females with a normal range BMI was statistically significant higher than those with an abnormal range BMI.

In group 2, no statistically significant difference between the mean TBS of L2 in females with a normal or an abnormal range BMI was seen ($P=0.125$). In all other regions like L1 ($P=0.027$), L3 ($P=0.004$), L4 ($P=0.001$), and L1–L4 ($P=0.005$), the mean TBS in females with a normal range BMI was statistically significant higher than those with an abnormal range BMI.

In group 3, the mean TBS value in males with a normal range BMI was higher than in males with an abnormal range BMI. However, there was no statistically significant difference in any regions like L1 ($P=0.184$), L2 ($P=0.613$), L3 ($P=0.991$), L4 ($P=0.129$), and L1–L4 ($P=0.332$). These results are provided in Table 3.

Among 400 study subjects, the TBS values of 27 (6.75%) patients did not follow the BMD rule so they did not have the TBS of best region, they were seven patients in group 1, 19 patients in group 2, and 1 patient in group 3. In others, a statistically significant difference was found among the mean TBS of the best region in all groups ($P<0.001$). This value in group 1 was highest among the other two groups ($P<0.001$).

There was no statistically significant difference between the mean TBS value of the best region in terms of BMI in group 1 ($P=0.741$), group 2 ($P=0.240$), and group 3 ($P=0.304$). These results are illustrated in Figure 2.

Besides, patients were categorized into several classes from the TBS viewpoint. According to the TBS classification in group 1, 7 patients (6.8%) were unknown because their TBS did not follow the rule. 81 (76.8%), 13 (12.6%), and 2 (1.9%) patients were NM, PDM, and FDM, respectively. The best regions of TBS in 88 (85.4%), 14 (13.6%), and 1 (1%) patients were NM, PDM, and FDM, respectively.

According to the TBS classification in group 2, 19 (7.9%), 103 (42.6%), 93 (38.4%), and 27 (11.2%) patients were unknown, NM, PDM, and FDM, respectively. The

Table 1. Mean TBS of different regions in the study group

Variable	Group			*P* value
	Female < 50 years	Female ≥ 50 years	Males	
	Mean ± SD	Mean ± SD	Mean ± SD	
L1	1.42 ± 0.104	1.31 ± 0.127[a]	1.31 ± 0.111[a]	< 0.001
L2	1.45 ± 0.098	1.35 ± 0.109[a]	1.37 ± 0.104[a]	< 0.001
L3	1.44 ± 0.094	1.33 ± 0.099[a]	1.36 ± 0.098[a]	< 0.001
L4	1.38 ± 0.092	1.28 ± 0.105[a]	1.32 ± 0.099[a]	< 0.001
L1–L4	1.42 ± 0.083	1.32 ± 0.094[a]	1.34 ± 0.099[a]	< 0.001

[a] Statistically significant compared to group 1.

Table 2. Correlation between age and mean trabecular bone score in different regions based on gender

			Regions				
			L1	L2	L3	L4	L1–L4
Gender	Male	Pearson correlation (*P* value)	0.131 (0.341)	-0.004 (.979)	-0.026 (0.851)	0.021(0.877)	0.029 (0.834)
	Female	Pearson correlation (*P* value)	-0.473 (<0.001)	-0.471 (<0.001)	-0.511 (<0.001)	-0.454 (<0.001)	-0.541 (<0.001)

Table 3. Comparison between mean TBS according to the BMI categories and study groups

Group	BMI category	Regions				
		L1	L2	L3	L4	L1-L4
Females < 50 years	Normal	1.44 ± 0.093	1.48 ± 0.079	1.47 ± 0.064	1.41 ± 0.079	1.45 ± 0.059
	Abnormal	1.41 ± 0.111	1.43 ± 0.105	1.42 ± 0.104	1.37 ± 0.097	1.41 ± 0.092
	P value	0.224	0.009	0.007	0.034	0.013
Females ≥50 years	Normal	1.34 ± 0.107	1.37 ± 0.099	1.36 ± 0.092	1.32 ± 0.094	1.35 ± 0.083
	Abnormal	1.30 ± 0.133	1.35 ± 0.113	1.32 ± 0.100	1.27 ± 0.107	1.31 ± 0.097
	P value	0.027	0.125	0.004	0.001	0.005
Males	Normal	1.34 ± 0.088	1.38 ± 0.072	1.36 ± 0.107	1.35 ± 0.070	1.36 ± 0.065
	Abnormal	1.30 ± 0.119	1.36 ± 0.116	1.36 ± 0.095	1.30 ± 0.108	1.33 ± 0.100
	P value	0.184	0.613	0.991	0.129	0.322

BMI, body mass index; TBS, trabecular bone score.

best regions of TBS in 92 (38%), 124 (51.2%), and 26 (10.7%) patients were NM, PDM, and FDM, respectively.

