Efficacy of Clinical Methods to Assess Jawbone Tissue Prior to and During Endosseous Dental Implant Placement: A Systematic Literature Review

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Purpose: *To evaluate the evidence for the diagnostic accuracy of clinical methods to assess bone density, quantity, or quality prior to and during dental implant placement.* ***Materials and Methods:*** *A PubMed literature search with specific indexing terms and a hand search were made. From the retrieved titles and abstracts, 3 reviewers selected publications on the basis of predetermined inclusion and exclusion criteria. Data were extracted from the selected publications using a protocol. Original studies were interpreted with the aid of the Quality Assessment of Diagnostic Accuracy Studies (QUADAS) tool.* ***Results:*** *The literature search yielded 145 titles and abstracts, of which 71 were selected and read in full text. Seven studies were judged relevant. In 1 study, no method was presented as the test method. In 6 studies, the results of the test method were compared to those of a reference method. However, only 1 study presented the results in terms of percentage of correct diagnoses. In that study, the use of periapical radiography together with reference images yielded correct assessment of the trabecular pattern of the mandible in 3 categories in 58% of the sites. The kappa index of interobserver agreement was 0.35 and intraobserver agreement was 0.67. Corresponding kappa values for 4 classes of bone quality presented by Lekholm and Zarb were 0.33 and 0.43, respectively. No study examined the accuracy of the method originally described by Lekholm and Zarb.* ***Conclusion:*** *The evidence for the efficacy of clinical methods to assess jawbone tissue prior to and during endosseous dental implant placement is sparse. This emphasizes the need for studies that incorporate accepted methodologic criteria for diagnostic efficacy.* INT J ORAL MAXILLOFAC IMPLANTS 2007;22:289–300

Key words: *bone, bone density, dental implants, diagnostic accuracy*

The use of endosseous dental implants to replace missing teeth has become increasingly widespread over the last 30 years. Excellent results have been claimed for implants placed in bone of good quality[1,2] and quantity.[3] The long-term success for implant therapy, however, has been reported to be less certain when implants are placed in bone of poor quality ("soft bone")[1,4–7] or quantity (limited bone volume).[3,6,8]

The terms *bone density, bone quantity,* and *bone quality* are complex and open to considerable interpretation. Different classifications to describe these characteristics of the bone tissue have been proposed. The most widely accepted classification of bone quantity and bone quality in dental implant treatment was established by Lekholm and Zarb[9] and based on preoperative radiographs and exploratory drilling at implant site preparation. This classification has been modified by other authors.[4,10–12] Misch[13] introduced a classification of bone density based on tactile feel during drilling and implant insertion. Considering that trabecular bone tissue varies in structure and that the compact layer surrounding trabecular bone varies in thickness, Lindh and coworkers[14] suggested that it would be appropriate to assess the radiographic bone trabecular pattern of individual sites of the jaws.

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For the clinical assessment of jawbone tissue, several methods have been utilized. These include subjective tactile perception during implant preparation[15]; cutting torque/peak insertion torque; Periotest; resonance frequency analysis (RFA)[16–20]; and diagnostic imaging methods—conventional radiography,[14,21] computed tomography (CT),[22,23] and dual-energy x-ray absorptiometry (DXA).[24]

The aim of this study was to evaluate the evidence for the diagnostic accuracy of clinical methods to assess bone density, quantity, and/or quality prior to and during dental implant placement. The intended readers are general practitioners and specialists who treat patients with dental implants as well as radiologists and related field professionals.

MATERIALS AND METHODS

The systematic approach of the literature review was adapted according to Goodman[25] and comprised the following steps: *(1)* specify the problem; *(2)* formulate a plan to conduct the literature search with specified indexing terms and retrieve publications; and *(3)* interpret the evidence from the literature retrieved.

Specification of the Problem

The following question was developed to specify the problem: What is the diagnostic accuracy of the clinical methods used to assess bone density, bone quantity, and bone quality prior to and during dental implant placement?

The following elements were defined on the basis of medical subheadings (MeSH) prior to the formal literature search:

- Dental implants: biocompatible materials placed into (endosseous) or onto (subperiosteal) the jawbone to support a crown, bridge, or artificial tooth or to stabilize a diseased tooth.
- Dental implantation: insertion of an implant into the bone of the mandible or maxilla. The implant has an exposed head which protrudes through the mucosa and is a prosthodontic abutment.
- Clinical diagnostic method: a method that should be utilized for planning or establishing the dental implant treatment, but should not be more invasive than the implant insertion procedure itself. (note: "clinical diagnostic method" is not a MeSH term).
- Diagnostic imaging: any visual display of structural or functional patterns of organs or tissues for diagnostic evaluation. This includes measuring physiologic and metabolic responses to physical and chemical stimuli as well as ultramicroscopy.

