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Correlation of Singh's Index with The Calcaneal Index in the Assessment of Osteoporosis in Patients with Distal Radius Fragility Fractures

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ABSTRACT

Introduction: Osteoporosis is a significant public health problem, contributing to fragility fractures that lead to prolonged periods of immobilization, dependence, and a poor quality of life. Early detection and screening for osteoporosis are therefore critical. Radiographic analysis with Singh's index and the Calcaneal index, which assess the trabecular bone pattern, remain essential tools for osteoporosis screening in settings where advanced diagnostic tools such as DEXA and quantitative ultrasound (QUS) are unavailable.
Objective: This study aimed to examine the correlation between Singh's index and the Calcaneal index in patients aged 60 years and above presenting with distal radius fragility fractures, with a focus on the reliability of these indices as screening tools for osteoporosis.
Methodology: A cross-sectional study was conducted among 65 patients aged 60 years and above with distal radius fractures at Government Medical College, Kozhikode. Data collected included patient demographics, fracture characteristics, and radiological features. Singh's index and the Calcaneal index were evaluated from radiographs, and statistical analysis was performed to assess the correlation between the two indices.
Results: The study revealed a statistically significant correlation ($p<0.05$) between the two indices in the study population. Patients with higher grades of osteoporosis in either index exhibited a greater probability of sustaining fragility fractures, indicating that both indices are reliable indicators of bone density in elderly patients.
Conclusion: The Calcaneal index and Singh's index are significantly correlated and can be used effectively for screening for osteoporosis in resource-limited settings offering a cost-effective, practical solution for identifying individuals at risk and helping prevent further morbidity.

Keywords: Osteoporosis, Fragility fractures, Singh's index, Calcaneal index.

INTRODUCTION

Osteoporosis is a major public health concern, particularly in aging populations, and is often referred to as a "silent epidemic" owing to its relatively asymptomatic nature until fragility fractures occur [1]. It is characterized by decreased bone mineral density (BMD) and deterioration of bone microarchitecture, leading to an increased risk of fragility fractures [2]. These fractures, which commonly affect the hip, vertebrae, and wrist, contribute to significant morbidity, mortality, and healthcare costs worldwide [3]. Among fragility fractures, distal radius fractures are among the most common and are often the first indication of underlying osteoporosis [4]. These fractures typically occur from low-energy trauma, such as a fall from a standing height. Given their high prevalence in the osteoporotic population, they serve as a clinical marker for increased fracture risk at other sites, such as the hip and spine [5].

The gold standard for diagnosing osteoporosis is **dual-energy X-ray absorptiometry (DEXA)**, which provides accurate measurements of BMD [6]. However, the accessibility and cost of DEXA limit its widespread use, particularly in resource-limited settings. Similarly, **quantitative ultrasound (QUS)**, another diagnostic modality, has been explored for its cost-effectiveness but remains underutilized due to variability in standardization and accuracy [6]. Therefore, there is a need for alternative, easily accessible, and cost-effective screening tools to assess osteoporosis at primary and secondary healthcare levels.

Historically, plain radiographs have been utilized to assess bone quality through the analysis of trabecular patterns. Two such indices—Singh's index and the **calcaneal** index—have been extensively studied for their effectiveness in osteoporosis screening. **Singh's index (SI)**, first described by Singh, Nagrath, and Maini (1970), evaluates the trabecular pattern of the proximal femur and grades osteoporosis from **Grade 6 (normal bone quality) to Grade 1 (severe osteoporosis)** on the basis of trabecular bone loss [7]. Multiple studies have demonstrated that Singh's index is correlated with BMD and is a useful indicator of osteoporosis risk (Krischak et al., 1999; Wachter et al., 2001) [8,9].

Similarly, the **Calcaneal Index (CI)**, described by Jhamaria et al. (1983), assesses trabecular patterns in the calcaneum, another weight-bearing cancellous bone [10]. It follows a five-grade classification, where lower grades indicate higher grades of osteoporosis. Several studies have validated the use of the calcaneal index as a reliable tool for assessing bone strength and predicting fracture risk (Aggarwal et al., 1986) [11]. While some researchers have raised concerns about interobserver variability (Cockshott & Park, 1983) and racial differences in calcaneal trabecular patterns (Medicus et al., 1971), modified versions of the index have improved its reproducibility (Aggarwal et al., 1986) [12,13,11].

Despite individual studies validating both indices, there has been limited research directly comparing the **correlation between Singh's index and the calcaneal index**, especially in a focused cohort of patients who have already sustained fragility fractures. This study aims to fill this gap by investigating the correlation between the two indices in patients with **fragility fractures of the distal radius**, thereby evaluating their combined effectiveness as an osteoporosis screening tool in settings where DEXA and QUS are unavailable.

