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COMPARATIVE STUDY

Comparison of implant survival with implants placed in acceptable and compromised bone: a literature review

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Abstract
Background Survival rates for conventional dental implant systems are relatively high in normal healthy bone. However, there are subgroups of patients that are at an increased risk of implant failure. In particular, patients with compromised quantity or quality of bone present a significant challenge to the dental implantologist.
Objective To perform a review of the literature in an attempt to quantify the relative risk of implant failure in compromised bone compared to good or acceptable bone and to identify whether certain anatomical regions are at greater risk.
Search Strategy We conducted a systematic electronic database search of Medline, Cinhahl and the Cochrane Library through March 2006 identifying articles meeting the eligibility criteria.
Results We calculated an increased risk of implant failure in compromised bone compared to healthy bone in both the maxilla and the mandible using conventional dental implant systems. Relative risks ranged from 2 to 12 with the highest risk of failure in the maxilla. Conventional systems are often used in combination or after bone augmentation procedures or more innovative methods for stimulating bone growth in patients with compromised bone. These approaches do have their limitations including high costs, the accumulation of the surgical risks, and delayed time to loading.
Discussion Quantifying the risk of implant failure in patients with compromised bone should assist the implantologist in treatment decision making and patient counseling. Alternative methods for treating patients with compromised bone include zygomatic and lateral implants, neither of which typically require bone augmentation procedures. More studies are needed to evaluate their safety and efficacy.

Keywords Dental implants · Bone quantity · Bone quality · Compromised bone

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Introduction

Survival rates for conventional dental implant systems are relatively high in normal healthy bone [1]. However, there are subgroups of patients that are at an increased risk of implant or treatment failure. In particular, patients with reduced quantity or quality of bone (from here on referred to as 'compromised' bone) present a significant challenge to the dental implantologist. Disease, trauma, or atrophy due to the aging process leads to this compromised quality or quantity of bone.

A lack of occlusal force in fully- or partially edentulous patients often leads to a decrease in the residual alveolar ridge, thus compounding the effects of osteoporosis or other underlying conditions. Dental implants may help to preserve bone due to their positive load-related effects on the jawbone surrounding the implant [2,3] hence, appropriate solutions should be explored and discovered to facilitate this process in these challenging patients.

The management of compromised bone with root-form dental implants typically requires additional or augmentative procedures to ensure sufficient stability. Bone augmentation may be necessary through procedures such as grafting, transplanting, or more novel therapies including augmentation

of bone combined with substitutes and/or morphogenetic proteins [4]. These methods, though often necessary, typically add treatment steps to the procedure, delay loading, and increase the total costs. Under certain conditions, the benefits may outweigh the costs. In other conditions, these additional challenges may not be feasible and alternative methods may be considered.

Quantifying the increase risk of implant failure in patients with compromised bone compared to patients with acceptable bone is of both clinical and research value. Such knowledge will allow clinicians to make treatment decisions and provide patient with potential prognoses. Several questions exist when considering implant therapy in patients with compromised bone:

1) How is compromised bone defined in the literature as it relates to dental implantology?
2) Are patients with compromised bone at greater risk of implant failure than patients with acceptable bone quantity and quality?
3) Are implants placed in the maxilla at greater risk of failure than implants placed in the mandible in patients with compromised bone?
4) Are some implants more effective than others in treating patients with compromised bone?
5) Are there alternative approaches for managing patients with compromised bone?

The purpose of this article was to answer these questions by systematically searching and summarizing the literature on this topic.

Materials and methods

Eligibility criteria

We conducted a systematic electronic database search of MEDLINE, CINHAHL and the Cochrane Library through March 2006 identifying articles meeting the eligibility criteria. Two individuals reviewed the reference lists of all key articles for additional eligible articles. We conducted a Science Citation Index search of frequently cited articles to identify potentially relevant studies that cited these articles. We applied the following eligibility criteria: (1) studies evaluating outcomes in patients treated with 'fixed' dental implants comparing patients with and without compromised bone that reported complete raw data for the calculation of relative risks and confidence intervals, (2) studies evaluating outcomes in patients with compromised bone comparing different