Formulation of a Plan, Literature Search, and Retrieval

To be included in this review, publications that might elucidate diagnostic accuracy, ie, addressed observer performance, percentage of correct diagnoses, sensitivity, specificity, predictive values, measures of receiver operating characteristic (ROC) curve height or areas, the likelihood ratio, or other relevant measures were sought.[26] Studies in which an independent, blind comparison had been made between the test method and a reference method were sought. Original studies that elucidated a correlation between the results of different clinical diagnostic methods were also included in this review.

The inclusion criteria are presented in Table 1. The publication had to be published in English and the study had to be conducted on human tissues or on individuals older than 19 years. Publications on local bone reaction, ie, healing, the temporomandibular joint, and bone grafts were excluded.

The first step of the search was to use MeSH terms to search the electronic database PubMed. The search was limited to publications with an abstract and with an entrez date in the period from 1 January 1966 to 2 September 2005 (Table 1).

The decision to include the article was made by reading the title and the abstract. All 3 authors read all abstracts. When an abstract was considered by at least 1 author to be relevant, the publication was ordered and read in full text, and data were extracted.

The second step was to hand-search the reference lists of the original studies that had been found to be relevant in the first step (Fig 1). The reference lists of review articles were also hand-searched. Titles containing any of the words in the following categories were searched for:

- Words suggesting a clinical examination method: Periotest, RFA, cutting torque, cutting resistance, drilling resistance, peak insertion torque, implant stability
- Words suggesting a diagnostic imaging method: intraoral radiography, panoramic radiography, CT, quantitative CT (QCT), single-energy x-ray absorptiometry (SXA), DXA, direct digital radiography, ultrasound, magnetic resonance imaging (MRI)
- Miscellaneous words: clinical and radiographic evaluation, radiographic analysis, clinical evaluation, bone density, bone quality, trabecular pattern, trabecular bone, bone mineral content, bone mass, bone type 1, bone type 2, bone type 3, bone type 4, cancellous bone, bone classification

Table 1 Search Strategies and No. of Publications Retrieved from PubMed

	Number retrieved
Indexing terms (First strategy)	
1. jaw [MeSH] AND bone density [MeSH]	224
2. dental implants [MeSH] OR dental implantation [MeSH]	2,884
3. (1 AND 2)	84
4. magnetic resonance imaging [MeSH] AND (1) AND (2)	0
5. magnetic resonance imaging [MeSH] AND (1)	1
6. magnetic resonance imaging [MeSH] AND (2)	3
Total no. of abstracts	88
Indexing terms (Second strategy)	
1. Dental implants [MeSH]	2,256
2. Dental implantation [MeSH]	2,152
3. Bone density [MeSH]	9,837
4. Dental implants	2,461
5. Dental implantation	2,163
6. Bone density	10,664
7. (1 OR 4)	2,461
8. (2 OR 5)	2,163
9. (3 OR 6)	10,665
10. (7 OR 8 AND 9)	143
11. Wound healing [MeSH]	8,392
12. Wound healing	9,910
13. (11 OR 12)	9,910
14. Bone regeneration [MeSH]	1,681
15. Bone regeneration	1,783
16. (14 OR 15)	1,783
17. Alveolar ridge augmentation [MeSH]	614
18. Alveolar ridge augmentation	615
19. (17 OR 18)	615
20. Bone transplantation [MeSH]	4,599
21. Bone transplantation	4,617
22. (20 OR 21)	4,617
23. Case reports [Publication Type]	372,984
24. (10 NOT 13 NOT 16 NOT 19 NOT 22 NOT 23)	56
25. Magnetic resonance imaging [MeSH]	60,299
26. Magnetic resonance imaging	66,056
27. (25 OR 26)	66,056
28. (27 AND 10)	0
29. (27 AND 7 OR 8)	4
30. Jaw [MeSH]	12,048
31. Jaw	15,577
32. (30 OR 31)	15,577
33. (27 AND 32 AND 9)	1
Total no. of abstracts	61

Inclusion criteria: (1) Entrez date 1 January 1966 to 2 September 2005; (2) subjects at > 19 years old, and (3) publications indexed as "item with abstract," "English," and "Human."