OBJECTIVES

The specific objectives include the following:

1. **To assess Singh's index and the calcaneal index in elderly patients** with distal radius fragility fractures.
2. **To determine the statistical correlation** between the two indices and their ability to reflect osteoporosis severity.
3. **To identify whether Singh's index and the calcaneal index can serve as alternative screening tools** for osteoporosis in primary and secondary healthcare settings.
4. **To evaluate the prevalence and severity of osteoporosis** among patients presenting with distal radius fragility fractures.
5. **To highlight the need for early osteoporosis screening** via simple radiographic methods to prevent future fragility fractures.

REVIEW OF THE LITERATURE

Osteoporosis is recognized as a major public health problem in the aging populations, affecting millions of individuals worldwide. According to the World Health Organization (WHO), osteoporosis is the most common metabolic bone disease, with an estimated 200 million people affected globally [2]. In developed countries, the lifetime risk of osteoporotic fractures is reported to be 40% in women and 13% in men [3]. The burden is expected to increase due to increasing life expectancy especially in developing nations such as India, where osteoporosis remains largely underdiagnosed [4]. Fragility fractures contribute significantly to morbidity, mortality, and economic costs associated with osteoporosis [5].

Several risk factors contribute to osteoporosis, with advanced age and female sex being the most significant determinants [5,6]. Other major risk factors include low body weight, a family history of fractures, smoking, alcohol consumption, vitamin D deficiency, and physical inactivity [14]. Chronic diseases such as rheumatoid arthritis, diabetes mellitus, chronic kidney disease, and hyperthyroidism also contribute to secondary osteoporosis by interfering with bone metabolism [15]. Moreover, prolonged use of corticosteroids, anticonvulsants, and proton pump inhibitors is associated with increased bone loss and fracture risk [16]. Lifestyle factors such as excessive caffeine intake and a poor calcium-rich diet further aggravate osteoporosis, particularly in postmenopausal women [17]. Singh's index (SI), introduced by Singh and Nagrath (1970), is a semi-quantitative grading system that evaluates the trabecular patterns of the proximal femur. It categorizes osteoporosis into six grades, with Grade 6 representing normal bone and Grade 1 indicating severe osteoporosis [7]. Several studies have validated Singh's index as a cost-effective tool for osteoporosis screening, particularly in geriatric populations [8,9]. Similarly, the Calcaneal Index (CI), first described by Jhamaria et al (1983), assesses trabecular bone quality in the calcaneum and is categorized into five grades, with lower grades indicating greater osteoporosis severity. The calcaneum, which is a weight-bearing cancellous bone, undergoes osteoporosis-related changes similar to those observed in the femoral neck, making it a reliable indicator of bone fragility [10]. Modified versions of the Calcaneal Index have been introduced to improve its reproducibility, addressing concerns about interobserver variability [11]. Jhamaria et al. (1983) were among the first researchers to compare trabecular patterns in the calcaneum and proximal femur and reported that these two indices are strongly correlated with osteoporosis severity. Aggarwal et al. (1986) conducted a study on 200 radiographs of the femoral neck and the calcaneum and proposed a six-grade calcaneal index, which was significantly correlated with Singh's index. *Cockshott & Park* (1983) [12] noted significant interobserver variations in grading trabecular patterns, particularly in North American populations, where differences in body weight, footwear, and muscle activity influence calcaneal trabeculae. Similarly, Medicus et al. (1971) [13] observed ethnic and geographical variations in bone mineral density, cautioning against the universal application of Singh's and Calcaneal Indices without population-specific adjustments. A more recent study by *Soontrapa & Soontrapa* (2011) [18] introduced a modified Singh's index, which improved reproducibility by using quantitative measurements instead of visual grading. Despite these variations, the majority of studies support the clinical utility of Singh's Index and the Calcaneal Index in screening for osteoporosis. This study aims to further investigate their correlation in a specific patient population—elderly individuals with distal radius fragility fractures—to determine whether these indices can reliably predict osteoporosis risk in real-world clinical settings.

METHODOLOGY

Study Design

This was a **cross-sectional study** aimed at examining the correlation between **Singh's index** and the **calcaneal index** in assessing osteoporosis in elderly patients with fragility fractures of the distal radius. The study was designed to evaluate the feasibility and effectiveness of using these indices as screening tools for osteoporosis in resource-limited settings.

Study Period and source of data

Two-year period, from January 2021 to January 2023. During this period, data were collected from patients who met the study's inclusion criteria and presented to the Department of Orthopaedics at Government Medical College, Kozhikode, for the treatment of distal radius fragility fractures.

Sample size

The **minimum sample size** required was calculated via the following formula:

$$N=1+\frac{4(Z\alpha+Z\beta)^2}{(fn\ c)2}$$

To assess the correlation between the two indices with **95% confidence** and **80% power**, **at least 58 subjects** were needed in the study.

A total of **65 patients** aged **60 years or above** who sustained **fragility fractures of the distal radius** were included in the study.