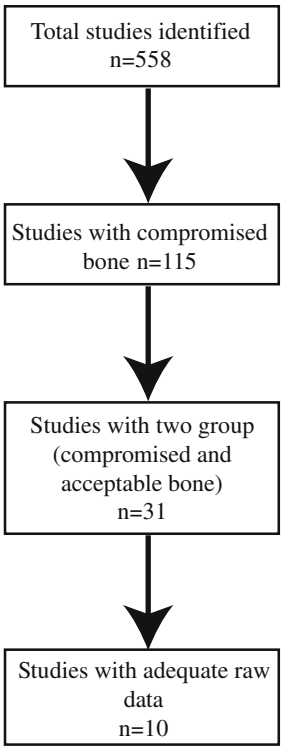

Fig. 1 Search results for studies reporting implant failure in acceptable and compromised bone

'fixed' dental implant systems that reported complete raw data for the calculation of relative risks and confidence intervals, (3) systematic review articles that summarize and provide relative risk estimates comparing implant failure in compromised and acceptable bone (4) studies of high methodological quality (systematic reviews, randomized controlled trials and cohort studies). Case series, case reports, studies evaluating radiation therapy, or patients with structural bone deficits (e.g., osteopetrosis), and animal studies were not included.

Data extraction

Two reviewers independently extracted data from each study by completing standardized dummy tables with respect to study patient population, method of assessing bone quality, total subject population (i.e., denominator), total count of events (i.e., numerator), and type of events. Discordant information obtained between reviewers was resolved through discussion.

Statistical analysis

We reported effect measures (relative risks) when provided by the article. This rarely occurred. Therefore, we only included studies where the raw data was reported (i.e., number of failures and number of implants) by group (i.e., acceptable bone and compromised bone). We used the raw data to calculate the relative risk and 95% confidence interval (CI). The relative risk is a relative comparison of outcomes (e.g., failure) between patient groups of differing exposures (e.g., bone quality). Wide confidence intervals around relative risk estimates indicate a large amount of variability in measurements and/or a small number of subjects. Unless 'acceptable' versus 'compromised' bone was defined, we designated poor quality of bone as level 4 defined by Lekholm and Zarb [5] and poor quantity of bone as level C-E defined by Lekholm and Zarb. No attempt was made to quantitatively pool data across studies due to the large number of retrospective studies, the variation in inclusion criteria, and the variation in determining bone quality and quantity. All analyses were performed using STATA (Version 9.0), college station, TX, (2005).

Results

Literature search

We identified 10 clinical studies that met our eligibility criteria, (Fig. 1). These studies are summarized in the section entitled 'Relationship between compromised bone and dental implant failure rates'. Furthermore, the raw data, relative risks and 95% confidence intervals are reported in the supporting tables. Three comparison (i.e., cohort or case-control) studies were identified reporting similar rates of failure in patients with compromised and acceptable bone whereas seven comparison studies were identified reporting different rates of failure between these two groups. The majority of the studies identified evaluated both the mandible and maxilla and most defined compromised bone based on quality using the Lekholm and Zarb system.

Definitions of compromised bone in the literature

The term 'compromised' bone is generally applied to describe bone of compromised quantity and/or quality as a result of trauma, disease state, or the natural aging process. The term 'compromised' includes developments like fatty degeneration, a decrease of

Table 1 Clinical studies that reported similar rates of failure in compromised and acceptable bone with calculated effect estimates

Author	Region	Method of assessment	n/N (implants) compromised bone	%	n/N (implants) Acceptable bone	%	RR (95% CI)	p - value
Friberg (2002)	Maxilla	LZ 1–4 (quality)	3/109	2.8	14/189	7.4	0.37 (0.11, 1.3)	0.10
		LZ A-D (quantity)	2/29	6.9	12/160	7.5	0.92 (0.22, 3.9)	0.91
Truhlar* (2000)	Maxilla/Mandible (combined)	LZ 1–4 (quality)	22/253	8.7	202/2740	7.3	1.2 (0.77, 1.8)	0.44
Truhlar (1994)	Maxilla/Mandible (combined)	LZ 1–4 (quality)	6/154	3.9	57/1977	2.9	1.4 (0.60, 3.1)	0.47

*Truhlar also performed this analysis stratified by Hydroxyapatite (coated versus non-coated). See results in table 3.