According to the TBS classification in group 3, 1 (1.8%), 21 (38.2%), 30 (54.5%), and 3 (5.5%) patients were unknown, NM, PDM, and FDM, respectively. The best regions of TBS in 22 (40%), 29 (52.7%), and 4 (7.3%) patients were NM, PDM, and FDM, respectively. There was a significant association between the results of these two quantities from the weighted kappa viewpoint. Therefore, if women < 50 years (group 1), the weighted kappa = 0.881, 95% CI (0.769–1; $P<0.001$). If women >50 years (group 2), the weighted kappa = 0.715, 95% CI (0.637–0.794; $P<0.001$). If the patient was men (group 3), the weighted kappa = 0.845, 95% CI (0.714–0.976; $P<0.001$). Figure 3 depicts these outcomes.

The data analysis showed that the TBS decreased from L1 to L2 in 116 patients (29%), remained unchanged in two patients (0.5%), increased up to 10% in 227 patients (56.8%), and enhanced by more than 10% in 55 patients (13.8%). Besides, the TBS decreased from L2 to L3 in 238 patients (59.5%), it remained unchanged in five patients (1.3%), increased up to 10% in 145 patients (36.3%), and enhanced by more than 10% in 12 patients (3%). As shown, this values decreased by 10% from L3 to L4 in 102 patients (25.5%), reduced up to 10%, and declined by more than 10% in 53 patients (13.3%). Accordingly, changes from L1 to L3 were associated with increasing TBS in 233 patients (58.3%), while variations from L3 to L4 were accommodated to decreasing TBS in 298 patients (74.5%). In 197 patients (49.3%), the TBS increased from L1 to L3 and decreased from L3 to L4.

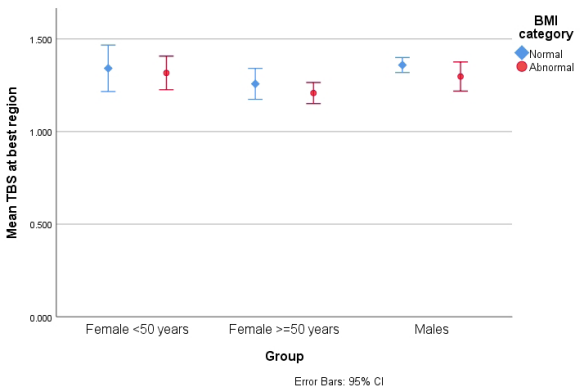

Figure 2. Mean TBS at best region in terms of body mass index in study groups.

Discussion

A retrospective descriptive study has been developed to

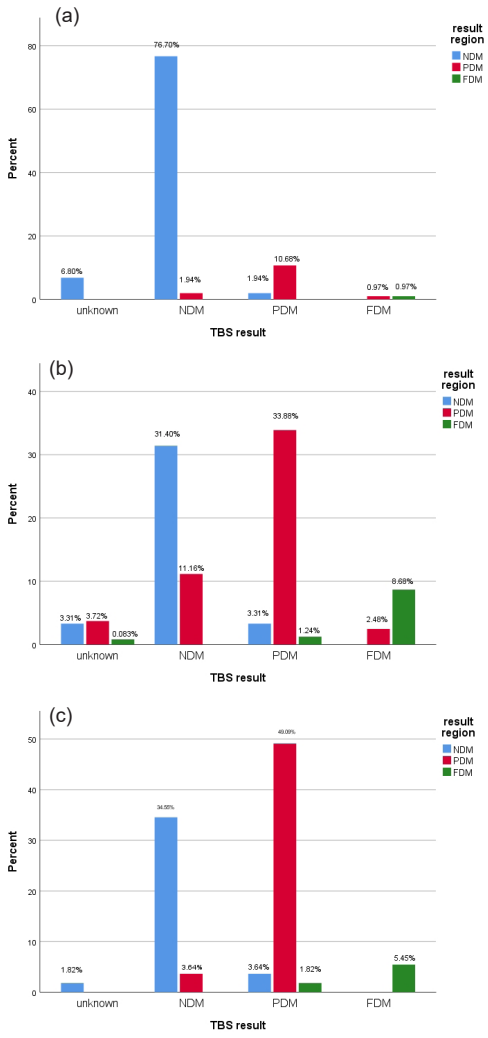

Figure 3. Distribution of study group members by TBS result level and result region. (a) Women under 50, (b) Women over 50 and (c) Men.

assess the TBS and BMD in 400 patient. We observed in all regions, the TBS in women <50 years was higher than in other subjects. Schousboe et al (17)found a relationship between high TBS and age in men.