Inclusion criteria

- Patients aged 60 years or older.
- Radiologically proven fragility fractures of the distal radius.
- Both male and female patients were included.
- Patients with controlled comorbidities such as diabetes, hypertension, chronic kidney disease, and thyroid disease.
- Patients willing to provide informed consent for participation in the study.

Exclusion criteria

- Patients who were less than 60 years of age.
- Patients with uncontrolled comorbidities or malignancies.
- Patients who refused to give consent to participate in the study.
- Patients with fractures other than those of the distal radius or fractures resulting from high-energy trauma (e.g., motor vehicle accidents).

Data collection

The data was collected with a proforma which included the following components:

- *Demographic details* (age, sex, contact information, etc.)
- *Fracture characteristics*, including the side of the fracture (left or right), type of fracture (closed or open), and *Frykman classification* of distal radius fractures.
- *Comorbidities*
- *Radiographs*: X-ray images of the distal radius (fractured side), *Right hip*, and *right calcaneum* were obtained. These radiographs were assessed for Singh's index (using the trabecular pattern of the proximal femur) and the calcaneal index (based on trabecular patterns in the calcaneum).
- *Singh's index* was graded *from Grade 6 (normal) to Grade 1 (severe osteoporosis)* on the basis of plain radiographic assessment of trabecular patterns in the proximal femur.
- The *Calcaneal index* was similarly graded from *Grade V (normal) to Grade I (severe osteoporosis)* on the basis of radiographic assessment of trabecular patterns in the calcaneum.

Figure 1: Case illustration

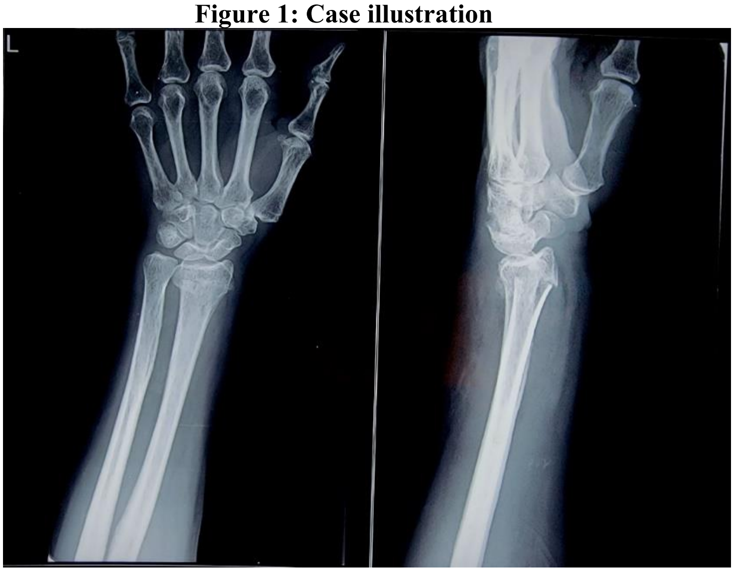

Figure 1a: Plain AP and lateral radiographs of the left wrist depicting Frykman type 1 Extra-articular Distal Radial fracture

Figure 1b: Plain lateral radiograph of the Right calcaneum showing Grade 2 (Definite osteoporosis)

Figure 1c: Plain AP radiograph of the Right hip showing Grade 3 Singh's index (Definite osteoporosis)

Statistical analysis

The data were analysed via the chi-square test to assess the correlation between Singh's index and the calcaneal index. A p value of <0.05 was considered to indicate statistical significance, indicating a strong correlation between two indices. The analysis was performed via R software (version 4.0.1), and the results are presented in contingency tables to summarize the distributions of Singh's index and the calcaneal index in the sample population. Descriptive statistics were also calculated for the demographic and clinical characteristics of the patients, including mean age, sex distribution, fracture side, and comorbidities.

Table 1: Correlation between Singh's Index and the Calcaneal Index

Calcaneal Index (CI)/Singh's Index (SI)	Grade 5 (Normal)	Grade 4 (Normal)	Grade 3 (Borderline)	Grade 2 (Definite Osteoporosis)	Grade 1 (Severe Osteoporosis)	Total
Grade 6 (Normal)	0	0	1	2	0	3
Grade 5 (Normal)	0	3	4	5	2	14
Grade 4 (Borderline)	0	2	6	8	1	17
Grade 3 (Definite Osteoporosis)	1	3	9	10	5	28
Grade 2 (Frank Osteoporosis)	0	0	1	2	9	12
Total	1	8	21	27	17	65

Explanation of the Data

This table reflects the distribution of Singh's and Calcaneal Index grades in 65 patients with distal radius fragility fractures aged 60 years and above.

- Singh's index (SI) and the calcaneal index (CI) are graded from Grade 6 (normal) to Grade 1 (severe osteoporosis) and Grade 5 (normal) to Grade 1 (severe osteoporosis) on the basis of radiographic analysis of the trabecular patterns in the **proximal femur** (Singh's index) and **calcaneum** (calcaneal index).
- The columns represent Singh's Index grades, and the rows represent the Calcaneal Index grades. Each cell represents the number of patients who had a specific combination of Singh's and Calcaneal Index grades. For example, the cell in the first row and first column (under "Grade 6 (Normal)") shows 0 patients, indicating that no patients had both normal trabecular patterns in both their proximal femur (Singh's Index) and calcaneum (Calcaneal Index).

