Relationship between Systemic Bone Mineral Density and Local Bone Quality as Effectors of Dental Implant Survival

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ABSTRACT

Purpose: This study aimed to assess (1) the relationship of systemic bone mineral density (BMD) and osteoporotic status with the surgeon's subjective assessment of local jawbone quality, and (2) whether the surgeon's subjective assessment of local jawbone quality is a predictor of implant failure.

Materials and Methods: A retrospective analysis of 2,867 dental implants placed in 645 patients was accomplished. The surgeon's assessment of bone quality at the time of dental implant placement was recorded. Of those, 208 patients with 701 implants had BMD data available within 3 years. Statistical analyses were conducted to determine relationships between BMD, osteoporotic status, and local jawbone quality and to determine the relationship between local jawbone quality and implant survival.

Results: There was no association between systemic BMD and the surgeon's assessment of bone quality ($p = .52$) nor between osteoporotic status and the surgeon's assessment of local jawbone quality (Spearman rank correlation coefficient = 0.08). Additional retrospective analysis revealed implants placed in moderate- (hazard ratio = 1.67; $p = .043$) or poor-quality (HR = 3.45, $p < .001$) bone (surgeon's assessment) were significantly more likely to fail than implants placed in good-quality bone.

Conclusion: Systemic BMD and osteoporotic status are not associated with local jawbone quality. Implants placed in good-quality bone, as assessed subjectively by the surgeon at the time of implant placement, have significantly better survival characteristics than implants placed in moderate-/poor-quality bone.

KEY WORDS: BMD, bone quality, dental implant, implant survival, osteoporosis, retrospective

INTRODUCTION

An indication of bone quality/quantity is crucial for the suitability of bone to successfully house a dental implant. Bone quality recordings of the osteotomy site at the time of implant placement are subjective and based upon a surgeon's assessment usually accomplished by visual and tactile inspection/palpation at the time the osteotomy site is prepared. Clinicians would benefit from an objective measure to reliably predict osseointegration. Some methods have been proposed to quantitate and qualify bone quality.[1] Assessing the trabecular pattern before endosseous implant treatment on preoperative radiographs with reference images has been suggested.[2] Useful radiographs include periapical, panoramic, and three-dimensional radiographic surveys such as computed axial tomographic images, cone-beam computed tomography (CT; resulting in reduced radiation to the patient) or conventional CT.[3] Other methods[1] include cutting resistance technique, Periotest® (Siemens AG, Bensheim, Germany), resonance frequency analysis,[4] and peak insertion torque. The

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TABLE 1 World Health Organization Osteoporosis Diagnosis Classification

Normal	A value for BMD that is not more than 1 SD below the young adult mean value
Osteopenia	A value for BMD that lies between 1 and 2.5 SDs below the young adult mean value
Osteoporosis	A value for BMD that is more than 2.5 SDs below the young adult mean value
Severe/Established osteoporosis	A value for BMD more than 2.5 SDs below the young adult mean value in the presence of one or more fragility fractures

BMD = bone mineral density.

accuracy of each of these techniques requires further study, as all present with strengths and weaknesses. Clearly, an important goal for the clinician is to determine a useful method for assessing bone quality.

Osteoporosis is a condition that affects bone mass and causes deterioration of bony architecture over time. Osteoporosis is defined by the World Health Organization based upon the measurement of bone mineral density (BMD) at the hip, lumbar vertebrae, wrist, or heel (Table 1). A diagnosis of osteoporosis suggests bone fragility and, consequently, increased fracture risk. In a previous study, Holahan and colleagues[5] found that osteoporosis and osteopenia, conditions that could affect jawbone quality, are not contraindications to dental implant therapy. Slatger and colleagues[6] also confirm that endosseous implant placement in osteoporotic patients is not contraindicated. However, the relationship of systemic measures of bone mineral density and osteoporotic status on local jawbone quality remains poorly understood.

Therefore, the specific aims of this study were to identify (1) the relationship of systemic BMD and osteoporotic status with the surgeon's subjective assessment of local jawbone quality, and (2) whether the surgeon's subjective assessment of local jawbone quality is a predictor of implant failure.

MATERIALS AND METHODS

A retrospective chart review was completed on all women 50 years of age or older who had had a dental implant placed at the Mayo Clinic between October 1, 1983, and December 31, 2004. The dental implants were placed by either the Division of Oral and Maxillofacial Surgery or the Division of Periodontics. The list of patients was generated by performing a "query" within the *Dental Implant Tracker*™ (Implant Tracking Systems LLC, West Hartford, CT, USA) program by using the guidelines listed previously. The *Dental Implant Tracker* program is a program generated within *Microsoft Access* (Microsoft Corporation, Redmond, WA, USA) and updated when a patient has a dental implant placed, restored, or repaired within the Mayo Clinic system. The study was approved by the Mayo Clinic Institutional Review Board.

The medical and dental charts of each patient were reviewed to collect the following information: (1) BMD T-score within 3 years of implant placement if available, (2) osteoporotic diagnosis based on BMD T-score, (3) surgeon's assessment of bone quality at the time of implant insertion, and (4) any implant failures. Because there is no evidence that osteoporotic status influences frequency, duration, or intensity of infection, an implant failure was defined as any implant that had to be removed because of any reason other than infection or internal implant manufacturing defect. If purulence was noted at the time of implant removal, this was considered to be an infection-related failure.