Table 2 Clinical studies that reported an increased risk of compromised bone* versus acceptable bone with calculated effect estimates

Author	Region	Method of assessment	n/N (implants) compromised bone	%	n/N (implants) Acceptable bone	%	RR (95% CI)	p-value
Blomqvist (1996)	Maxilla	BMD% (quality)	32/74	43.2	4/71	5.6	7.7 (2.9, 20.6)	<0.001
Rocci (2003)	Maxilla/Mandible (combined)	LZ 1–4 (quality)	6/23	26.1	5.98	5.1	5.1 (1.7, 15.3)	0.002
Higuchi (1995)	Maxilla/Mandible (combined)	LZ 1–4 (quality)	28/404	6.9	5/154	3.2	2.1 (0.84, 5.4)	0.09
Jemt (1995)	Maxilla	Bone graft vs.fixed prosthesis	16/83	19.3	34/449	7.6	2.5 (1.5, 4.4)	<0.001
		Removable denture vs. fixed prosthesis	36/127	28.3	34/449	7.6	3.7 (2.4, 5.7)	<0.001
Jaffin	Post. Maxilla	LZ 1–4	23/52	44.2	14/392	3.6	12.4 (6.8, 22.5)	<0.001
	Ant. Mandible	(quality)	11/30	36.7	10/147	6.8	5.4 (2.5, 11.5)	<0.001
	Mandible		2/20	10.0	5/413	1.2	8.3 (1.7, 40.0)	0.002
Friberg (1991)	Maxilla	LZ 1–4	23/57	40.3	19/322	5.9	6.8 (4.0, 11.7)	<0.001
	Mandible	(quality)	2/73	2.7	13/491	2.6	1.0 (0.24, 4.5)	0.96
	Maxilla	LZ A-D	37/257	14.4	5/122	4.1	3.5 (1.4, 8.7)	0.003
	Mandible	(quantity)	8/265	3.0	7/299	2.3	1.3 (0.47, 3.5)	0.62

* If not defined by author, we calculated effect estimates using the following categories for quality (compromised=level 4; normal = level 1-3) and quantity (compromised=level C-D; normal = level A-B)
†Case control studies produce odds ratios (these approximate RRs); rates cannot be calculated

mineralization as well as morphological changes (atrophy). Determination of bone quantity and quality may be accomplished by various densitometry methods including radiographs, Computerized Tomography (CAT scans), Single Photon Absorptiometry (SPA), Dual-Photon Absorptiometry (DPA), Dual-energy x-ray technology (DEXT) and peripheral Dual-Energy X-ray (pDEXA) [10].

Bone quantity indicates a quantitative bone measurement and may be described in terms of alveolar ridge height and width. A decrease in bone quantity is marked by resorption at the alveolar ridge. This atrophy may progress to a state of total or severe atrophy in the maxilla or mandible rendering it unable to support a conventional endosseous dental implant [4]. Clinically, those who describe bone quantity are usually referring to the vertical bone supply and not to the horizontal bone supply. The horizontal bone supply is usually present in all individuals including those with extremely reduced vertical bone. Further, the term 'atrophy', in the context of dental implantology, usually means 'reduced vertical bone' in combination with 'reduced sagittal bone' in the anterior maxilla, without reference to the basal horizontal bone supply. Complete atrophy of the alveolar bone is often found in the distal maxilla and is rarely observed in the mandible. Both the expansion of the maxillary sinus and the resorption of the alveolar bone contribute to the overall maxillary atrophy, while in the mandible,

Table 3 Comparison of implant failure rates by bone quality level using various dental implant methods