OBSERVATIONS

1. The incidence of Grade 3 CI (definite osteoporosis) according to Singh's index was notably distributed across multiple calcaneal index grades, with the highest clustering at Grade 2 CI (10 patients) and Grade 3 CI (9 patients). However, it was also observed in Grade 1 (5 patients) and Grade 4 (3 patients) patients, suggesting some degree of variability rather than a strict correlation.

2. Grade 2 (Frank Osteoporosis) in Singh's Index aligns with Grade 1 (Severe Osteoporosis) in the Calcaneal Index in 9 out of 12 cases and with Grade 2 in the Calcaneal index in 2 cases, indicating a strong correlation between the two indices. These findings suggest that frank/severe osteoporosis in the femur (Singh's index) is often associated with severe osteoporosis in the calcaneum (calcaneal index).
3. Grade 4 (borderline) Singh's index was observed in 6 cases of the Grade 3 calcaneal index. However, it is more frequently associated with Grade 2 CI (8 cases). This suggests that while moderate osteoporosis in the femur may sometimes align with the calcaneum, it often presents with slightly greater severity in the calcaneum.

There are no cases where both indices are normal. The closest match is Grade 5 SI & Grade 4 CI, which occurs in only 3 cases. These findings suggest that patients with fragility fractures of the distal end of the radius always have a significant degree of osteoporosis.

Key Findings from the Data

- The **Calcaneal Index** and **Singh's Index** both seem to be reliable screening tools for identifying patients with **high-grade osteoporosis** and **increased fracture risk**.
- **Borderline and severe osteoporotic patients** exhibit a similar pattern in both indices, suggesting that **high-grade osteoporosis** detected in one index is usually reflected in the other index.

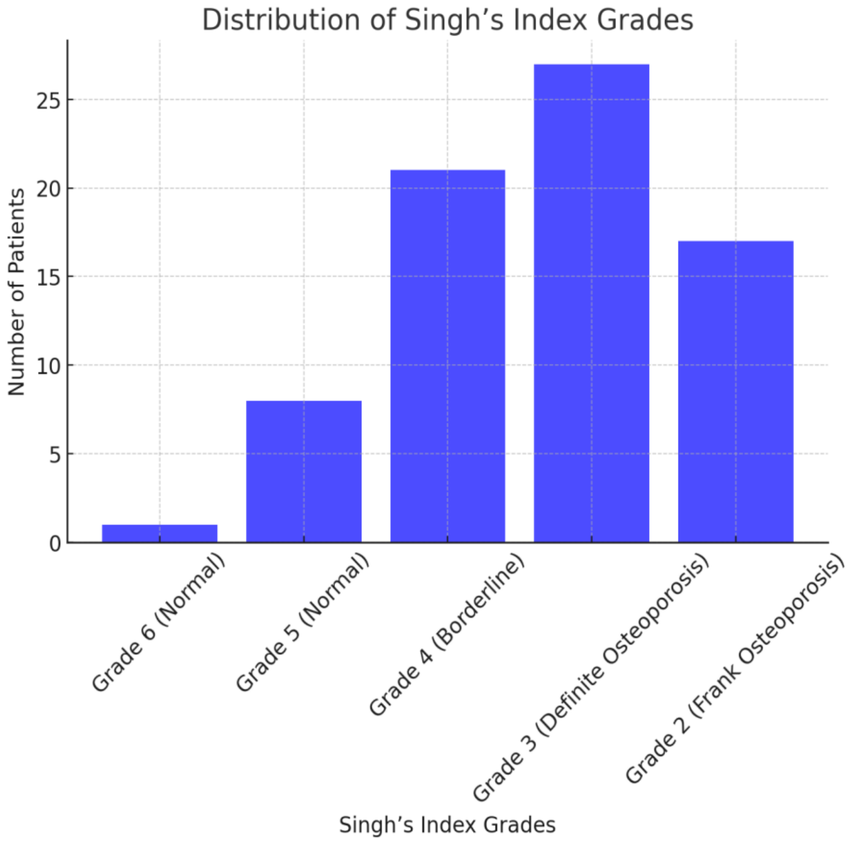

Figure 2: Bar Chart depicting the distribution of Singh's Index Grades. Singh's index grades on the X-axis and the number of patients in each grade on the Y-axis