Ho-Pham et al (18) reported that the average TBS in men was higher than in women. In our study, women <50 years had mean TBS value higher than women ≥50 years or men. These results may arise from the effect of menopause on the TBS in women. A statistically significant correlation was observed between aging and lower TBS in women but not in men. In this regard, Dufour et al (19) found that TBS decreased with aging in both genders, contradicting our findings. However, they reported that patients with a high BMI had a lower TBS. This finding has been matched with ours. In addition, we found that patients with a normal BMI had a higher TBS than the other case.

Kim et al (20) observed a significant relationship between BMI and TBS in both genders. They reported that the correlation coefficient in men increased from the normal to the osteoporotic groups. They observed a significant positive correlation between height and TBS in women. However, a significant negative correlation was found between weight and TBS in men. Then, the authors concluded that TBS negatively correlated to BMI and weight. We observed no correlation between BMI and TBS in males, but a significant correlation was found between BMI and TBS in females. This finding has been matched with the results reported by Kim et al (20).

As we founded, at least 65% of patients had an increase of 10% or more in TBS value from L1 to L2. Besides, 39% of patients showed an increase of 10% or more in TBS value from L2 to L3. But 60% of patients demonstrated TBS reduction in this area. In addition, 75% of patients had a TBS decline from L3 to L4.

Roux et al (21) observed no correlation between TBS and BMD. However, we proved that TBS could measure bone texture quality, and it is somewhat a valuable alternative for BMD.

Conclusion

The analyses showed a significant difference between the TBS values in women with an age range under and above 50 years. Younger women had a higher TBS values in their lumbar vertebrae than older women. No relationship was found between the men's age and TBS value in the lumbar vertebrae. The lumbar spine TBS negatively correlated with BMI in women, while it did not correlate with BMI in men. In most patients, the TBS complies with a similar rule as BMD, and thus it can be employed as a solitary or complementary index for evaluating the bone quality.

Limitations of the study

One of the limitations was related to the patients' dissatisfaction with participating in this research. Besides, there were some cofounder non-adjusted variables like patient's comorbidities. Another limitation was dealing with the low men population. It is possible the non-significant relationship between TBS and BMI or age in the men population arises from the few populations of men.

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Authors' contribution

AR, PD, and SH were the principal investigators of this study. In this research, AR and SH developed the concept and design of the problem. All authors revised the manuscript, prepared the final draft, and critically evaluated the intellectual contents. The manuscript's content has been read and approved by the authors.

Conflicts of interest

All authors declare they have no conflict of interests.

Ethical issues

The research followed the tenets of the Declaration of Helsinki. The ethics committee of Shahid Beheshti university of medical sciences approved the study protocols and Ethical code (IR.SBMU.RETECH.REC.1400.237). All participants provided written informed consent before performing any interventions. Besides, the authors have entirely observed ethical issues, including plagiarism, data fabrication, and double publication.

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References

1. Cooper C, Campion G, Melton LJ 3rd. Hip fractures in the elderly: a world-wide projection. Osteoporos Int. 1992;2:285-9. doi: 10.1007/BF01623184.
2. Watts JJ, Abimanyi-Ochom J, Sanders KM. Osteoporosis costing all Australian: a new burden of disease analysis-2012 to 2022. Melbourne: Osteoporosis Australia; 2013.
3. Food and Drug Administration. Guidelines for preclinical and clinical evaluation of agents used in the prevention or treatment of postmenopausal osteoporosis. Rockville, MD: Division of Metabolism and Endocrine Drug Products; 1994.
4. Goldman L, Bennett JC. Textbook of Medicine: WB Saunders Company; 2000.
5. World Health Organization. Assessment of fracture risk and its application to screening for postmenopausal osteoporosis: report of a WHO study group [meeting held in Rome from 22 to 25 June 1992]: World Health Organization; 1994.
6. Dawson-Hughes BE, Gold DT, Rodbard HW, Bonner Jr FJ, Khosla S, Swift SS, Development Committee. Physician's Guide to Prevention and Treatment of Osteoporosis. Washington, DC: National Osteoporosis Foundation; 2003.
7. Cummings SR, Black DM, Nevitt MC, Browner W, Cauley J, Ensrud K, et al. Bone density at various sites for prediction of hip fractures. The Study of Osteoporotic Fractures Research Group. Lancet. 1993;341:72-5. doi: 10.1016/0140-6736(93)92555-8.
8. Marshall D, Johnell O, Wedel H. Meta-analysis of how well measures of bone mineral density predict occurrence of osteoporotic fractures. BMJ. 1996;312:1254-9. doi: 10.1136/bmj.312.7041.1254.