Author	Region	Bone Quality (LZ)	n/N (implants)	%	n/N (implants)	%	RR (95% CI)	p-value
			TiUnite		Machined			
Rocci (2003)	Maxilla/Mandible (combined)	1	NA	NA	NA	NA		
		2	0/7	0	0/3	0	Not calculable	NA
		3	2/47	4.3	3/41	7.3	1.7 (0.30, 9.8)	0.54
		4	1/12	8.3	5/11	45.5	5.5 (1.0, 39.7)	0.04
			HA-Coated		Non-HA			
Truhlar (2000)		1	3/111	2.7	13/147	8.8	3.3 (1.0, 11.2)	0.04
		2	28/778	3.6	65/609	10.7	3.0 (1.9, 4.6)	<0.001
		3	32/780	4.1	61/320	19.1	4.6 (3.1, 7.0)	<0.001
		4	10/206	4.9	12/47	25.5	5.3 (2.4, 11.4)	<0.001

the development of the atrophy progresses caudally. Lekholm and Zarb (LZ) [5] have defined a qualitative rating scale of bone quantity as follows: A=no ridge resorption; B=moderate resorption; C=advanced resorption; D=some resorption of basal bone has begun; E=extreme resorption of basal bone.

Bone quality is generally described in terms of composition. A decrease in bone quality is marked by a change in bone density, including a loss of cortical bone, a decreased density of trabecular bone and a weakened collagenous framework [12]. Bone quality as opposed to quantity may have a greater effect on implant osseointegration. Some have reported bone quality at the implant site as being the best indicator of success [5] have defined a rating scale of bone quality as follows (Lekholm and Zarb 1985): 1=entire jaw comprised of homogenous compact bone; 2=thick cortical layer surrounds a core of dense trabecular bone; 3=thin cortical layer surrounds a layer of low-density trabecular bone; 4=thin layer of cortical bone surrounds a core of low-density trabecular bone.

Bone quantity is considered to be synonymous with bone volume and bone quality with relative bone density which can be determined and quantified with computerized tomography scanning and other sophisticated radiological techniques [7].

Relationship between compromised bone, anatomical region and dental implant failure rates

Dozens of studies were identified that followed a series of patients with compromised bone and made comparisons to 'historical controls' from previously published literature. Only a small number were identified comparing patients with compromised bone to those with acceptable bone in the same study that provided adequate raw data to calculate effect estimates. Those studies (n=10) identified that made such a comparison were included in this section of the review.

The following three studies reported similar rates of dental implant failure comparing patients with compromised bone to patients with acceptable bone [7,8]. Hence, effect estimates were not statistically significant (Table 1). Friberg et al. [15] evaluated 98 patients retrospectively for the purpose of comparing failure rates between varying diameters of Brånemark implants [8]. As part of the analysis, they reported rates of failure in both the mandible and the maxilla by bone quality (LZ 1–4) and bone quantity (LZ A-D; no patient identified with level E). The mean follow-up was 2 years and 8 months (range, 0.5 to 5.5 years). No failures occurred in the mandible. Paradoxically, rates of failure with respect to bone quality were less in those with compromised bone compared to those with acceptable bone (2.8% and 7.4%; respectively); however, this was not statistically significant. Rates of failure with respect to bone quantity were similar (6.8% and 7.5%, respectively).

Truhlar et al. [7] performed a retrospective analysis on 2,131 dental implants to determine if there was a relationship between bone quality and implant failure. Mean follow-up time in this group of patients was not clear. The highest rate of failure was found in patients with the highest quality of bone (LZ 1 = 4.3%); however, when the data was combined per Enquist's modified system (LZ 4 versus LZ 1–3), the rates of failure were similar (compromised bone = 3.9%, acceptable bone = 2.9%; p = 0.47).

In another retrospective analysis, Truhlar et al. [6] reported on 2,998 implants with a follow-up period of 36 months [6]. It is unclear if these data overlap with the data from the previous study published 6 years earlier. These data were more complete and more factors were assessed and analyzed. In particular, data was stratified by implant design and hydroxyapatite (HA) coating. Rates of failure were similar in patients with compromised (LZ 4=8.7%) versus acceptable (LZ 1–3=7.3%; p=0.44) bone. However, when stratified by HA coating (coated versus non-coated) a significant difference was observed. These findings are reported in a subsequent section.