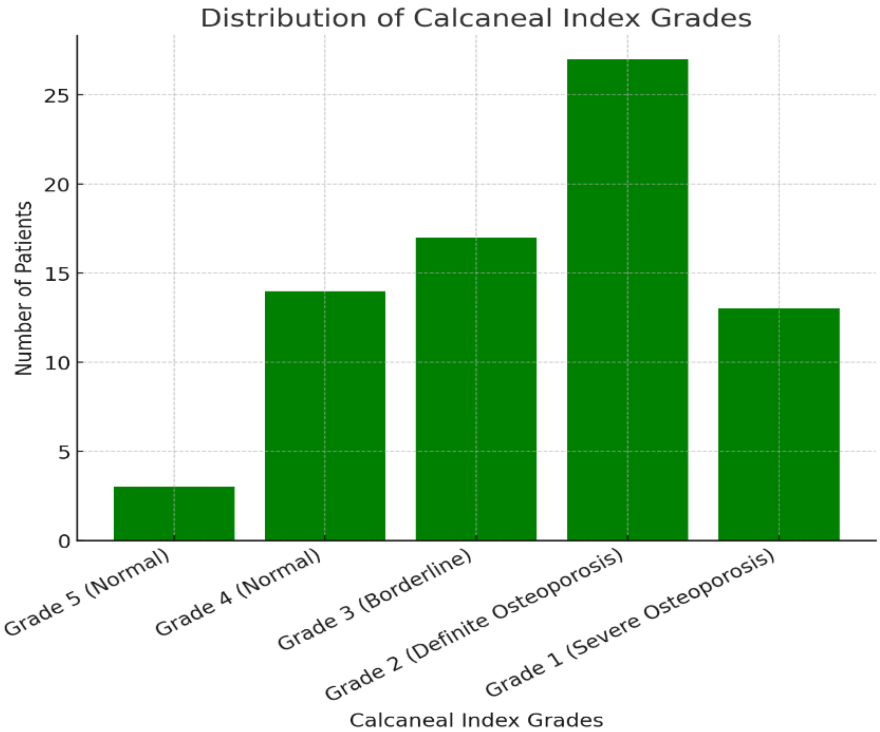

Figure 3: Bar Chart depicting the distribution of Calcaneal Index Grades. Calcaneal index grades on the X-axis and the number of patients in each grade on the Y-axis

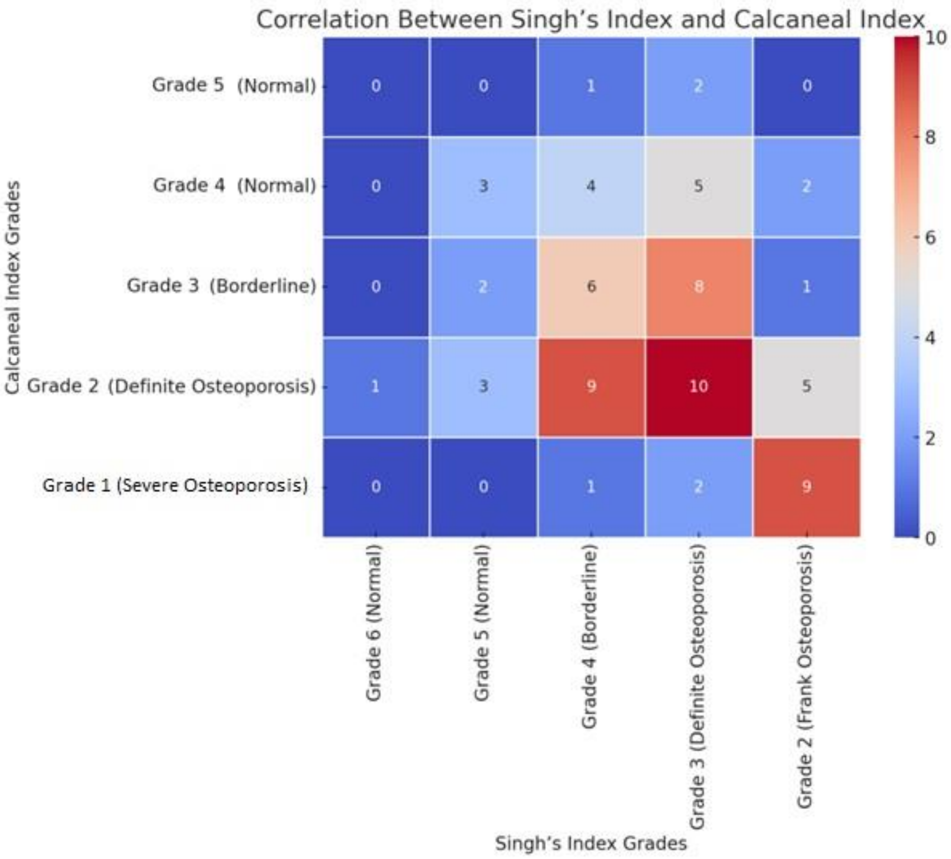

Figure 4: Heatmap illustrating the correlation between the two indices, with darker colours representing higher frequencies.