Inclusion and exclusion criteria were also considered in the hand search. The abstracts of the selected references were ordered. When an abstract was considered by at least 1 author to be relevant, the publication was ordered in full text. Book chapters and reviews were excluded, since the second step of the search focused on original studies.

Data Extraction

Data were extracted with the aid of a protocol (Appendix 1) designed on the basis of literature about the critical appraisal of studies on diagnostic methods.[27,28]

Original studies that presented a clinical method to assess 1 or more of the terms bone density, bone quantity, and bone quality prior to and during dental implant placement were interpreted according to the Quality Assessment of Diagnostic Accuracy Studies (QUADAS) tool.[29] In the present review, a modified protocol that comprised 13 of the 14 questions of the original tool was applied as presented in Table 2.

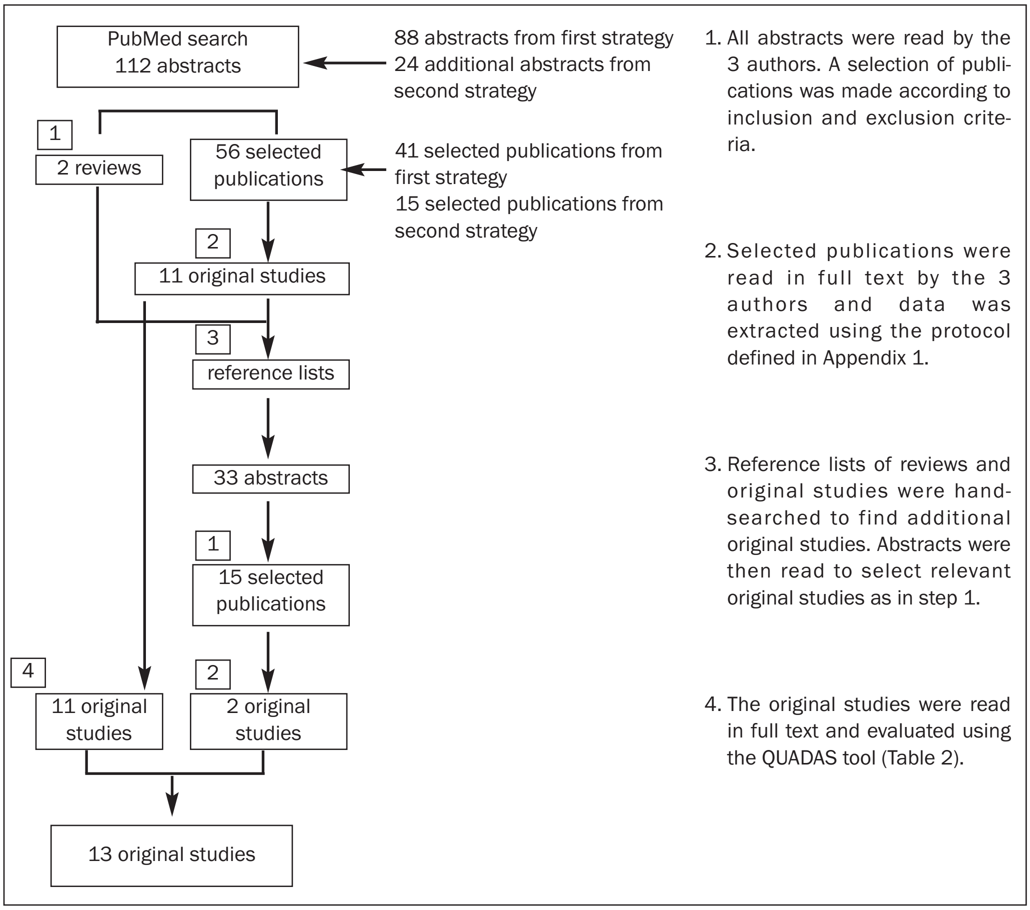

Fig 1 Flowchart of the selection strategy used in the systematic review and publications remaining in each stage (stages 1 to 4).

RESULTS

Systematic Literature Search

The number of publications retrieved, read, and interpreted is presented in Fig 1. The 2 PubMed searches resulted in 112 titles and abstracts. Of these abstracts, 56 publications were judged to meet the inclusion criteria and read in full, and data were extracted according to the pre-established protocol (Appendix 1). This resulted in 11 original studies being considered relevant for the review. The second step of the search—the hand search of the reference lists of 11 original studies and 2 reviews—resulted in an additional 33 abstracts. After these abstracts had been read, 15 publications were selected, ordered, and read in full, and data were extracted. After the publications had been read in full, 2 were selected.