The following six studies reported higher rates of failure in patients with compromised bone compared to those with acceptable bone [1,9,11,20,21] (Table 2). Blomqvist et al. identified 11 patients (n=74 implants) with severely atrophied maxillary alveolar processes who received implants and sinus floor bone grafting by a one-stage procedure and followed them for a mean period of 30 months [11]. These patients were matched for sex and age with a control group of 22 patients (n=71 implants) who did not require bone grafting procedures. Bone mineral content in the forearm was measured and relative Bone Mass Density (BMD%) was calculated. The mean BMD% for the compromised and acceptable bone groups was 89.2 and 98.6 (p<0.01), respectively. Patients with compromised bone quality were nearly eight times more likely to experience an implant failure (RR = 7.7, 95% CI 2.9, 20.6; p<0.001).

Table 4 Limitations of the current treatments for compromised bone

Method	Description	Limitations
Bone Grafting [4]	• Augmentation by means of autogenous, allogeneic or bone substitute grafting	• Delayed loading due to bone healing time • Additional surgery (e.g. bone harvesting) • Complications (e.g., pain, infection) • Costly • Potential lack of harvestable bone
Enamel Matrix Derivative (EMD) [14]	• An extract derived from developing pig teeth used to help regenerate lost tissue following severe periodontitis	• Delayed loading • Authors suggest that overall treatment effect may be overestimated. • Costly
Long-term high-dose glucocorticosteroids, estrogen replacement therapy, calcium plus vitamin D_3, bisphosphonate therapy [16]	• Systemic treatments used to treat osteoporosis symptoms	• Study results are conflicting regarding effects of these therapies • Loss of Osseointegrated implants after bisphosphonate therapy has been reported • Costly
Bone Morphogenetic Proteins (BMPs) [4]	• A family of osteoinductive proteins used to reduce the resorptive effects of osteonal remodeling • Increases bone density	• Long treatment course (4-months bone induction before implant placement in Phase II clinical trial) • Delayed loading during augmentation response • In clinical trial stage • Costly

Rocci et al. [23] performed a randomized clinical trial (RCT) to evaluate two implant systems (TiUnite and machine-surfaced Branemark systems) in an immediate loading protocol. As part of the analysis, their results were presented by bone quality level (LZ 2–4; no level 1). Patients with compromised bone were greater than five times more likely to experience an implant failure than patients with acceptable bone (RR=5.1, 95% CI 1.7, 15.3; p=0.002). However, when stratified by implant system (TiUnite versus machine-surfaced), the elevated risk was observed in just one system. These findings are reported in a subsequent section.

Jemt and Lekholm performed a retrospective cohort study to compare the 5–year treatment results of the Brånemark treatment technique between different maxillary shapes all with edentulous maxillae [21]. Groups were divided by the following categories based on the amount of bone available for implant placement: bone graft, severe-resorption (treated with removable overdentures), intermediate (treated with removable overdentures), and a fixed-prostheses (judged to have 'sufficient bone'). Patients who received bone graft were 2.5 times more likely to experience an implant failure than those that received a fixed prosthesis (RR=2.5, 95% 1.4, 4.4; p=0.002). Patients with severe resorption who received a removable prosthesis were 3.7 times more likely to experience an implant failure than those that received a fixed prosthesis (RR=3.7, 95% CI 2.4, 5.7; p<0.0001). The mean bone quality score was 3.6 (±0.5) and 3.1 (±0.44) in the bone graft and fixed-prosthesis groups, respectively.

Higuchi et al. [25] (van Steenberghe, Lekholm et al. 1990; Higuchi, Folmer et al. 1995) performed an analysis of 558 Brånemark implants in partially edentulous patients after 3 years of follow up. Cumulative success rates for the maxilla (93.9%) and the mandible (92.5%) were similar; however, patients with compromised quality bone were more than two times more likely to experience an implant failure than those with acceptable bone (RR=2.1, 95% 0.84, 5.4; p=0.09). This difference was approaching statistical significance.

Jaffin and Berman reported on 1,054 implants using the Brånemark technique placed in various bone qualities (LZ 1–4) in various regions of the mouth (maxilla, anterior mandible, posterior mandible). When comparing compromised quality bone (level 4) to more acceptable quality (levels 1–3), patients were greater than 12 times more likely to experience a failure in the maxilla (RR=12.4, 95% CI 6.8, 22.5; p<0.001), more than five times more likely in the posterior mandible (RR=5.4, 95% CI 2.5, 11.5; p<0.001), and more than eight times more likely in the anterior mandible (RR=8.3, 95% CI 1.7, 40.0; p=0.002). These differences were all highly statistically significant.