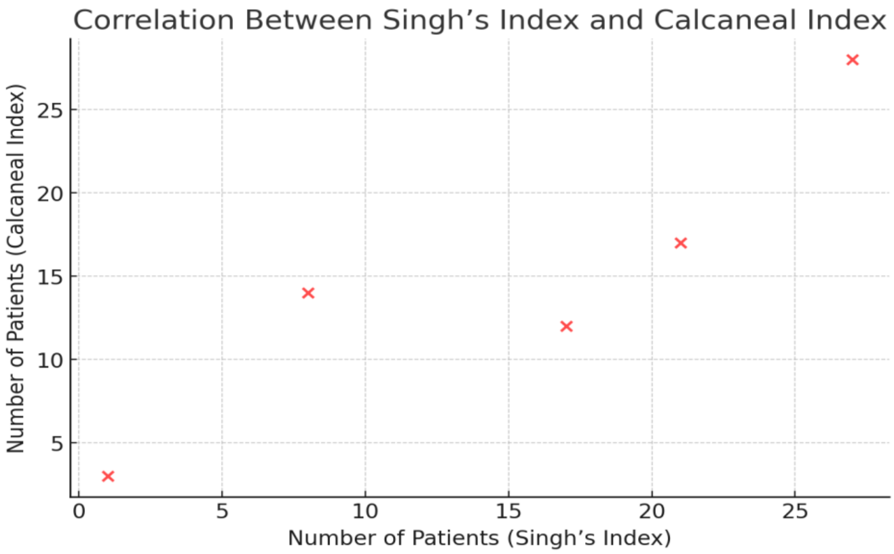

Figure 5: Scatter plot depicting the correlation between Singh's Index and the Calcaneal Index: Relationship between the number of patients categorized under both indices.

RESULTS

Demographic Data

The study included 65 patients aged 60 years and above who sustained fragility fractures of the distal radius. The age distribution of the participants was as follows: 44.6% (n=29) were aged 60--70 years, 32.3% (n=21) were aged 70--80 years, and 23.1% (n=15) were aged 80--90 years. The gender distribution was nearly equal, with 50.8% (n=33) being male and 49.2% (n=32) being female. With respect to the laterality of fractures, 52.3% (n=34) of fractures occurred on the left side, whereas 47.7% (n=31) were right-sided fractures. These findings indicate that distal radius fragility fractures are common among the elderly population and affect both sexes equally [11].

The presence of preexisting conditions was assessed to understand their contribution to osteoporosis-related fractures. Among the 65 patients, 44.6% (n=29) had hypertension, 32.3% (n=21) had diabetes mellitus, 15.4% (n=10) had bronchial asthma, 16.9% (n=11) had coronary artery disease, and 10.8% (n=7) had chronic kidney disease. Only patients with controlled comorbidities were included, as uncontrolled systemic illnesses can independently affect bone metabolism [19]. These findings align with previous studies that have demonstrated a strong association between chronic diseases and an increased risk of osteoporotic fractures [2].

The Frykman classification system was used to categorize distal radial fractures based on joint involvement and ulnar styloid fractures. Among 65 patients, extra-articular fractures (Types I and II) were the most common, each seen in 30.8% (n=20). Fractures extending into the radiocarpal joint (Types III and IV) accounted for 12.3% (n=8), while those involving the distal radioulnar joint (Types V and VI) made up 20% (n=13). Fractures affecting both joints (Type VIII) were seen in 6.2% (n=4), and no Type VII fractures were observed. Extra-articular fractures were the most frequent, followed by intra-articular fractures involving the distal radioulnar joint.

The primary objective of this study was to evaluate the correlation between Singh's index (SI) and the calcaneal index (CI) in the assessment of osteoporosis among patients with fragility fractures of the distal radius. Statistical analysis via the chi-square test revealed a highly significant correlation ($p = 0.039$) between the two indices. Specifically, the Calcaneal Index (CI) showed a strong correlation with Singh's Index (SI) across all grading categories, with the majority of patients with Grade 2 (Frank Osteoporosis) in the Calcaneal Index also exhibiting equivalent grades in Singh's Index.

DISCUSSION

The findings of this study demonstrate a strong correlation between the CI and Singh's index (SI) in the assessment of osteoporosis among patients with fragility fractures of the distal radius. The statistically significant correlation ($p = 0.039$) observed between these two indices suggests that the trabecular pattern of the proximal femur (Singh's index) and the calcaneum (calcaneal index) exhibit similar patterns of osteoporosis-related bone loss. These results are in agreement with those of previous studies that established Singh's index and the calcaneal index as viable alternatives for assessing bone health, particularly in settings lacking access to DEXA or QUS scans [7,10].