A total of 13 original studies were interpreted for this review.[14,15,18–22,24,30–34] In 6 studies, the results of the test method were compared to those of a reference method (Tables 3 and 4).[14,15,20,21,23,30] These studies were interpreted according to the protocol (Table 2) based on the QUADAS tool.[29] Based on this, it could be reported that in some studies the sample spectrum was not representative,[30] the sample spectrum was not clearly described,[15] or the selection criteria were not clearly described,[15,21] and the test method[15,20] or the reference method[30] was not described in such detail that it could be reproduced. The reference standard test (morphometric measurements) in 2 studies[20,30] was performed in the peri-implant bone region of an implant in situ.

In 1 original study, a correlation between the results of different clinical diagnostic methods was presented (Table 5).[31] However, there was no account of which method was to be evaluated. Six studies and the reasons for their exclusion are presented in Table 6.[18,19,24,32–34]

Diagnostic Accuracy

In 3 of the 6 studies where the results of the test method were compared with the results of a reference

Table 2 Protocol Based on the QUADAS Tool[29] for Interpretation of Relevant Original Studies on Clinical Methods to Assess Jawbone Tissue Prior to and During Dental Implant Placement

First author:______	Article no. ______		
Item	**Yes**	**No**	**Unclear**
1. Was the spectrum of patients/jaws/sites representative of what will be diagnosed in practice?			
2. Were the selection criteria clearly described?			
3. Is the reference method likely to correctly classify the target condition?			
4. Did patients receive the same reference method regardless of the test result?			
5. Was the execution of the test method described in sufficient detail to permit replication of the test?			
6. Was the execution of the reference method described in sufficient detail to permit its replication?			
7. Were the test results interpreted without knowledge of the results of the reference method?			
8. Were the reference method results interpreted without knowledge of the results of the test method?			
9. Were the same clinical data available when test results were interpreted as would be available when the test is used in practice?			
10. Were uninterpretable/intermediate test results reported?			
11. Were withdrawals from the study explained?			
12. Are data presented on observer or instrument variation that could have affected the estimates of test performance?			
13. Were appropriate results presented (percentage of correct diagnoses, sensitivity, specificity, predictive values, measures of ROC, likelihood ratios, or other relevant measures) and were these calculated appropriately?			

Interpreter: ______ Date:______

Comments: ______

method, the test method was a preoperative radiographic method—periapical radiography,[14] panoramic radiography,[21] or QCT[23] (Table 3). In the 3 other studies, the jawbone tissue was assessed during placement of the endosseous dental implant based on the hand-felt perception of the surgeon,[15] using the cutting resistance technique,[30] Periotest,[20] or peak insertion torque[20] (Table 4). The reference methods consisted of QCT[21] and morphometry based on either histologic sections[15,20] or radiographs.[14,23,30]

Concerning diagnostic accuracy, only 1 study[14] presented its results as percentage of correct diagnoses (Table 3). When periapical radiography was used together with reference images, the trabecular pattern was correctly categorized in 58% of the sites. The accuracy was highest for the category "dense trabeculation" (78% of the sites) compared to "alternating trabeculation" (57%) and "sparse trabeculation" (28%). Without reference images, diagnostic accuracy decreased in all categories. Lindh and colleagues[14] also evaluated the method of Lekholm and Zarb[9] in their study. The evaluation was based only on preoperative radiographs, but it was not possible to evaluate the method[14] with morphometry. This was because the trabecular pattern visualized by contact radiography differed from the pattern that was illustrated in the drawings of Lekholm and Zarb.[9] No study was found on diagnostic accuracy that compared the method based on preoperative radiographs and explorative drilling at implant site preparation as originally described by Lekholm and Zarb[9] with a reference method.

As presented in Table 3, bone mineral density (BMD) as determined by QCT was correlated with trabecular bone volume (TBV) as estimated by morphometry on contact radiography.[23] Likewise, the classification of trabecular pattern into 5 different grades using panoramic radiographs was correlated with BMD as measured with QCT.[21]

For methods used during placement of dental implants (Table 4), Friberg and associates[30] found a correlation between cutting resistance and bone area values. Nkenke and colleagues,[20] however, found no correlation between peak insertion torque and bone volume or between Periotest values and bone volume assessed by histomorphometry.[20] Trisi and coworkers[15] reported a correlation between the surgeon's perception of 4 different classes of bone density based on hand-felt drilling resistance and the amount of bone trabeculae assessed by morphometry.