Statistical analyses were performed by using the SAS version 9.1 software package (SAS Institute, Inc., Cary, NC, USA). A general linear model was fit to evaluate the association between T-score and bone quality. The model incorporated generalized estimating equation methodology using an exchangeable correlation structure to take into account the correlation between multiple implants per patient. The Spearman rank correlation coefficient was utilized to estimate the correlation between osteoporotic status and jawbone quality, two ordinal characteristics. The majority of the implants within a patient were implanted on the same date and therefore were linked to the same T-score and osteoporotic status. Likewise, for the majority of the patients with multiple implants, the bone quality was the same for the multiple implants. Therefore, the preceding analyses were also performed per patient by using the lowest T-score or poorest diagnosis per patient and the poorest quality of bone per patient.

For each implant, the duration of follow-up was calculated from the time of placement to the date of failure or date of last follow-up. The association between

implant survival and bone quality was estimated by fitting a marginal Cox proportional hazards model. The robust standard error method of Lin and Wei[7] was used to account for the correlation between the multiple implants from the same patient. Associations were summarized by calculating hazard ratios and corresponding 95% confidence intervals by using the robust standard errors.

RESULTS

Study Sample

A total of 746 patients received 3,224 implants in the aforementioned time frame. Of these patients, 208 patients (with 701 implants) had a BMD T-score within 3 years of implant placement.

Systemic BMD and Jaw Bone Quality

The 701 implants were assessed in terms of the surgeon's assessment of bone quality at the time of implant placement. Data were missing from three implants, resulting in a data compilation of 698 implants. Of the 698, 414 (59.3%) implants were labeled by the surgeon as "good" bone quality. "Moderate" bone quality was found in 248 (35.5%), and 36 (5.2%) were found to have "poor" quality of bone. The mean (SD) T-score was –0.9 (1.7), –1.3 (1.3), and –0.5 (1.4) for patients with implants of good, moderate, or poor bone quality, respectively. A general linear model was fit to evaluate the association between T-score and bone quality that took into account the correlation between multiple implants per patient. Basing on this model, we were unable to detect a statistically significant association between BMD and bone quality ($p = .52$). Similar results were obtained when the analysis was restricted to the lowest T-score per patient (if patient had separate BMD assessments corresponding to different implant dates) and the poorest quality of bone per patient ($p = .46$).

Osteoporotic Status and Jawbone Quality

The World Health Organization Osteoporosis Diagnosis Classification is summarized in Table 1. Figure 1 summarizes the osteoporotic status of the patients at the time of their implant by their level of bone quality. Of the 414 implants that had "good" quality jawbone (surgeon's assessment), 213 (51.5%) were placed in patients with a BMD-directed diagnosis of "normal." Of the 248 implants placed in "moderate" quality jawbone, 85 (34.3%) were placed in patients diagnosed as "normal." Of the 36 implants placed in "poor" quality jawbone, 25 (69.4%) were placed in patients diagnosed as "normal." The correlation between osteoporotic status and bone quality was rather weak (Spearman rank correlation coefficient = 0.08). Similar results were obtained when the analysis was restricted to the poorest diagnosis per patient (if patient had separate BMD assessments corresponding to different implant dates) and the poorest quality of bone per patient (correlation = 0.04).

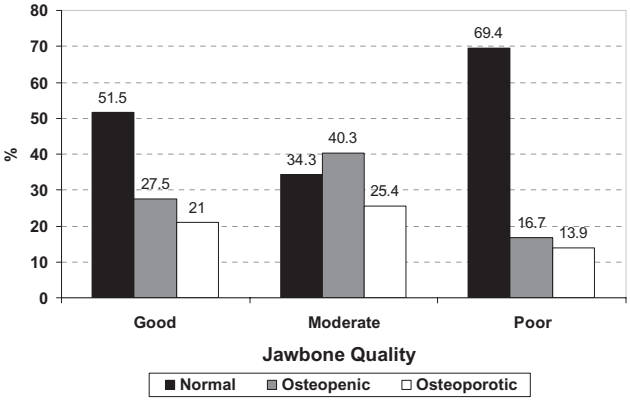

Figure 1 Summary of osteoporotic status by jawbone quality.

Jawbone Quality and Implant Survival

The association between bone quality and failure was based upon 2,867 of the 3,224 implants that had follow-up data. Among the 2,867 implants, 190 failures were noted. The loss of integration was the cause of 180 of these failures, while 10 were caused by implant fracture. These 190 implants failures occurred at a median of 341 days, with a range of 11 days to 13.4 years. An additional nine implants were associated with infection, and seven were defective implants, and their follow-up was "censored" at the date each was noted. Of the remaining 2,677 implants that did not fail, the median follow-up was 6.1 years, with a range of 9 days to 22.0 years. Among the 645 patients who contributed the 2,867 implants, the mean (SD) age at implantation was 63.3 (8.5) with a range of 50.0 to 92.4 years.