Friberg et al. [8] reported on 4,641 Branemark implants placed in various bone qualities (LZ 1–4) and bone quantities (A-E) in both the maxilla and the mandible. The objective of this study was to identify risk factors for failure prior to prosthetic placement. When comparing compromised quality bone to more acceptable quality, patients were nearly seven times more likely to experience a failure before prosthetic placement in the maxilla (RR=6.8, 95% CI 4.0, 11.7; p<0.001). The rates of failure in the mandible comparing bone types were very low (2.7% versus 2.6%, respectively). Little difference was observed (RR=1.0, 95% CI 0.24, 4.5; p=0.96). When comparing compromised bone quantity (level C-E) to more favorable bone quantity (level A-B), patients were three and a half times more likely to experience a failure before prosthetic placement in the maxilla (RR=3.5, 95% CI 1.4, 8.7; p=0.003). Again, little difference in rates were observed in the mandible (3.0% versus 2.3%; RR=1.3, 95% 0.47, 3.5).

Efficacy studies of various dental implantology methods for treating patients with compromised bone

Several case series were identified in the literature evaluating different dental implant systems in compromised bone; however, only a few were identified comparing methods to establish superiority of one method over another (i.e., RCT or cohort study). We identified three studies comparing different conventional implant systems in compromised bone that may be construed as 'efficacy' studies.

Friberg et al. [15] performed an RCT comparing a modified Branemark implant (modified to enhance primary stability) to the standard Branemark implant in regions of mostly LZ 4 bone (Friberg, Ekestubbe et al.. 2002). All failures occurred in the maxilla. The rate of failure in the standard implant group was slightly higher (12.8%) than the modified implant group (7.7%) 1-year after treatment; however, this difference was not statistically significant (RR = 1.3, 95% CI 0.70, 2.3; p=0.48), (Table 3).

In an RCT performed by Rocci et al. evaluating different methods of treatment in all qualities of bone, rates of implant failure were significantly higher in machined implants (45.5%) compared to TiUnite implants (8.3%) in patients with LZ–4 quality bone (RR = 5.5, 95% CI 1.0, 39.7; p = 0.04) [23], (Table 3). Such differences were not observed in the better quality bone levels, (Table 3). In the RCT by Truhlar et al. [6] HA-coated root-from endosseous implants had an overall failure rate of 3.9% over a 36 month period in all bone qualities combined compared to a 13.4% failure rate in non-coated implants (RR = 3.5, 95% CI 2.6, 4.5; p < 0.001), (Table 5). The highest failure rates and subsequent relative risks were in bone qualities 3 and 4 (19.1% and 25.5%, respectively). Non-coated implants were 4–5 times more likely to fail then coated implants in bone qualities 3 and 4 (RR = 4.6, 95% CI 3.1, 7.0; p <0.001 and 5.3, 95% CI 2.4, 11.4; p <0.001, respectively).

Discussion

We were able to find 10 articles that evaluated 'compromised bone' as a prognostic factor for dental implant failure with acceptable bone as a reference group and adequate data to calculate effect estimates. Generally, studies were heterogeneous with varied inclusion criteria, diverse definitions of compromised bone and different definitions for implant failure. Further, it was often not clear when authors started counting failures. Different conclusions may be drawn depending on whether authors define failure after implant placement (i.e., 'early' failures) or after functional loading (i.e., 'late failures') [22]. With the emergence and popularity of immediate loading protocols, it is essential that failures are counted immediately after implant placement to improve the validity of study.

The methodological qualities of the studies that we identified were moderate at best. Only one study accounted for potential confounding variables by producing adjusted odds ratios [10]. We calculated the effect estimates (i.e., relative risks) for all other studies. Because we were privy to only the number of implants and number of implant failures, we were only able to calculate crude estimates of the relative risk. Nonetheless, to our knowledge, this review is the first attempt to systematically review and summarize the disparate risk of implant failure in patients with and without compromised bone. Such a summary is useful both clinically and for research purposes. Patients with acceptable and compromised bone should be educated on their differential prognoses. This review provides a tool for such purposes, despite the lack of high quality studies.