9. Wainwright S, Phipps K, Stone J, Cauley J, Vogt M, Black D, et al. A large proportion of fractures in postmenopausal women occur with baseline bone mineral density T-score. Journal of Bone and Mineral Research; 2001;16:S155.
10. Luengo M, Picado C, Del Rio L, Guañabens N, Montserrat JM, Setoain J. Vertebral fractures in steroid dependent asthma and involutional osteoporosis: a comparative study. Thorax. 1991;46:803-6. doi: 10.1136/thx.46.11.803.
11. Schwartz AV, Sellmeyer DE, Ensrud KE, Cauley JA, Tabor HK, Schreiner PJ, et al. Study of Osteoporotic Features Research Group. Older women with diabetes have an increased risk of fracture: a prospective study. J Clin Endocrinol Metab. 2001;86:32-8. doi: 10.1210/jcem.86.1.7139.
12. Silva BC, Leslie WD, Resch H, Lamy O, Lesnyak O, Binkley N, et al. Trabecular bone score: a noninvasive analytical method based upon the DXA image. J Bone Miner Res. 2014;29:518-30. doi: 10.1002/jbmr.2176.
13. Thakare VS, Patil NN, editors. Classification of texture using gray level co-occurrence matrix and self-organizing map. 2014 international conference on electronic systems, signal processing and computing technologies (pp. 350-355); IEEE. 2014.
14. Hans D, Goertzen AL, Krieg MA, Leslie WD. Bone microarchitecture assessed by TBS predicts osteoporotic fractures independent of bone density: the Manitoba study. J Bone Miner Res. 2011;26:2762-9. doi: 10.1002/jbmr.499. PMID: 21887701.
15. Winzenrieth R, Michelet F, Hans D. Three-dimensional (3D) microarchitecture correlations with 2D projection image gray-level variations assessed by trabecular bone score using high-resolution computed tomographic acquisitions: effects of resolution and noise. J Clin Densitom. 2013;16:287-296. doi: 10.1016/j.jocd.2012.05.001.
16. Simonelli C, Leib E, Mossman N, Winzenrieth R, Hans D, McClung M. Creation of an age-adjusted, dual-energy x-ray absorptiometry-derived trabecular bone score curve for the lumbar spine in non-Hispanic US White women. J Clin Densitom. 2014;17:314-9. doi: 10.1016/j.jocd.2013.09.002.
17. Schousboe JT, Vo TN, Langsetmo L, Taylor BC, Cawthon PM, Schwartz AV, et al; Osteoporotic Fractures in Men (MrOS) Study Research Group. Association of Trabecular Bone Score (TBS) With Incident Clinical and Radiographic Vertebral Fractures Adjusted for Lumbar Spine BMD in Older Men: A Prospective Cohort Study. J Bone Miner Res. 2017;32:1554-1558. doi: 10.1002/jbmr.3130.
18. Ho-Pham LT, Hans D, Doan MC, Mai LD, Nguyen TV. Genetic determinant of trabecular bone score (TBS) and bone mineral density: A bivariate analysis. Bone. 2016;92:79-84. doi: 10.1016/j.bone.2016.08.015.
19. Dufour R, Winzenrieth R, Heraud A, Hans D, Mehsen N. Generation and validation of a normative, age-specific reference curve for lumbar spine trabecular bone score (TBS) in French women. Osteoporos Int. 2013;24:2837-46. doi: 10.1007/s00198-013-2384-8.
20. Kim YS, Han JJ, Lee J, Choi HS, Kim JH, Lee T. The correlation between bone mineral density/trabecular bone score and body mass index, height, and weight. Osteoporos Sarcopenia. 2017;3:98-103. doi: 10.1016/j.afos.2017.02.001.
21. Roux JP, Wegrzyn J, Boutroy S, Bouxsein ML, Hans D, Chapurlat R. The predictive value of trabecular bone score (TBS) on whole lumbar vertebrae mechanics: an ex vivo study. Osteoporos Int. 2013;24:2455-60. doi: 10.1007/s00198-013-2316-7.