Furthermore, the study revealed that 60% of patients with Frank or definite osteoporosis (grades 2 and 3) according to Singh's index also had similar grades according to the calcaneal index, whereas borderline osteoporosis (grade 4) was observed in 24.6% of patients. These findings suggest that patients with advanced osteoporosis in one index are very likely to have advanced osteoporosis in the other, reinforcing their clinical utility in osteoporosis screening. Research by Blake and Fogelman (2007) highlighted that Singh's index, though an older method, still provides a reasonable estimate of bone quality, particularly in low-resource settings where advanced imaging techniques are unavailable. Similarly, Jhamaria et al (1983) demonstrated that the calcaneal index could serve as an effective alternative to Singh's index, given its strong correlation with femoral trabecular patterns.

However, some studies have raised concerns regarding observer variability in both indices. Cockshott & Park (1983) [12] reported that interobserver agreement was lower for Singh's index than for the calcaneal index, possibly because of the influence of femoral rotation in radiographs. Additionally, Wachter et al. (2001) [9] reported that Singh's index tends to underestimate bone loss in some populations, particularly in elderly males, which might explain minor variations in the results across different studies. Despite these limitations, both indices have been consistently validated as useful tools for osteoporosis assessment, particularly when DEXA scans are not accessible.

LIMITATIONS

Despite the study's significant findings, certain limitations must be acknowledged. First, the study was geographically limited to patients from a single tertiary care hospital in Kozhikode, India, which may not be representative of broader populations. Ethnic and racial variations in bone density and trabecular patterns have been documented, meaning that these results may not be generalizable to all populations [20]. Second, the sample size was relatively small (n=65), limiting the ability to draw definitive conclusions regarding the predictive accuracy of the indices. A larger, multi-centre study with a more diverse population would provide stronger validation of these findings. Third, selection bias may have been present since only patients with fragility fractures were included. This means that the study did not include nonfractured osteoporotic patients, preventing an analysis of osteoporosis severity before fractures occur. Additionally, secondary osteoporosis cases were not segregated, which could have influenced the results. [21]. Finally, while interobserver variability was not formally assessed, it remains a potential concern. Future studies should incorporate multiple orthopaedic surgeons and/or radiologists with blinded evaluations to minimize subjectivity in index grading [22].

CONCLUSION

This study revealed a strong correlation between Singh's index and the calcaneal index in the assessment of osteoporosis among elderly patients with distal radius fragility fractures. Both indices are reliable, cost-effective tools for osteoporosis screening, particularly in resource-limited settings. To increase the clinical applicability of these indices, the following recommendations are proposed. Integrate SI and CI into routine screening protocols in primary healthcare centres and rural hospitals. Implement lifestyle modifications, pharmacotherapy, and fall prevention strategies for high-risk individuals identified through these indices. Healthcare professionals should be trained in the accurate interpretation of the SI and CI and establish standardized grading protocols to minimize observer variability. Further research is needed to validate these findings across larger, more diverse populations and to compare these indices with advanced diagnostic tools such as DEXA and QUS.

List of Abbreviations

BMD – Bone Mineral Density
DEXA – Dual Energy X-Ray Absorptiometry
QUS – Quantitative UltraSound
SI – Singh's Index
CI – Calcaneal Index

Ethical considerations

Approval was obtained from the Institutional Ethics Committee and Institutional Research Committee of the Government Medical College, Kozhikode. Informed consent was obtained from all participants prior to their inclusion in the study. The confidentiality of patient data was maintained at all stages of the study, and only aggregate data were reported.

Conflict of interest
The authors declare that they have no conflict of interests.

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The authors confirm that this manuscript was written by the authors without generative AI assistance in content creation. AI-based tools were used solely for formatting, language refinement, and grammar enhancement to improve readability and clarity. No AI-generated text was included as original scientific content, and all intellectual contributions remain those of the authors. The research, data analysis, interpretation, and conclusions presented are solely the work of the authors. I affirm that this manuscript adheres to ethical publishing standards and transparency in the use of AI tools.

Figure legends
Figure 1: Case illustration

> **Figure 1a:** Plain AP and lateral radiographs of the left wrist depicting Frykman type 1 Extra-articular Distal Radial fracture
> **Figure 1b**: Plain lateral radiograph of the Right calcaneum showing Grade 2 (Definite osteoporosis)
> **Figure 1c:** Plain AP radiograph of the Right hip showing Grade 3 Singh's index (Definite osteoporosis)

Figure 2: Bar Chart depicting the distribution of Singh's Index Grades. Singh's index grades on the X-axis and the number of patients in each grade on the Y-axis
Figure 3: Bar Chart depicting the distribution of Calcaneal Index Grades. Calcaneal index grades on the X-axis and the number of patients in each grade on the Y-axis
Figure 4: Heatmap illustrating the correlation between the two indices, with darker colours representing higher frequencies.
Figure 5: Scatter plot depicting the correlation between Singh's Index and the Calcaneal Index: Relationship between the number of patients categorized under both indices.
Table 1: Contingency table depicting Correlation between Singh's Index and the Calcaneal Index