Of the 2,867 implants evaluated, 1,830 were identified as placed in "good" quality jawbone, with a survival rate of 97.3% at 1 year, 95.8% at 3 years, 95.0% at 5 years, and 93.3% at 10 years. There were 95 total failures in this grouping. The 865 implants placed in "moderate" quality jawbone had 68 failures, with a 95.4% survival at 1 year, 92.9% at 3 years, 92.5% at 5 years, and 91.2%

TABLE 2 Survival Rates (%) of Implants by Surgeon's Assessment of Bone Quality

	1 Year	3 Years	5 Years	10 Years
Good ($n = 1,830$)	97.3	95.8	95.0	93.3
Moderate ($n = 865$)	95.4	92.9	92.5	91.2
Poor ($n = 168$)	88.4	83.4	82.6	82.6

at 10 years. The 168 implants placed in "poor" quality jawbone yielded 26 failures, and the survival was 88.4% at 1 year, 83.4% at 3 years, 82.6% at 5 years, and remained constant at 82.6% at 10 years (Table 2).

By using "good" bone quality ($n = 1,830$) as the referent group, implants placed in "moderate" bone quality ($n = 865$) was 1.67 times more likely to fail ($p = .043$). Strikingly, implants placed in "poor" bone quality ($n = 168$) were 3.45 times more likely to fail ($p < .001$) (Table 3).

DISCUSSION

Investigating the interaction between systemic bone parameters and jawbone quality or response to intraoral challenges, with the goal of providing better information to guide treatment decisions, has not yielded compelling associations in many studies. An initial premise is that a condition that affects bone systemically would also affect jawbones. Identifying and quantitating any such relationship with the intent to determine optimal patient care strategies are a principal goal. To date, then, a clear and compelling effect of either low systemic BMD or a diagnosis of osteoporosis on dental implant therapy remains unproven. Given the evidence that good jawbone quality is a prognosticator for implant survival and given the supposition that systemic bone condition may be associated with local jawbone quality, we investigated the relationship between jawbone quality and systemic BMD/osteoporotic diagnosis and further evaluated whether poor jawbone quality was a risk factor for implant failure.

TABLE 3 Hazard Ratios (HR) and 95% CIs for Implants Placed in Moderate- and Poor-Quality Bone

Factor	HR (95% CI)	*p* Value
Bone quality ($n = 4$ unknown)		
Good ($n = 1,830$)	Referent	
Moderate ($n = 865$)	1.67 (1.02–2.75)	.043
Poor ($n = 168$)	3.45 (1.82–6.55)	<.001

Bone quality as a term is a potentially ambiguous one. In this study, surgeons were asked to make a subjective assessment that brings inherent variability that we readily acknowledge. The surgeon whose assessments were included in the data set presented in this study used descriptors such as "feel" and "softness" to guide their interpretation of good-, moderate-, or poor-quality bone. This is important information for the reader because an endocrinologist interested in "bone quality" may use different surrogates such as BMD or trabecular pattern, whereas an orthopedic surgeon may use other criteria yet. Clearly, the term *bone quality* is not well defined.

In the present study, the fact that there are no guarantees that operator error will not be made, coupled with the notion that there are not clear-cut boundaries assigned between poor, moderate, and good bone quality, opens the door to the possibility of variability. However, data regarding the survival rates of the implants in relation to the surgeon's assessment of bone quality at the time of implant placement are consistent with those in other findings.[5,8,9] Furthermore, the reasonably large data sets (701 implants and 2,867 implants) for the two analyses performed may act to diminish the impact of the variability of subjective assessment.

Beyond surgeon assessment, diagnostic imaging methods to assess jaw-bone quality are available. Lee and colleagues[3] discussed the use of cone-beam CT and its use to identify bone quality and bone density. Turkyilmaz and colleagues[10] also discussed the use of bone density values in Hounsfield unit from preoperative CT as a predictor for bone quality. The current methods to evaluate bone quality that have been touted are not used routinely, and there are no guidelines in reference to a "gold standard" in this regard. The accuracy of diagnosis

of each of these preoperative diagnostic techniques is an area requiring future study. Of great importance is the fact that not all implants placed in poor-quality bone fail and that not all implants placed in good-quality bone survive. Clearly, bone quality is but one factor in implant failure/survival and, on an individual patient basis, it must be viewed in the context of other factors that might affect pertinent clinical outcomes. However, the findings in our article suggest that no such correlation exists between bone quality and BMD, and, in fact, patients with a higher BMD had the poorest bone quality. Because, in previous work from our center using this same data set, Holahan and colleagues[5] showed that neither systemic BMD nor osteoporotic condition affected titanium dental implant survival, our findings are consistent with the notion that systemic BMD measures and the resulting diagnosis of normal, osteopenic, or osteoporotic do not correlate with local jawbone quality.

CONCLUSIONS

Within the limitations of this retrospective chart review, the following conclusions can be drawn:

1. Systemic BMD scores are not associated with jawbone quality, as assessed by the surgeon's feel at the time of implant placement.
2. A surgeon's subjective assessment of osteotomy site bone quality at the time of implant placement is associated with implant survival.

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