There was 1 study on observer performance.[14] Interobserver agreement between 2 observers was 60% (kappa 0.32) with reference images and 64% (kappa 0.35) without reference images for classification of the trabecular bone pattern in 3 categories on periapical radiographs. Corresponding figures for

Table 3 Clinical Methods to Assess Bone Density, Bone Quantity, and Bone Quality Prior to Dental Implant Placement

Authors (year)	Sample/ jaw/site	Test method: Classification of bone tissue/ measurement unit/ observers	Reference method: Classification of bone tissue/ measurement unit	Measures to describe results/ statistical test	Results according to the authors	Comments based on evaluation with aid of QUADAS
Lindh et al[14] (1996)	• 9 cadavers 62–94 y (mean, 81 y) • 9 mandibles • 23 edentulous sites: 6 anterior and 17 posterior	Periapical radiography Classification of trabecular bone pattern in 3 categories: dense trabeculation, alternating dense/sparse trabeculation, sparse trabeculation A. Imaging interpretation with reference images B. Imaging interpretation without reference images • 7 observers (3 for intraobserver agreement)	Morphometry from contact radiographs TTBV within a region of interest was given as fractional area percentage of mineralized bone tissue	• Categories of radiographic trabecular bone pattern compared to mean TTBV • Interobserver agreement between 2 observers • Intraobserver agreement	• Mean accuracy of categorization: A. 58%, B. 50% • Interobserver agreement: A. 60%, B. 64%; kappa: 0.32, 0.35 • Mean intraobserver agreement: A.75%, B. 86%; kappa: 0.61, 0.67	Clinical data not available
Lindh et al[14] (1996)	• 9 cadavers 62–94 y (mean, 81 y) • 9 mandibles • 23 edentulous sites: 6 anterior and 17 posterior	Periapical radiography • Lekholm & Zarb[9] bone classification (types 1 to 4) • 7 observers (3 for intraobserver agreement)	Morphometry from contact radiographs TTBV within a region of interest was given as fractional area percentage of mineralized bone tissue	• Correlation between classes 1 through 4 and mean TTBV • Interobserver agreement between 2 observers • Intraobserver agreement	• Not possible to estimate accuracy • Interobserver agreement: 49%; kappa: 0.33 • Mean intraobserver agreement: 76%; kappa: 0.43	Clinical data not available
Lindh et al[14] (1997)	• 9 cadavers 62–94 y (mean, 81 y) • 9 mandibles • 22 edentulous sites: 6 anterior and 16 posterior	Quantitative computed tomography (QCT) BMD (amount of calcium hydroxyapatite in mg/cm^3) in a region of interest of trabecular bone tissue	Morphometry from contact radiographs TBV and TTBV within a region of interest was given as fractional area percentage of mineralized bone tissue	Correlation between: • BMD and TBV • BMD and TTBV Pearson's correlation coefficient	Significant correlation ($P < .001$) between • BMD and TBV ($r = 0.69$) • BMD and TTBV ($r = 0.70$)	Clinical data not available • Observer and instrument variation not presented • No results on diagnostic accuracy
Taguchi et al[21] (1997)	• 28 patients (16 F and 12 M) 19–81 y (mean 53 y for F and 57 y for M) • 28 mandibles • 47 edentulous premolar and molar sites	Panoramic radiography Trabecular bone pattern classified in 5 grades: • No visible bone trabeculae • A few thin and irregular bone trabeculae • Distinct bone trabeculae as observed in normal alveolar bone • Thick bone trabeculae partly occupying the bone marrow spaces • Dense bone without any visible bone trabeculae	QCT BMD measured in CT expressed as HU Two observers	Correlation between grading of trabecular bone pattern and mean HU ANOVA	Grading of trabecular bone pattern correlated to BMD ($P < .001$)	• Observer and instrument variation not presented • No results on diagnostic accuracy

ANOVA = analysis of variance; BMD = bone mineral density; CT = computerized tomography; F = female; HU = Hounsfield units; M = male; QCT = quantitative computed tomography; QUADAS = quality assessment of diagnostic accuracy studies; TBV = trabecular bone volume; TTBV = total trabecular bone volume.