REFERENCES

1. Osteoporosis: A Silent Epidemic – **Maria Polikandrioti**, Health Science Journal, 2010, Volume 4, Issue 1.
2. **Ralston SH, Fraser J**. Diagnosis and management of osteoporosis. Practitioner. 2015 Dec;259(1788):15-9, 2. PMID: 26882774.
3. **Blake GM, Fogelman** I. The role of DXA bone density scans in the diagnosis and treatment of osteoporosis. Postgrad Med J. 2007 Aug;83(982):509-17. doi: 10.1136/pgmj.2007.057505. PMID: 17675543; PMCID: PMC2600106.
4. **Bledsoe L**, Alessi K, Toro JB, Giordano B, Hanypsiak BT. Fragility Fractures: Diagnosis and Treatment. Am J Orthop (Belle Mead NJ). 2018 Dec;47(12). doi: 10.12788/ajo.2018.0112. PMID: 30650167.
5. **Crandall CJ**, Newberry SJ, Diamant A, et al. Comparative effectiveness of pharmacologic treatments to prevent fractures: an updated systematic review. *Ann Intern Med.* 2014;161(10):711-723.
6. **Hans D, Krieg MA**. The clinical use of quantitative ultrasound (QUS) in the detection and management of osteoporosis. IEEE Trans Ultrason Ferroelectr Freq Control. 2008 Jul;55(7):1529-38. doi: 10.1109/TUFFC.2008.829. PMID: 18986943.
7. **Singh M**, Nagrath AR, Maini PS. Changes in trabecular pattern of the upper end of the femur as an index of osteoporosis. *J Bone Joint Surg Am.* 1970;**52**(3):457–67. doi: 10.2106/00004623-197052030-00005.
8. **Krischak GD**, Augat P, Wachter NJ, Kinzl L, Claes LE. Predictive value of bone mineral density and Singh index for the in vitro mechanical properties of cancellous bone in the femoral head. *Clin Biomechanics.* 1999;**14**(5):346–51. doi: 10.1016/S0268-0033(98)90095-X.
9. **Wachter NJ**, Augat P, Hoellen IP, Krischak GD, Sarkar MR, Mentzel M, et al. Predictive value of Singh index and bone mineral density measured by quantitative computed tomography in determining the local cancellous bone quality of the proximal femur. *Clin Biomechanics.* 2001;**16**(3):257–62. doi: 10.1016/S0268-0033(00)00093-0.

10. **Jhamaria NL**, Lal KB, Udawat M, Banerji P, Kabra SG. The trabecular pattern of the calcaneum as an index of osteoporosis. J Bone Joint Surg Br. 1983 Mar;65(2):195-8. doi: 10.1302/0301-620X.65B2.6826630. PMID: 6826630.
11. **Aggarwal ND**, Singh GD, Aggarwal R, Kaur RP, Thapar SP. A survey of osteoporosis using the calcaneum as an index. Int Orthop. 1986 Jun;10(2):147-153. doi: 10.1007/BF00267758. PMID: 27743066.
12. **Cockshott WP, Park WM** (1983) Observer variation in skeletal radiology. Skeletal Radiol 10:86
13. **Medicus H**, Gron AM, Moorrees CFA (1971) Reproducibility of rating stages of osseous development (Tanner-Whitehouse system). Am J Phys Anthropol 35:359
14. **Maurel DB**, Boisseau N, Benhamou CL, Jaffre C. Alcohol and bone: review of dose effects and mechanisms. *Osteoporos Int.* 2012;23(1):1-16.
15. **Yoon V**, Maalouf NM, Sakhaee K. The effects of smoking on bone metabolism. *Osteoporos Int.* 2012;23(8):2081-2092.
16. **Delmas PD**, Adami S, Strugala C, et al. Intravenous ibandronate injections in postmenopausal women with osteoporosis: one-year results from the dosing intravenous administration study. *Arthritis Rheum.* 2006;54(6):1838-1846.
17. **Santesso N**, Carrasco-Labra A, Brignardello-Peterson R. Hip protectors for preventing hip fractures in older people. *Cochrane Database Syst Rev.* 2014;3:CD001255.
18. **Soontrapa S, Soontrapa S**. Modified Singh index in diagnosing femoral neck osteoporosis. *J Med Assoc Thai.* 2011;**94**(Suppl 5):S79–83.
19. **Jeremiah MP**, Unwin BK, Greenawald MH, Casiano VE. Diagnosis and Management of Osteoporosis. Am Fam Physician. 2015 Aug 15;92(4):261-8. PMID: 26280231.
20. **Dretakis EM**, Christodoulou NA (1983) Significance of endogenic factors in the location of fractures of the proximal femur. Acta Orthop Scand 54:198
21. **Moyer VA** U. S. Preventive Services Task Force. Prevention of falls in community-dwelling older adults: U.S. Preventive Services Task Force recommendation statement. *Ann Intern Med.* 2012;157(3):197-204.
22. **Ott S**, M: Cortical or Trabecular Bone: What's the Difference? Am J Nephrol 2018;47:373-375. doi: 10.1159/000489672