The majority of the studies that compared compromised to acceptable bone populations that had raw data available for summarizing demonstrated that patient's with compromised bone are at greater risk of implant failure. Relative risks ranged from 2 to 12. Risks were greater in the maxilla; however, compromised bone in the mandible was also a risk factor. The most common method for measuring compromised bone was the system by Lekholm and Zarb which was found to be more predictive than pDEXA for identifying 'at risk' patients.

The current methods routinely reported in the literature for managing patients with compromised bone include bone augmentation procedures, enamel matrix derivatives (EMDs), long-term systemic drug therapies, bone morphogenic proteins (BMPs), combinations of these therapies, and various other alternatives. One must weigh the costs and benefits of these procedures. Though they allow for patients to receive fixed dental implants, they also have a number of limitations including high costs, increased surgical risk, and delayed time to loading, all of which add to the physical and emotional challenges of the patient, (Table 4). Several bone grafting materials are currently in use, including the following: Autogenous bone from the iliac crest, calvarian bone, tibia, fibula, the mandibular angle or maxillary tuberosities, allogenic bone, bone graft substitutes (e.g. xenografts), or a combination [4]. Success rates of dental implants when combined with bone grafting have been reported at 75–90% (Hohlweg-Majert, Schmelzeisen et al. 2006).

There are alternative methods for treating patients with compromised bone which may be less costly, incur less surgical risk, and allow for early loading in lieu of prolonged healing periods because they generally do not require bone augmentation procedures. The dental implantologist should be aware of these options especially when these challenges are an important consideration.

Zygomatic implants are in some cases an alternative to bone augmentation in the severely atrophic maxilla or following maxillectomy in cancer patients [13–16]. One to three zygomatic implants can be placed in the body of the zygomatic bone, with a couple of conventional dental implants in the frontal region of the maxilla to stabilize the prosthesis. These implants are placed transsinusally without augmentation. Eliminating the need for bone grafting allows for earlier implant loading.

Another alternative to treating patients with compromised bone without the need for augmentation procedures are trans-osseous, lateral implants (e.g. BOI brand, Diskimplant brand). Those implants are inserted from the lateral aspect of the jaw bone and are anchored bicortically. These implants utilize the horizontal supply of the bone, rather than the vertical. In those cases, where the augmentation is only performed in order to provide bone for conventional screw-type implants (and not for aesthetical reasons), usage of BOI-implants can usually avoid bone augmentation procedures; however, in aesthetical zones, augmentations may be still necessary. The vestibular struts of BOI implants may project out of the bone and support the augmentation material. In this technique, augmentation may be performed simultaneously with the implant placements (Fig. 1), and even the extraction of the tooth. Root form endosseous implants generally require > 10mm of vertical bone height for safe placement to achieve primary stability and subsequent osseointegration. Unlike the two-stage surgical technique used to place root-form implants, BOI implants allow for a single surgical procedure with immediate implant loading, even in patients with limited vertical bone supply [19,24]. The estimated decrease in cost is ~ 50% [18] compared to treatment protocols requiring augmentations. The decrease in total treatment time can reach up to 98%. Lateral implants are placed in both patients with acceptable and compromised bone; however, they may have a unique indication in patients with compromised quality or quantity bone. These and other alternative methods to standard bone augmentation

procedures need further evaluation to establish their safety and efficacy.

Conclusion

There appears to be an increase risk of implant failure in compromised bone compared to acceptable bone in both the maxilla and the mandible. This risk is up to 12 times greater in the maxilla. Studies comparing the failure rates of different implants are limited; however, a few good quality studies have been performed demonstrating that dual acid-etched implants are less likely to fail than machine-surfaced implants in patients with compromised bone. Further, rates of implant failure are greater in machined implants compared to TiUnite implants and non-coated root-form implants compared to HA-coated root-form implants. Conventional methods for managing patients with compromised bone have their limitations including higher costs, an accumulation of surgical risk in two-stage treatment approaches, and delayed time to loading. Alternative methods for treating patients with compromised bone include zygomatic and lateral basal implants, neither of which typically require bone augmentation procedures. More studies are needed to evaluate their safety and efficacy.

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