Table 4 Clinical Methods to Assess Bone Density, Bone Quantity, and Bone Quality During Dental Implant Placement

Authors (year)	Sample/ jaw/site	Test method: Classification of bone tissue/ measurement unit/	Reference method: Classification of bone tissue/ measurement unit	Measures to describe results/ statistical test	Results according to the authors	Comments based on evaluation with aid of QUADAS
Friberg et al[30] (1995)	• 7 cadavers (3 F and 4 M) 61–90 y (mean, 73 y) • 10 jaws (6 maxillae and 4 mandibles) • 28 implant sites	Cutting resistance technique True cutting resistance (mJ/mm^3)	Morphometry from microradiographs Total amount of • Mineralized bone • Trabecular bone • Compact bone expressed in % bone area	Correlation between mean cutting resistance values (mJ/mm^3) and total bone area values Spearman's correlation	Correlation between total bone area values and mean cutting resistance values (r = 0.74; P < .001)	• Morphometric measurements performed with implant in situ • Difficult to interpret results • Execution of reference method not described in sufficient detail
Trisi and Rao[15] (1999)	56 patients	Surgeon's hand-felt perception of drilling resistance Classification of bone density according to Misch[13]: • D1 - Dense compact • D2 -Thick porous compact, coarse trabecular • D3 - Thin porous compact, fine trabecular • D4 - Fine trabecular	Morphometry of histologic slides from biopsy specimens obtained at implant site preparation • Bony trabeculae as a percentage of the total bone area	Correlation between clinical scoring bone density (D1–D4) and morphometric values Spearman's correlation ANOVA	Correlation (P = .000) between amount of bone trabeculae in biopsy specimen and clinical scoring density • D1 and D4 significantly different from total population • D2 and D3 not significantly different	• Sample spectrum and selection criteria not clearly described • Execution of test method not described in sufficient detail • Observer and instrument variation not presented
Nkenke et al (2003)[20]	• 3 subjects (M) 56–90 y (mean, 74 y) • 4 edentulous jaws (2 maxilla and 2 mandibles) • 48 sites	• Peak insertion torque (Ncm) • Periotest	1. Morphometry of histologic slides from cadaver specimens • BV/TV (%) • Buccal and oral cortical bone volume (cortical bone volume per tissue volume %) • TBPF 2. QCT BMD calculated from average CT values (HU)	Correlation between Periotest values, peak insertion torque and • BV/TV • Cortical bone density—oral aspect • Cortical bone density—buccal aspect • TBPF ANOVA	No correlation was found	• Peak insertion torque not described in sufficient detail • Morphometric measurements performed with implant in situ • Observer or instrument variation not presented

ANOVA = analysis of variance, BMD = bone mineral density, BV/TV = trabecular bone volume, F = female, HU = Hounsfield units, M = male, QUADAS = Quality Assessment of Diagnostic Accuracy Studies, QCT = quantitative computed tomography, TBPF = trabecular bone pattern factor.

Table 5 Clinical Method to Assess Bone Density, Bone Quantity, and Bone Quality Prior to Dental Implant Placement

Authors (year)	Sample/ jaw/site	Method A: Classification of bone tissue/ measurement unit/	Method B: Classification of bone tissue/ measurement unit	Measures to describe results/ statistical test	Results according to the authors
Norton and Gamble[31] (2001)	39 sites (maxilla: 42 anterior and 27 posterior; mandible: 25 anterior and 45 posterior) from fully or partially edentulous patients	CT: HU	Subjective assessment of CT scans of bone according to Lekholm and Zarb[9] classification	• Correlation between bone density (HU) and subjective bone quality (1 to 4) Mantel's test	Strong correlation between HU and bone quality of the same site ($P = .002$)

CT = computed tomography; HU = Hounsfield units.

Table 6 Clinical Methods for the Assessment of Bone Density, Bone Quantity, and Bone Quality Prior to and During Dental Implant Placement: Publications Excluded after Full-Text Evaluation

Author (year)	Test method and reference method	Reason for exclusion
Friberg et al[18] (1999)	Cutting torque compared to Lekholm and Zarb[9] classification of bone quality	No correlation was presented in results
Friberg et al[19] (1999)	Cutting torque during drilling compared to resonance frequency analysis	Test method was applied after implant placement
Barewal et al[32] (2003)	Bone quality was categorized according to Lekholm and Zarb[9] and compared to resonance frequency analyses	Test method was applied after implant placement
Chöel et al[24] (2003)	Dual-energy x-ray absorptiometry	No reference method and no correlation were presented in the results
Bischof et al[33] (2004)	Resonance frequency analyses correlated to Lekholm and Zarb[9] classification of bone quality	Test method was applied after implant placement
Becker et al[34] (2005)	Resonance frequency analyses	Test method was applied after implant placement No reference method and no correlation were presented in the results

mean intraobserver agreement were 75% (kappa 0.61) and 86% (kappa 0.67). For the 4 classes of bone quality presented by Lekholm and Zarb[9], interobserver agreement was 49% (kappa 0.33), and mean intraobserver agreement was 76% (kappa 0.43). Three studies[21,23,30] presented the precision of the reference method but not of the test method.

DISCUSSION

Methodologic Approach of the Systematic Review

Systematic reviews aim to identify and evaluate available research evidence relating to a particular objective. In the present study, the assessment problem defined prior to the search included methods used prior to or during implantation for diagnostic purposes. This resulted in the exclusion of studies on RFA[19,20,32–34] applied just after implant placement. Another reason for the exclusion of studies was the absence of a reference method or any correlation between the results of different clinical diagnostic methods.[18,24,34]

Quality assessment is an integral part of any systematic review. If the results of individual studies are biased and synthesized without any consideration of quality, then the results of the review will also be biased. It is therefore essential that individual studies included in a systematic review be interpreted in terms of potential for bias, lack of applicability, and quality of reporting. A standardized approach to extraction of the data and interpretation of the studies is important when determining the studies to be included in a review. A quality assessment tool that is biased by preconceived ideas can then be avoided.[35] In the present review, 2 protocols were created, 1 based on literature about the critical appraisal of studies on diagnostic methods[27,28] and a second based on QUADAS.[29]

Although several checklists for assessment of the quality of studies of diagnostic accuracy exist, none of these have been systematically developed or evaluated, and they differ in terms of the items that they assess.[36] QUADAS was the first systematically developed, evidence-based assessment tool to be used in systematic reviews of studies on diagnostic accuracy.[29] QUADAS is the generic part of what in practice may be a more extensive tool incorporating design and topic-specific items. However, the main advantage of using this tool in the present study was that it was systematically developed for use in systematic reviews of studies on diagnostic accuracy because the criteria needed to assess the quality of diagnostic test evaluations differ from those needed to assess evaluations of therapeutic interventions. Also, the detailed description of each item included in the final tool, (ie, what is meant by the item, situations in which the item does not apply, and how to score items), as well as the availability of an additional file with the original 28 possible items for inclusion in the quality assessment tool, allow minor adaptations to be made in specific areas. In the present study, 3 questions (numbers 4, 5, and 7) were excluded from the 14 questions of the final QUADAS tool[29] and 2 others were added from the original list of 28 questions.[29] This modification was made to adapt the tool to better fit the study design and objectives.

The QUADAS tool[29] does not include quality scores, which are frequently used in systematic reviews to assess level of evidence and the scientific conclusion. Incorporation of quality scores into the results of a review can, however, alter conclusions on estimates of diagnostic accuracy based on the quality of a study.[37] Instead, it has been proposed that either the results of the entire assessment or only the results of key components of the assessment be reported.[33] Furthermore, in the present review, where only a few original studies had used a reference method and there was a lack of consensus on what the terms bone density, bone quantity, and bone quality actually mean, the present authors did not find it worthwhile to score the quality of or judge the level of evidence. The presentation of all the studies, where the results of a test method were compared to those of a reference method in an attempt to analyze the accuracy of the test method, could better express the status of what had been published on the clinical assessment of jawbone tissue prior to and during endosseous dental implant placement.

Results

Although several methods have been used to assess the jawbone prior to or during implant placement, the results of this review show that the methods have not been evaluated as diagnostic or prognostic tests. The results of 6 of the 7 interpreted studies were expressed as correlations between the test method and the reference method. Although a high correlation indicates that the test may yield clinical information, it is insufficient to evaluate the accuracy of a method. Information obtained from a test should help the clinician to become more certain of the patient's condition, that is, more certain of the probability that the bone tissue is of "good" or "poor" quality. Therefore, tests typically have 2 features: *(1)* a separator variable, which is a measurable property that relates to a particular disease or condition, and *(2)* a positivity criterion, which is a particular value of the separator variable that distinguishes patients who are "normal" from those who are considered "diseased" or to have the condition.[38] The positivity criterion divides the test population into correct (true) and incorrect (false) diagnostic categories. It is necessary to distinguish between these categories, as they form the basis for evaluation of the efficacy of the method. Variability in the manipulation, processing, or reading of a test or reference standard will affect diagnostic accuracy. Therefore, it is also important to describe observer performance of a method.

To estimate the important characteristics, that is, the correct and incorrect categories, an independent estimate of the probability of the condition in the form of the results of a reference method is necessary. Few studies[14,15,20,21,23,30] reported the use of a reference method. Only one[14] of these studies also presented the results in terms of percentage of correct diagnoses. The diagnostic accuracy was highest for identifying dense trabeculation (78% of the sites) when periapical radiography was used together with reference images to distinguish 3 categories of trabecular pattern, while the accuracy was lowest for sparse trabeculation.[14] The results for dense trabeculation were partly in accordance with those of Trisi and Rao,[15] who concluded that the extremes of the bone classes or bone types were easier to identify than the intermediate groups.

So far, the classification proposed by Lekholm and Zarb[9] has been used in most clinical studies on dental implant treatment to describe jawbone shape and quality. However, no original study was found in which this method, which involves the use of radiographs and drilling resistance during surgery, was compared with a reference method. The interobserver performance of 2 observers using the method of Lekholm and Zarb[9] was comparable to the interobserver performance of the method proposed by Lindh and associates.[14] Intraobserver agreement expressed as kappa indices was higher for the latter method.[14] One reason that the intraobserver agreement for the method of Lekholm and Zarb[9] may have been lower is that 4 categories of bone quality were being assessed, in contrast to only 3 categories for the method of Lindh and associates,[14] and that the bone tissue was assessed only on the basis of radiographs.

It is commonly stated[1–8,39,40] that jaw shape and bone quality or density are some of the most influential factors affecting the implant survival rate. Also, it has been suggested that if bone quality could be rated at different sites or in different regions, the length of the healing period needed for osseointegration could be more accurately determined.[30] Bone quality and quantity may influence the primary stability of dental implants, and poor initial or primary stability is thought to play a significant part in the early loss of implants when the healing period has been insufficient.[5,32,39] Therefore, methods used prior to dental implant placement are valuable as diagnostic tests for the planning of implant placement in bone tissue. Only the imaging methods[14,21,23] were used for this purpose. The other clinical methods reviewed[15,20,30] evaluated bone tissue at the time of implant placement to provide information that could be used to determine the healing period necessary before loading. However, all of the methods reviewed can serve as prognostic tests to help predict future successes and failures and determine marginal bone reaction over time.

MRI[41] and quantitative ultrasound (QUS)[42] have been referred to in the literature as possible noninvasive and radiation-free methods for bone assessment. Besides the absence of radiation, one of the main advantages is said to be ability to obtain information about bone microstructure and other parameters of bone quality. However, no original studies that compared MRI or QUS with a reference method were found for implant treatment. MRI and QUS are still primarily used for research on osteoporosis.[43–45]

The results of studies that have been performed until now on different types of dental implants where bone tissue density and quality have been regarded as important parameters can be questioned. The quality of the reviewed studies was less than optimal, concerning the evaluation of diagnostic or prognostic methods whose aim was to identify different types of bone tissue density or quality. Only 6 studies[14,15,20,21,23,30] that compared the results of a test method and a reference method could be identified. In only 1 study,[14] however, were the categories of the results of the test method and the reference method defined so that the diagnostic accuracy of the test method could be estimated. There is a need for studies on methods for use prior to and during implant treatment, where accepted methodologic criteria for diagnostic efficacy are incorporated. The Standards for Reporting of Diagnostic Accuracy[46] statement, which contains a checklist of 25 items developed to improve reporting of diagnostic methods, should be helpful in designing studies in the field. Such studies are already important for clinicians who are being faced with an ever-growing selection of implants.

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Appendix 1 Protocol for the Interpretation of the Retrieved Publications

First author:______________________________ **Article no.**__________

Title:______________________________

Journal:______________________________

Year:__________ **Volume:**__________ **Pages:**__________

1. Well-defined hypothesis /aim/problem: Yes No

2. Design of the study:

Randomized controlled trial	Clinical trial	Meta-analysis
Cross-sectional study	Clinical controlled trial	Systematic review
Cohort study	Case-control study	Other

3. Sample characteristics:
   Type of sample
   Selection criteria:
   Patient characteristics
   Socio-economic factors:

	Sample	Control	Age (mean/range) Sample	Age (mean/range) Control
Number of individuals				
Number of women				
Number of men				
Maxilla				
Mandible				
Implants/sites				

4. Classification: Bone density: Bone quantity: Bone quality:

5. Measurement units: Bone density: Bone quantity: Bone quality:

6. Measurement and classification of test method: Clinical Radiography Others

7. Definition of reference method:

8. Observers: Number: Professional experience: ___years (mean/range)

9. Methods describing the result: Percentage of correct diagnoses; measures of ROC; Sensitivity; Likelihood ratios; Specificity; Other relevant measures; Predictive values

10. Is this article relevant for the project? Yes No Cannot be determined

11. Overall result ______________________________

12. Comments ______________________________

Assessor: ______________________________ Date: __________